

# Study on the Form and Production Technology of Wood Structure Building

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**Abstract:** Wood structure is a structure that only or mainly bears the load by wood, and it is connected and fixed by various metal connectors or mortise and tenon means. According to the classification of materials used, it can be divided into: ordinary wood structure, glulam structure, and light wood structure. Wood is the only renewable material in building materials. As a structural material, the seismic performance of wood is obviously better than other materials. Timber structure building usually uses standard timber and wood-based structural board or gypsum board to make timber frame wall, floor and roof system. Light wood structure building, log structure building and ordinary structure building have their own characteristics, production technology and processing equipment are different. Wood structure architecture has a long history, but at the same time, the development of wood structure is also facing a series of problems. The misunderstanding of wood structure buildings is first reflected in the belief that cutting down trees to build wood structure buildings destroys ecology and is not environmental friendly. Another important misunderstanding is flammability. In addition, there are many misunderstandings about wood structure architecture, such as weak strength, easy corrosion and so on. In fact, all these problems have been better solved with the development of modern technology. This paper studies the form and production technology of wood structure building, and discusses the existing problems of wood structure building as well as the protection technology of wood structure.

**Keywords:** Wood Structure, Building Form, Production Technology, Building Material

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## 1. Introduction

Wood structure is a structure that only or mainly bears the load by wood, and it is connected and fixed by various metal connectors or mortise and tenon means [1].

According to the classification of materials used, it can be divided into: Ordinary wood structure: it refers to the single-layer or multi-layer wood structure made of square wood or log. It is a manual construction site manufacturing structure, which is easy to process, the earliest development and the most widely used; glulam structure: it refers to the load-bearing structure composed of Glulam bearing members or Glulam structures [2]. This kind of wood structure is not limited by the size of natural logs, and can use shorter and thinner wood to form tens of meters or even hundreds of meters long-span members. Its common structural forms are:

beam, arch, steel wood truss, gantry, folded plate structure, thin shell structure; light wood structure: it refers to the single-layer or multi-layer building structure made of standard wood, wood-based structural board or gypsum board, which is composed of wood structure wall, wood floor and wood roof system. The bearing capacity, stiffness and integrity of light wood structure buildings are provided by the main structural members (wood frame) and secondary structural members (wall panel, floor panel and roof panel) [3].

Modern wood structure residential buildings can be divided into: Traditional and modern beam column wood structure: the main structural system is the beam column with large spacing, which transfers the floor and roof load to the column through the beam, and then to the foundation; light frame wood structure: it is a kind of structure form which is composed of uniform and dense connection of standard

timber with small section. The main structural members (structural skeleton) and secondary structural members (wall panel, floor panel and roof panel) act together, bear various loads, and transfer them to the foundation; well dry wood structure: it is composed of circular, rectangular or hexagonal members, which are overlapped layer by layer parallel to the top and crossed at the corner to form enclosure wall. The load of floor and roof is transferred to the foundation through the wall [4]. This paper studies the form and production technology of wood structure building, and discusses the existing problems of wood structure building.

## 2. Characteristics of Wood Structure

### 2.1. Earthquake Resistance

As a structural material, wood has better seismic performance than other materials, and has good resistance to instantaneous impact and periodic failure. Wood as the main structure of staggered connection, has good stability, and the tensile and compressive performance is average, has a certain ductility, and its flexibility is better than other materials, can absorb and dissipate energy. Practice has proved that wood structure shows stability and structural integrity under various extreme load conditions. Even if the strong earthquake makes the whole building away from its foundation, its structure is often intact [5].

### 2.2. Thermal Insulation

Wood is a poor heat conductor, so wood structure building has good heat insulation performance. Based on the same thermal insulation requirements, the thickness of wood is only 1/400 of steel and 1/16 of concrete. Compared with the ordinary brick concrete structure, the energy saving is more than 40%.

### 2.3. Fire Resistance

The wood in the building structure is usually treated with flame retardant, and the carbonized layer will be formed on the surface of the wood in case of fire. Because of its low conductivity, it can effectively prevent the flame from spreading inward and ensure that the wood will not be damaged in a certain period of time. According to the classification of wood structure, light wood structure and heavy wood structure have different fire prevention methods. Because the light wood structure is composed of uniform dense, small cross-section of the components of the specification of wood connection, so can be coated on the members of the fire treatment. Or use wood block to stop fire. Heavy wood structure usually uses strong and durable large section log or engineering wood, which can play the role of heat insulation and protect the internal structure from fire with the help of carbonized layer formed by large section wood members in case of fire. The minimum size of structural components is specified in fire protection design to ensure the formation of carbonized layer in case of fire [6].

