

# Research on the Development of Wood Structure Buildings in China and Abroad

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**Abstract:** Wood structure is a kind of space or plane structure which is mainly loaded by wood or wood products and connected and fixed by various metal connectors or mortise and tenon. Wood structure building refers to the building with wood as load-bearing components. Wood used in wood structure building materials, wood from renewable natural resources, is green material. Wood is the only renewable green building material in the main building structure materials. It has unique advantages different from other traditional building materials in recycling, energy saving, and environmental protection, earthquake resistance and disaster reduction, assembly and prefabrication, construction efficiency, and so on. Scientific management and use of forest resources, under the condition of ensuring resource renewal, timber can be produced continuously, which can effectively solve the problem of shortage of raw materials. In wood structure building, wood can be used for both structural load-bearing and interior and exterior decoration. With the development and popularization of modern integrated material technology, the application technology of wood for building structure is becoming more and more modern. It is no longer a brick and wood house in the traditional sense. More and more small-size or even fragmentary wood is used to process and synthesize large-scale building components. This paper introduces the characteristics of wood structure building, studies the development status and existing problems of wood structure building in China and abroad, and puts forward some suggestions for the future development direction of wood structure building.

**Keywords:** Wood Structure Building, Wood Structural Materials, Renewable Resources, Green Environmental Protection, Circulation

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## 1. Introduction

In steel, concrete, stone, wood and other building structural materials, wood is the only natural resource with renewable characteristics [1]. Under suitable environmental conditions, wood resources can be recycled and an ideal mode of material utilization can be established. Wood structure is a kind of structure which is mainly loaded by wood or wood products and connected and fixed by various metal connectors or mortise and tenon [2]. Wood structure building refers to the building with wood as the main load-bearing component. In wood structure buildings, wood can be used not only for structural load-bearing, but also for

internal and external decoration. Different from reinforced concrete or metal materials, wood as a natural building material can bring people warm, quiet and comfortable feeling, which is also an advantage of natural wood as a building decoration material [3].

As China's construction industry more and more advocates the utilization of green building materials, wood has attracted more and more attention. As the main component material in wood structure, wood plywood breaks the floor height limit of traditional wood structure buildings. Modern mixed wood structure buildings also greatly shorten the construction time, improve the seismic performance of buildings, and have obvious advantages in energy saving. Wood structure building is forming a new industrial outlet. This paper introduces the

characteristics of wood structure building, studies the development status and existing problems of wood structure building in China and abroad, and puts forward some suggestions for the future development direction of wood structure building.

## 2. Characteristics of Wood Structure Building

Wood is the only renewable green building material in the main building structure materials. It has unique advantages different from other building materials in recycling, energy saving and environmental protection, earthquake resistance and disaster reduction, assembly and prefabrication, construction efficiency and so on [4]. In addition, wood structure buildings can play an excellent role in carbon sequestration. By increasing the use of wood in construction activities, the carbon sequestration stock can be improved to cope with climate change. By applying it to buildings, the carbon sequestration cycle of trees can achieve the same or even longer life cycle as buildings [5]. Even if buildings are demolished, wood building materials can still be reused. With the development and popularization of modern integrated material technology, the application technology of wood for building structure is becoming more and more modern. It is no longer a brick and wood house in the traditional sense. More and more small-size or even fragmentary wood is used to process and synthesize large-scale building components. Compared with other buildings, modern wood structure buildings have the following characteristics [6].

### 2.1. Wood Is a Renewable Resource

Wood used in wood structure building materials, wood from renewable natural resources, is green materials. Scientific management and use of forest resources, under the condition of ensuring resource renewal, timber can be produced continuously, which can effectively solve the problem of shortage of raw materials.

