
Study on the Application of Oak in Wood Structure Building

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Abstract: This paper studies the application of oak in wood structure building. Oak is a type of high-grade building timber. Due to its high density and high hardness, there was few equipment or tools to process oak in the past. Most of them were only used for burning or making charcoal, but they were not well developed. With the development of science and technology, there are no obstacles in processing tools and technology for oak, and oak has been widely used. At present, China is in the period of urbanization and rapid development of new rural construction. Oak structure has unique advantages in energy saving and environmental protection, earthquake resistance and fire prevention, and housing industrialization. However, at present, the available oak resources are relatively few and the price is relatively high. The imported oak is mostly used in interior decoration, cask and other fields with less material in our country. The development of oak wood structure building still needs to make a lot of efforts. Based on the principle of sustainable utilization, we should develop and plant high-quality oak varieties that can be applied to wood structure, improve yield, realize self-sufficiency and reduce cost. At the same time, the government should vigorously promote the relevant policies of oak wood structure building construction, encourage design units and enterprises to actively participate in the design and construction of oak wood structure building, combine oak wood structure with other building materials, reduce the comprehensive construction cost, and improve the standards and specifications of oak wood structure design, construction and maintenance, so as to promote the better application of oak wood in wood structure building.

Keywords: Oak, Wood Structure Building, Application, Property, Construction

1. Introduction

Quercus belongs to *Quercus* of Fagaceae. There are about 289 species of *Quercus*. It is distributed in Asia, Europe, Africa and America. There are about 50 kinds in China. According to the national standard of Chinese main timber name, the timber is divided into four kinds of commercial timber. *Quercus acutissima* and *Quercus variabilis* are ring porous wood, while *Quercus alpina* and *Quercus Wugang* are loose porous wood. According to the national standard of "name of main imported wood in China", this kind of wood can be divided into two kinds of commercial wood: white oak and red oak. Oak is ring hole wood, and its structural characteristics are similar to those of *Quercus* and *Quercus* wood produced in China.

Macroscopic characteristics: Heartwood and sapwood are

distinguished obviously, sapwood is light yellow; Heartwood yellowish brown, dark yellowish brown to reddish brown. The annual rings are obvious and wavy. The wood has luster; No special smell; the dry density is 0.78-0.89g/cm³. Some tree species have the tendency of semi ring hole wood. The early wood has large tube hole, which is obvious by naked eyes. It is arranged into early wood belt, and there are infilling bodies in the tube hole; later wood tube hole is very small, slightly seen under the magnifying glass, radial or flame shape; the axial parenchyma is mainly tangential or off tubular. It is obvious under the magnifying glass; the narrow ray is not easy to see with naked eye, the wide ray is obvious, and the chord section presents Brown spindle or fine line.

Oak is also divided into white oak and red oak. The only source of red oak is the natural hardwood forest in the eastern part of the United States, extending from Maine in the north

to Mississippi in the south. Red oak occupies a large area in this hardwood forest, which has different characteristics due to different climate and soil types from other parts of the world. The heartwood of white oak is mostly grayish brown, ring hole wood. The early heartwood has abundant infilling bodies in the tube hole, while the late heartwood has thin wall and most of them are polygonal. The heartwood of red oak is mostly reddish brown, from half ring hole to ring hole. The early heartwood controls little or no infilling body, and the late heartwood controls wall thickness and is round. Oak has excellent material properties: oak is hard, straight texture, thick structure, elegant color, beautiful texture, high mechanical strength and wear resistance, but it is not easy to dry, saw and cut [1].

2. Types and Application of Oak Wood Structure

2.1. Light Wood Structure

Refers to the truss composed of wood members. It is the main load-bearing structure of wooden roof, bridge and tower. When used for wooden roof, it is generally called wooden roof truss. According to the material of the bottom chord, the wooden roof truss is divided into wooden roof truss and steel wooden roof truss. The main forms of wooden roof truss are triangle, trapezoid and polygon.

The selection of roof truss form should be based on the water flow gradient of the roof, in addition to the consideration of material saving. Clay flat tile, cement flat tile or small green tile require larger slope, so triangular roof truss should be selected; The gradient of asbestos cement tile is relatively slow, so trapezoidal layer frame can be selected; The trapezoidal or polygonal roof truss should be selected for the coiled material or sheet iron roof. In order to avoid obvious deflection of wooden roof truss under long-term load, the camber should be pre cambered during fabrication [2].