### 2.4. Sustainability

Wood is the only renewable material in building materials. Compared with a large number of solid wastes produced by other types of buildings, it occupies a large amount of land and pollutes soil and water to a certain extent. The advantages of sustainable processing and utilization of wood become particularly prominent. When the original wood structure building is demolished or abandoned, its wood can still be recycled, which will not cause environmental pollution. At the same time, under the reasonable construction and maintenance, the wood structure house can maintain longer than the concrete building.

### 2.5. Energy Saving and Environmental Protection

By testing the environmental pollution index of the main building materials, the results show that wood does not cause pollution to water, air, soil and the surrounding environment. The energy consumption of wood construction materials is lower than that of steel or concrete. The life cycle energy consumption of wood structure building is compared with that of light steel structure, reinforced concrete structure and brick concrete structure [7]. At the same time, wood materials have a good regulatory effect on human physiological properties.

### 2.6. Flexibility

The wood material is soft and high toughness, so it has high design flexibility, can break through the size limit, and is convenient for construction. It is easy to adjust the building layout at any time during construction, even easier for expansion and reconstruction, and the construction period is shorter.

### 2.7. Sound Insulation

The molecular structure of wood is filled with innumerable tiny air sacs, which help to attenuate the vibration transmission of sound. The principle of sandwich and air barrier is used in modern wood structure wall, which makes it have stronger heat insulation and sound insulation performance.

## 3. General Situation of Wood Structure Building Development

Since the 1980s, wood structure has been developing fastest in the world. From log structure to Glulam structure, and then to composite wood structure, wood structure is no longer the traditional concept of wood structure, and has firmly occupied a dominant position in the field of architectural structure. In Europe, America, Japan and other developed countries, a large number of research and application of wood structure also promote the benign cutting and utilization of forest resources, forming a mature forest management system [8].

In North America, wood structure construction has always

been in the dominant position in the market. There are nearly 1.5 million new residential buildings in the United States every year, 90% of which use wood structure. In Canada, the industrialization, standardization and supporting installation technology of wood structure residence are very mature. There are also Japan and Northern Europe Finland and Sweden, the construction of private housing is also the first choice of wood structure building.

Wood is the main building material in China's traditional building system, so wood structure is the main structural way. According to the archaeological findings of Chinese experts, there were traces of the original construction of "building wood as nest" in ancient China. At that time, the wooden column had been processed into a rectangular section, and the wooden pile or wooden board was used as the foundation. The remaining wooden members in the site show that the mortise tenon structure has been perfected. This connection mode has evolved into the main form of ancient wooden structure connection in China in the following years, forming two main systems of beam column frame and through bucket frame, with columns, beams, Fang, pad, Yan Tan, dou Gong, rafters, Wang ban and other basic components [9].

At the end of the 18th century, the structural system of wood truss supported by brick wall was introduced into China. Since the 1950s, due to the shortage of steel and cement, most civil buildings and a small part of industrial buildings have adopted brick wood structure, and its proportion has increased greatly. By the 1980s, China's structural timber was gradually reduced, and the country did not have enough foreign exchange savings to import timber. In order to protect China's forest resources, the development of wood structure buildings was stagnant. In recent years, with China's economic development, the continuous improvement of people's living standards, the awareness of energy conservation and environmental protection, and the continuous improvement of wood processing technology, With the gradual development of plantations which can be used as raw materials, wood structure buildings in China can continue to develop.

When the Canadian forestry delegation visited China in 2001, they had in-depth exchanges with the Chinese government and scientific research institutions on the materials and technology of wood frame building, and believed that there was a broad space for cooperation in formulating wood building standards, improving wood product rules and training technical personnel [10].

Modern reinforced concrete building energy consumption is very high and belongs to nonrenewable materials, according to the national energy conservation and environmental protection policy, we must reduce the use of such nonrenewable materials, vigorously develop energy-saving building as the next development goal, wood structure building has the characteristics of durability, stability and flexibility, which can be the primary focus of the development of energy-saving and emission reduction building in China. Although the one-time investment of wood structure building is higher than that of concrete

building, the construction period of wood structure building is short, and the project requires less labor, which is not limited by climate conditions. In the long run, the energy consumption of wood structure building is low in heating and temperature control, which can greatly reduce the operation cost.