### 2.2. Heat Preservation and Energy Saving

Wood structure building is more energy-saving than other buildings in the life cycle of raw material mining and processing, component production and transportation, assembly and construction, use and maintenance, recycling and treatment, which is mainly reflected in three aspects: (1) low production energy consumption. Compared with metal materials, wood has low energy consumption in the process of mining, manufacturing, transportation and construction. The power consumption of producing one ton of wood is far lower than that of producing one ton of steel. According to a 2016 study by the Renewable Energy Association, in the United States, wood accounts for 49% of all industrial raw materials used, but only 3% of energy is consumed. Therefore, the energy consumption of wood production is low; (2) In the process of use, heat preservation and energy saving. Wood has low thermal conductivity and good thermal

insulation performance. Research shows that: if the same insulation effect is achieved, the thickness of wood is only 1/15 of that of concrete and 1/400 of that of steel. Under the same outdoor temperature in winter, the indoor temperature of wood structure buildings is higher than that of concrete buildings; (3) Energy saving in recycling. After the use of wood structure building, wood can be degraded naturally. Compared with concrete, masonry, steel and other inorganic materials, wood recycling can save energy.

### 2.3. Flexible Design and Convenient Transformation

The design of wood structure is flexible, which can break through the size limit of wood and realize various designs; In the process of construction, the layout of the room and the position of the doors and windows can be adjusted and changed at any time, and it can be expanded and reconstructed more easily in the process of use.

### 2.4. The Construction Period Is Short and the Impact on the Environment Is Small

The construction period of timber structure is short. Most of the components are factory standardized production, and the walls and roofs can be prefabricated in the factory and assembled on site. An ordinary wooden structure house only needs 6 people and takes 4 months to complete [7]. The construction process has less noise, less dust and less impact on the surrounding environment.

### 2.5. Good Fire Resistance

Wood structure has good fire resistance. In the United States, wood structural materials generally improve their fire resistance through reasonable design. Although wood is a combustible material, a layer of carbonized layer on its surface can delay the combustion process and prevent the spread of fire. In case of fire, large-span steel structure building components are prone to collapse suddenly at high temperature, while the surface of large-span wood structure components forms a fire-retardant carbonized layer at high temperature, and its strength retention time is longer than that of steel structure [8].

### 2.6. Strong Seismic Capacity

Wood structure has good resistance to instantaneous impact and periodic damage. The aseismic test of wood structure building in Japan shows that the medium height wood structure building has a high tolerance to strong earthquake

## 3. Wood Structure Architecture in Europe and America

Modern wood structure buildings are widely used in Europe and America, including residential areas, commercial buildings, public buildings and so on. In the United States, more than 95% of low rise civil buildings

and more than 50% of commercial buildings adopt wood structure [9]. Coniferous wood is often used to build houses, landscape facilities and bridges in the United States. Terraces, pavilions, footpaths, docks, fences and other landscape facilities are mainly American southern pine. Generally, southern pine is pressurized and antiseptic in advance to increase durability. The application of North American Softwood in wood structure can be either in the form of log and sawn timber, or in the form of wood-based panel or other wood-based composite materials. Among them, plywood is mainly used for roof panel, cement formwork, cabinet side panel, bucket panel, etc; Oriented particleboard is mainly used for wall core board, floor, etc; Low, medium and high density fiberboard, mainly used for wall core board, furniture hopper, laminate floor substrate, wardrobe and cabinet partition, etc; LVL and Glulam are mainly used for bearing beams.

In recent decades, wood structure building has developed rapidly in Europe and America, and is developing towards industrialization, large-scale and standardization [5]. The production and manufacture of wood structure buildings gradually realize industrialization, that is, mass production of components in the factory and assembly on site. The characteristics of wood are not suitable for large-scale buildings, but through the development of new products and design and the development of wood structure technology, combined with brick concrete and steel structure technology, a variety of hybrid structures have been formed. The large-span buildings have realized the structural system of thin shell, grid and reticulated shell, which can realize the application of large-span buildings for wood.

#### **4. Current Situation of Wood Structure Market in China**

China is the birthplace of wood structure building, with a long history of wood structure building. As early as 1000 BC, China basically formed a framework system of mortise tenon structure connecting beams and columns, which reached its peak in the Tang and Song dynasties. Ancient Chinese wooden architecture is famous for its elegant style and dexterous structure. Ancient architectural engineers have accumulated rich experience in long-term practice, including mortise and tenon structure, cornice, bucket arch, shingle, stairs, beams and columns, as well as unique national design style. The Chinese traditional timber structure building adopts natural timber completely, but because of the defects of timber itself, such as (1) natural defects such as knots and cracks in timber, these defects may lead to a considerable degree of strength reduction; (2) When the moisture content changes, the wood will shrink, expand and crack; (3) The traditional mechanical processing cuts off the wood fiber, which has a great influence on the mechanical properties of wood; (4) Natural wood is flammable and easy to decay; (5) The traditional wood structure consumes a lot of