2.2. Heavy Wood Structure

As the name suggests, wood frame is a frame form that uses wood as the main building material, which is widely used in buildings, bridges, landscape and other fields of construction and industry. Wood frame structure is the skeleton of the house made of wood columns and beams. The weight of the house is concentrated on the columns through the beams. The wall only acts as a partition, and it does not bear the weight of the house.

The wood frame has the advantages of anti-seismic, heat insulation and insulation. At the same time, it is skillful in workmanship. It can be overlapped through Falcon head, plug bolt and other processes, so the external connection can hardly be seen, and the material is easy to process [3].

2.3. Door Frame and Window Frame

The door frame is the frame and upper sill on both sides and top of the doorway, which is inlaid in the wall and

usually supports the door leaf and the exposed door. The window frame is the transition layer between the wall and the window, which plays a role in fixing and preventing the collapse of the surrounding wall. Oak is used as door frame and window frame is mostly used for exterior decoration [4].

2.4. Stairs

A member of a building used for vertical traffic between floors. It is used for traffic connection between floors and when the height difference is large. Oak material is often used in the construction of stairs in private houses, which has the advantages of environmental protection, noise reduction, safety and durability.

3. Development of Oak Wood Structure Architecture in China

As a high-grade building material, oak can be used to build palaces and temples since ancient times. Due to the high density and high hardness of oak trees, there were few equipment or tools for processing oak trees in the old days. Most of oak trees were only used for burning or making charcoal. Traditionally, the utilization of oak trees was not well developed. With the development of science and technology, there are no obstacles in processing tools and technology for oak wood with high density and high hardness [5].

In recent years, China's import of all kinds of oak has increased significantly, most of which are from the United States and France. Among them, China is the largest market for red oak and white oak from the United States, which are the most popular broad-leaved tree species in the United States. It provides a lot of wood resources for the utilization of oak in China [6]. Therefore, the oak wood structure architecture in China has been popularized again.

4. Development of Oak Wood Structure Buildings in Europe and America

As early as 3000 years ago, wood structure became the basic form of beam column structure in ancient Egypt and Greece, and there was mature wood truss technology in ancient Rome. Ancient Western wood structure has been widely used in residential buildings, and developed in parallel with masonry buildings.

Quercus acutissima, native to the United Kingdom and most northern European countries, is one of the most popular species. In the era of sailing, wood is a strategic material, especially oak, just like modern high-quality steel and rare metal deposits. Oak contains tannic acid, so it is hard, strong and corrosion-resistant, so oak has been popular in ancient European shipbuilding industry [7].

The most common American species is the white oak, a cash cow of the Massachusetts Bay Company. The Massachusetts Bay Company shipped the timber back to

England and helped the migrants on board to cross the Atlantic Ocean. Another American species, *Quercus virginiana*, known as the "living oak", is the longest living species and is now less used as commercial timber.

Before the appearance of metal hull, the wood used in shipbuilding needs to meet the following requirements: the wood needs to come from the strong trunk, and the wood made of wood should be malleable, light and waterproof. Oak trees meet the above two conditions, so oak has always been the choice to build ships, which also helped Britain gain maritime hegemony. As a result, since the 16th century, oak trees mainly growing in Britain have been exported to Scandinavia and other Baltic countries to meet their needs for building ships, houses, furniture and firewood [8].

In the 18th century, most of the oak used in European shipbuilding came from Germany and Poland. According to the law at that time, all the thick oak trees were the property of the king, and this provision was mainly to meet the demand of the shipbuilding industry for oak trees. Oak is abundant in North America and Europe. Therefore, oak is a common building material in North America and European countries. After many years of development and improvement, these countries have formed a complete standard system for Oak structure. Now, the research on oak structure is no longer limited by geographical conditions. It can change the structure according to local conditions, or be combined with stone, wood and other materials Reinforced concrete and other structural decoration materials complement each other and seek various design styles on the basis of safety, energy saving, environmental protection and durability.

At present, countries with mature wood structure building production system have begun to develop to Glulam building, prefabricated building and multi-storey wood structure building. Some countries are actively promoting industrialized wood structure building, which not only saves construction time, but also controls the construction quality of wood structure to the greatest extent. As a common wood, oak continues to keep up with the improvement and development of materials [9].