In recent ten years, China's wood structure building has been a lot of development, light wood structure has been widely used, Glulam structure is gradually rising. At the same time, the development and application of bamboo and bamboo wood composites with Chinese characteristics have made remarkable progress. A series of technical standards for timber structures have been formulated or are being formulated and revised. Relevant professional colleges and research institutions re open the course of wood structure, train relevant professionals for our country, and constantly expand international exchanges and cooperation.

The main raw materials of wood structure are coniferous logs and sawn timber. At present, due to the serious shortage of high-quality wood resources in China, wood structure raw materials mainly rely on imports. With the development of wood structure industry, especially since the commercial logging of all natural forests in China was stopped in 2017, China's timber imports are increasing [3]. In recent years, China's wood structure industry policy, design specifications, construction specifications, acceptance specifications are constantly improved, and the number of wood structure production and construction enterprises is increasing. At present, tourism development projects of wood structure industry occupy the largest market, followed by private residential projects, landscape projects, cultural tourism and health care projects also occupy an important position, but the proportion of public buildings is still relatively small. After the state further introduced relevant standards, hotels, apartments, nursing homes, schools and other fields have become market fields with good development prospects.

But at the same time, the development of wood structure in China is also facing a series of problems: wood structure as a redeveloped building structure model in recent years, the design enthusiasm of comprehensive design institute is not high, the design of wood structure enterprise is still weak, the stress analysis in design is too simplified, and the understanding of wood structure related specifications is not deep. In view of these problems, our government should vigorously guide the design institutes and related enterprises from the policy and other aspects, improve their enthusiasm for the research and development of wood structure buildings, and actively promote the study and compliance of wood structure design specifications in the industry.

## 4. Connection of Wood Structure

### 4.1. Tenon and Mortise Joints

Mortise tenon connection is the main connection mode of ancient wood structure buildings in China, which is made of main components such as column, beam and purlin. The

main principle of mortise tenon structure is to connect the two structures through the concave convex part. The protruding part and the concave part are called mortise and tenon respectively. Because of the semi-rigid characteristics of this connection, the wood parts are combined in this way. Mortise tenon structure, as a traditional integral frame structure, perfectly coordinates the mechanical action between various structures, and has the ability of tension, compression, bending and torsion. In the application of mortise and tenon joints, there are T-shaped, angled or cross connection of horizontal and vertical materials.

With the continuous development and renewal of science and technology, mortise and tenon structures have been preserved in more ways. Some of them can continue to be used by machine, or flexibly use computer technology. Inspired by mortise and tenon structures and adhering to the concept of green environmental protection, the mortise and tenon structures give up the use of metal parts and completely use wood to build buildings. For example, Sakamoto, a Japanese architect, built the Zurich media group office building by connecting the fixed wooden beams and other wooden structures with wooden bolts, which broke the limitations of mortise tenon structure in the traditional concept, and integrated the concept of environmental protection, giving the mortise tenon connection a new definition.

#### **4.2. Tooth Connection**

In the wood structure made of square wood or log, tooth connection is the most commonly used way. According to the number of teeth, it can be divided into single tooth connection or double tooth connection.

#### **4.3. Plywood Structure**

Plywood is a kind of three-layer or more plate-like material, which is made of wood section, veneer or wood square, sliced into thin wood and glued with adhesive. Plywood used in plywood structure should be different from ordinary plywood, with high water resistance and corrosion resistance. The surface veneer of plywood is called surface veneer, the inner veneer is called core veneer, the front veneer is called panel, and the back veneer is called back veneer; In the core board, the fiber direction parallel to the surface board is called long core board or medium board. Plywood production principle is symmetrical and adjacent layers of veneer fiber perpendicular to each other, the number of layers is odd. Plywood makes up for the shortcomings of small size, deformation and large difference in vertical and horizontal mechanics.

#### **4.4. Nail and Bolt Connection**

Pin connection in the common nail, bolt connection, mainly using steel, wood materials to make round rod-shaped or plate-shaped objects to realize the connection of mobile construction, using this structure better tightness, so it is widely used in connectors, more frequently used [4]. In the

wood structure, the working principle of nail and bolt is the same, which is to prevent the relative movement of the component from being squeezed by the hole wall wood. With the development of modern technology and the accumulation of experience, in order to prevent the bolt and nail from being too thick, arranged too closely or the component from being too thin, which leads to the splitting or shearing of the wood, The minimum thickness of wood and the minimum spacing between bolts and nails have been specified.