large-diameter wood, so it can't realize large-size design. These problems of wood itself have caused some misunderstandings of people's understanding of wood structure. They think that wood is not firm, stable and lasting as a building. At present, there are still more than 30 wooden structures that have been preserved for more than one thousand years in China, and the intact wooden structures that have been preserved for more than hundreds of years can be found everywhere, such as the Forbidden City, the temple of heaven, Yingxian Wooden Tower and so on. It can be seen that as long as the wood structure design is correct, the construction is careful, the use is reasonable and the maintenance is timely, the wood structure building has high durability.

With the development of modern industrialization, wood as a traditional building material gradually gives way to brick concrete, reinforced concrete, steel and other new building materials. In the late 1980s, in order to alleviate the contradiction of lack of forest resources, the state advocated the protection of natural forests, limited the development of wood building materials, and advocated the use of aluminum, steel, plastic and other materials. At that time, the foreign exchange reserve was not abundant and it was difficult to import wood. Therefore, the development of wood structure construction was restricted. In recent years, with China's accession to the World Trade Organization and the improvement of people's living standards, people begin to pay attention to energy conservation and environmental protection, and advocate the use of low-carbon buildings. Foreign modern wood structure buildings gradually enter the domestic market. In the late 1990s, the coastal developed areas introduced 1-3-storey light wood structure residential buildings in North America one after another, and thousands of them have been built so far. At the end of 2012, the Ministry of housing and urban rural development announced that it will build multi-storey wood structure residential buildings in Beijing, Shanghai, Tianjin, Hebei and other places, which will become the first batch of assembled multi-storey pure wood structure or mixed wood structure residential buildings in China. It is predicted that China will have at least 200000 timber structure buildings by 2015, and the market prospect is attractive.

Light wood structure has also been listed in the national standard code for design of wood structures (GB 5005-2003) and code for acceptance of construction quality of wood structure engineering (GB 50206-2002). On June 1, 2017, the technical standard for prefabricated wood structure buildings was officially implemented. More and more real estate developers, landscape design companies, construction units and consumers have a strong interest in wood structure building, and the advantages of wood structure building gradually begin to appear. Although the building structure in our country is still mainly brick concrete, reinforced concrete and steel structure, and the application of wood structure in other types of buildings is rare except for some low rise residential buildings, but the development prospect is very good.

## 5. Development Prospect and Suggestion of Wood Structure Market in China

It is necessary to overcome some difficulties or correct some misunderstandings in the development of wood structure buildings in China. For example, it is generally considered that China is lack of forest resources, urban population density is too large, and land resources are insufficient, which is not suitable for the development of wood structure buildings, especially low rise wood structure buildings; The cost of wood structure construction is high and the price is too high; Wood structure building is unstable, easy to decay, poor fire performance; The wood strength of plantation in China is low, so it is not suitable for wood structure. In fact, in the development of wood structure building in China, it is suggested to start from the following aspects.

### 5.1. Vigorously Develop Wood Engineering Materials

In recent years, China began to promote plantation, plantation resources increased rapidly, while the volume of natural forest also continued to increase. According to the actual situation of our country, the development of wood structure building can focus on the development of wood engineering materials. The utilization rate of wood engineering materials to wood can reach 95%, while that of conventional solid wood products is only 60% [10]. Poplar and other low-quality fast-growing plantations are generally used to produce common plywood, building formwork and particleboard. In the future, some of them can be used to produce wood engineering material products, including Glulam, OSB, LVL, PSL, LSL, CLT, etc. So that the fast-growing timber of plantation can be more efficient and more widely used. At present, the development of these wood engineering wood products in China has just started. Although the production capacity of OSB has been greatly improved in recent years, the overall production scale is still small. Wood engineering materials have the advantages of uniform structure, high strength, flexible size, and not easy to deform, which can fully meet the requirements of wood structure buildings. It is in line with the principle of vigorously developing plantation resources, improving the added value of products, increasing the utilization rate of wood, improving economic benefits, and realizing sustainable development in China. In addition, there are abundant bamboo resources and a large number of crop residue resources in China. We can vigorously develop products such as reconstituted bamboo, bamboo fiber composite materials, wheat straw directional board, crop straw composite wall materials and so on as substitutes for wood engineering materials. In some nonstructural parts, ordinary man-made boards such as fiberboard, plywood, particleboard, wood plastic composite can be used to replace conventional wood. At the same time, it can also increase the quantity of imported softwood from Russia, the United States and other countries to supplement the shortage of domestic supply.