5. Analysis of Typical Oak Wood Structure Buildings

St. Boniface Cathedral, a convent built in the middle of the 19th century, is not only the oldest building in Winnipeg, but also the largest oak structure building in North America. The same is Notre Dame de Paris. Because of the high status of oak in people's mind at that time, oak was often used as an important structural material in Europe and America at that time, which was used for load-bearing structure, door frame, delicate window frame, floor and other decoration.

Located in England, this historic building was built in the 17th century; The hotel is regularly used by Bishop Lincoln as a stopover. The land is also related to the 11th century and may have been used by King John of England.

The concept of this project is to hide the oak frame behind the limestone, so the extension is consistent with the existing house. The stone carving in the extension matches the existing "bed saw" limestone, which will darken over time and blend into the surrounding environment. Our oak frame matches the style of the house perfectly; Break the hard stone carving and add modern oak shape and texture [10].

Another large-scale application of oak wood building transformation is also located in the UK - Newbury oak garden room. The transformation of this project is to integrate a compassionate design into the existing 17th century barn. Because there are several oak trusses through the existing barn, you can create a building that reflects these internal features. Through the correct material selection, users can enjoy their garden in all directions and introduce as much natural light as possible.

The construction and spacing of the roof also match the adjacent gables. The oak frame is handmade from air dried oak in the manufacturing workshop and assembled on site. Two oak waist shaped main column trusses support two oak purlins and several ordinary oak rafters, which can still be seen from the inside of the room.

The designer also designed and installed a protective ceiling lamp to help light penetrate into the adjacent rooms. The glass used is fixed by direct glazing. This process is the most effective way to glaze oak structure. The high quality 42 mm 1 / 4 sawn oak was used as the oak cover, and then the high density glass seal was used to clamp the glass on the oak structure.

Lead and copper waterproofing panels are integrated into these oak covers to create a structure that is not ventilated and completely free of water. This direct glazing system allows movement of the oak frame without any adverse effect on glazing and component sealing. The designer introduced two hand-made oak windows with flush windows for ventilation in warm months, and a pair of hand-made oak double doors for access to the terrace and dining area.

According to the characteristics of the wood, all the wood structural parts that can be used in the project have been put into the transformation scheme. It maximizes the advantages of oak wood and fully integrates with the original architectural style, achieving a perfect balance between technology and art.

Shoffice, built by platform 5 architects behind John's Wood's row house in 1950, is a perfect combination of garden pavilion and office. The shape of the building is extruded out of the oval wood building, which curls up from the ground, forming a small wooden platform on the lawn. The glass office space is embedded in the extruded wood oval shell, curling like wood, forming a small terrace on the lawn.

The architect made full use of the advantages of oak wood. The interior floor and wall were paved with oak wood plate, with storage space and cantilever desk. Two roof lights, one above the desk and the other outside the office, open to the sky and bring light into the workspace. The project is a close collaboration between architects, structural engineers and

contractors. The lightweight structure consists of two steel ring beams, wood ribs and a compressed plywood skin, which is located on the smallest pad foundation. Most of the project is prefabricated to reduce the amount of material that needs to be moved through the house during construction.

There are many cases in which oak has the advantages of durability and can be recycled sustainably, including the newly renovated EU headquarters building in Brussels, Belgium.

After the enlargement of the European Union in 2004, the construction of lipschius building, the seat of the European Council (hereinafter referred to as the Council), is gradually difficult to meet the needs of the daily operation of the European Union. In addition, under the Nice treaty, all European Commission meetings will be held in Brussels, which also creates new demands. In response to these problems, the Belgian government proposed to the Council that block a of the adjacent residence palace be transferred to the European Union, which can be used as a new office for the European Parliament and the Council after renovation.

Residence palace was built in 1920s and designed by Swiss architect Michel Polak. The complex is located in the city centre and includes a luxury serviced apartment. The project was only a short-term commercial success. After World War II, the Belgian government transformed the Art Deco building into a minister's office building.

In the 1960s, the original building underwent an expansion and a new section was built along the main street. In the late 1980s, the east wing was demolished to build the lipschius building, which became the seat of today's European Council. The original facade, entrance hall and first floor corridor have been listed as part of Belgium's cultural heritage.

As part of Belgium's cultural heritage, the facade of the old building has been preserved. The new double-layer glass curtain wall uses recycled oak windows and crystal like single-layer glass from different European countries. The double glass curtain wall insulates the noise from the street and provides the first layer of insulation barrier for the interior space.