#### **4.5. Tooth Plate Connection**

The toothed plate is made of galvanized steel plate with one-way toothing, which is mainly used for the connection of light wood truss joints made of specification materials in light wood structure buildings. The application of toothed plate in the truss connection can quickly locate the chord in the truss. The broken end of the compression component is made into a tenon, and the other component is made into a tooth groove. The tenon is supported in the tooth groove, and the bearing surface is used to bear the pressure and transmit the force. Tensile strength, shear strength, slip resistance and composite bearing capacity are the main bearing capacity of the toothed plate, which mainly plays the role of lengthening and thickening in the process of use. The tooth plate has the advantages of maintaining wood integrity and good plastic properties, which can improve the construction efficiency and show a good synergy with wood. But at the same time, the material of the tooth plate is very thin. Once it is corroded in some corrosive environment, the connection performance of the tooth plate will be lost. Therefore, the tooth plate should be used in dry and ventilated environment as far as possible.

## **5. Production Technology of Wood Structure**

Timber structure building usually uses standard timber and wood-based structural board or gypsum board to make timber frame wall, floor and roof system. Light wood structure building, log structure building and ordinary structure building have their own characteristics, production technology and processing equipment are different.

#### **5.1. Production Process of Light Wood Structure and Common Wood Structure**

The basic manufacturing process of light wood structure building and ordinary wood structure building is as follows: (1) Material selection for sawing. (2) planer planed wood surface. (3) Mortise and tenon the teeth of the comb. (4) refers to the docking material of the docking machine. (5) planed surface. (6) glue. (7) heavy duty wooden house anti cracking horizontal splicing products square machine splicing. (8) four sides planed to make standard square timber. (9) wooden house wall group frame unit frame. Waterproof layer and insulation layer are added in the middle of oriented particleboard on both sides (wooden house wall can also be

manufactured on site). (10) lay foundation on site. The overall frame of the wooden house is made of standard timber. (11) assemble the wall and roof (reserve the position of drainage pipe and line pipe) (12) interior decoration.

### 5.2. Production Process of Log Structure

The manufacturing process of log structure building is slightly different: (1) Wood drying. (2) Material selection for sawing. (3) planer planed wood surface. (4) Tenoning of heavy comb. (5) refers to the docking material of the docking machine. (6) planed surface. (7) glue. (8) heavy duty wooden house anti cracking horizontal splicing machine. (9) four sides planed to make standard square timber. (10) start angle saw cut into different specifications of the material. (11) wooden house wall drilling slotting machining parts. The dovetail slotting machine is used for slotting (12) wooden house walls. (13) dovetail grooving machine for wooden house end face. (14) Foundation construction on site. The wall and roof of the wooden house are made of standard square materials (the position of drainage pipe and line pipe is reserved). (15) interior decoration [5].

### 5.3. Production Process of Structural Glulam

Structural Glulam is the basic material of the main bearing components of Glulam structure. Because the production mode of Glulam is convenient for material engineering designers to design relevant components according to architectural requirements, Glulam material has better adaptability than wood itself.

The gluing process of Structural Glulam is similar to that of conventional Glulam, but in the splicing process, different levels of laminates should be used according to different stress sections. Structural Glulam can be made into large cross-section Glulam, which has many design forms, such as straight, I-shaped, arc, herringbone and so on. When the structure is glued with Glulam, according to the design, the forming pressure equipment is used to make the whole component uniformly compressed, and then the fixture or screw is used to fix, and the glue is solidified at a certain temperature. Generally, phenolic resin, resorcinol formaldehyde resin or melamine resin cured at room temperature are selected. In order to ensure the gluing quality, it should be avoided to mix trees with different gluing properties in the same component. Structural Glulam generally requires that the shear strength and tensile strength of glued joint should not be lower than that of glued wood, and it has good antibacterial and durability.

## 6. Summary

As a structural material, wood has better seismic performance than other materials, and has good resistance to instantaneous impact and periodic failure. Wood structure building usually uses standard timber and wood-based structural board or gypsum board to make timber frame wall,

floor and roof system. Light wood structure building, log structure building and ordinary structure building have their own characteristics, production technology and processing equipment are different. At present, the development of wood structure in China is facing a series of problems. In view of these problems, we should vigorously guide the design institutes and related enterprises from the aspects of policy, so as to improve their enthusiasm for the research and development of wood structure building. At the same time, we should actively promote the study and compliance of wood structure design specifications in the industry, and jointly promote the faster and better development of wood structure industry.

## Conflicts of Interest

The authors declare that they have no competing interest.

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