### 5.2. Develop Wood Structure Buildings of Different Styles and Uses According to Regional and Urban Characteristics

At present, the population density of large and medium-sized cities in our country is large, but low rise buildings are still needed in relatively small population areas such as towns and rural areas. There is great potential to develop wood structure buildings in these areas. In the new rural housing and township construction in the coastal economically developed areas, light wood structure buildings and some new wood-based materials buildings can be developed, such as the houses built with wood plastic composite materials; In earthquake prone areas, aseismic wood structure residential buildings can be developed; In some scenic tourist areas and characteristic livable cities, it can develop eco-friendly wood structure residence and garden landscape pavilion, platform, building, pavilion, etc; Large cities can also appropriately develop wood structure buildings, such as some large stadiums, libraries, cinemas, schools, halls, stations, hospitals, kindergartens and other public buildings. Special shaped buildings with unique style can be built by using the characteristics of easy construction and light materials of wood structure. High grade villas and theme parks with wood structure can be developed in the surrounding areas of cities.

### 5.3. Localization of Wood Structure Building

At present, most of the modern wood structure buildings in our market are located at the high end. The whole set of buildings copy the western design concept. All the equipment and materials including accessories are imported. The standards and specifications are from abroad, so the overall cost is high. If the promotion of wood structure building in China, we must take into account the needs of ordinary consumers. The design of building, wood structure materials, connectors, and even technical standards and specifications as well as supporting installation technology should be gradually localized. We should develop the design software suitable for the characteristics of wood structure building in China, improve the technical standards, and make the wood structure building really enter the public life [6].

### 5.4. Vigorously Cultivate Wood Structure Construction Professionals

At present, domestic wood structure construction enterprises lack of professional talents in wood structure construction design and related production and construction technology, which seriously restricts the development space of wood structure construction enterprises. The current situation is that some enterprises do not have professional designers and completely copy the construction system of North America or northern Europe; The other is only effect drawings (from the Internet, information), relying on the experience of construction personnel toss, this way is not desirable, because the building must be safety first, this practice will leave a lot of hidden dangers to the building,

will also disturb the wood structure construction market. In view of the above problems, enough attention has been paid in China. Some famous universities have begun to participate in the research and development of wood structure architecture, such as Tongji University, Harbin Institute of technology, Southeast University, etc., and a few forestry universities are recruiting and training undergraduate talents, and opening wood structure architecture related majors. The Canadian timber association also provides training programs for domestic builders and designers in the design and construction of timber structures. Relevant universities, scientific research institutions and enterprises should also cooperate with each other to break through the technical problems [7].

## 6. Summary

To sum up, the development of wood structure building in the domestic market has great potential, but it is still in its infancy, and many related research and development work is in progress. On the one hand, the corresponding policies should be issued to encourage the use of wood structure materials; On the other hand, formulate corresponding standards and norms to promote the development of wood structure market. At the same time, we should also increase the market promotion and publicity of wood structure buildings, so that consumers can further increase their understanding of modern wood structure buildings, and understand the advantages of energy saving, environmental protection, fire prevention, earthquake resistance and durability of wood structure buildings, so as to create a good environment for the development of wood structure buildings. In a word, the popularization and application of wood structure building can drive and promote a series of industrial development, such as forest processing, the production of equipment accessories, the progress of architectural design technology and so on. At present, wood structure building materials and equipment basically rely on imports. Vigorously developing wood structure building is not only a challenge but also an opportunity for domestic related industries.

## 7. Future work

Future work of wood structure building will be on making the long-term development plan of wood structure

architecture, solving the difficulties encountered in the development of wood structure, overcoming the development bottleneck, establishing the development strategic plan of wood structure industry, and guiding the development of wood structure industry.

## Conflicts of Interest

The authors declare that they have no competing interest.

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