6. Maintenance of Oak Wood Structure Building

The oak wood structure should be maintained and inspected regularly in the process of use. The inspection contents include: whether the load, deformation, overall stability and support system of the structure are completely effective, whether there is decay and decay, whether the ventilation, moisture-proof and anti-corrosion measures meet the requirements, whether the damage and cracks endanger the safety, whether the connection and nodes of the members meet the requirements, and whether the shear plane and the joints meet the requirements Whether the pressure bearing surface is reliable, whether the steel tie rod and bolt are loose and rusted, whether they meet the fire protection requirements, whether there is carbonization, etc.

In the maintenance of wood structure building, the first thing to do is to investigate and identify the building, which is generally divided into conventional repair and reinforcement or repair of load-bearing structure.

The bearing capacity of components decreases gradually, and there will be decay, bending, cracks, fracture and other phenomena. Conventional problems mainly include shrinkage cracks of wood and the existence of twill, knot, vortex and so on.

The man-made twill is caused by the inconsistency between the saw section and the grain direction. Any type of twill, including natural, reduces the strength of the wood, according to the different cracking position and direction.

According to the code for design of timber structure, the specific maintenance scheme is formulated for the load-bearing structure. In principle, local repair and reinforcement shall be carried out on the original structure and position as far as possible, and the damaged members shall be replaced.

The principles of reinforcement construction are as follows: (1) the original structure should be retained as much as possible, and temporary support should be set up when dismantling to avoid excessive knocking or vibration. (2) Reinforcement work is often carried out under the action of load. When installing and strengthening members, support facilities such as pillars, wedges or jacks are used to reduce the load on the structure as far as possible to ensure the construction quality and safety. (3) In order to carry out the construction according to the drawings, it is necessary to have a comprehensive understanding of the design requirements, wood strength and on-site wood supply, such as whether the wood species used are consistent with the design requirements, and whether the stress level adopted meets the plan requirements.

7. Problems Needing Attention in the Maintenance of Oak Structure Buildings

7.1. Anticorrosion and Mothproof

Decay and insects are one of the serious defects of wood. The decay of wood is caused by wood rot fungi. As long as the water content rate of wood is higher than 18% in a certain period of time, the wood rot fungus can grow. In the process of reproduction, the wood rot fungus will discharge several times of the original water used to maintain the growth, moisten the adjacent wood, and produce a vicious circle, causing the decay to spread. In the past, many support joints of wooden roof truss have been seriously damaged, and even caused the collapse of the whole roof. Wood is easy to be eaten by insects, which leads to hollow wood components, resulting in the reduction and variation of cross section and the loss of bearing capacity of components.

Wood structures or components that are frequently or intermittently affected with moisture, and wood beam ends or

wood bricks that have to be enclosed in walls, must be treated with preservatives to prevent the growth of wood rot fungi.

In order to prevent this kind of damage, the most effective way is to destroy its living conditions. In the design, the ventilation and moisture-proof requirements should be considered from the architectural scheme and structure, so that the wood structure can be often in a dry state, or even occasionally affected by moisture, it can be dried in time, so that the moisture content of the wood members during normal use can be controlled within 20%. Only then needs to carry on the antiseptic treatment to the wood. For example, the moisture-proof layer should be set under the truss and beam support, the wooden column should not be directly inserted into the soil, the column pier should be set, and the ventilation holes should be set in the concealed part of the wooden structure.

In order to ensure the durability of wood structure, many countries in the world use both anti-corrosion and anti-insect agents. For example, the boron phenol mixture prepared with boric acid, borax and sodium pentachlorophenol is a water-soluble agent. Wood components can be soaked in the aqueous solution of the agent. If about 5kg of agent can be absorbed per cubic meter of wood, the purpose of anti-corrosion and insect prevention can be achieved. As the agent is easy to run off when it meets with water, it is only suitable for wooden members that are not affected by moisture. Oil soluble pentachlorophenol and lindane mixture should be used for moisture susceptible wood members.

The fire prevention of wood structure and its components is mainly to measure its fire resistance limit, and take measures to improve the fire resistance limit of wood components according to the requirements of building fire resistance rating. The fire resistance limit of wood components refers to the time from the beginning to the loss of its original function (for load-bearing components, it is the loss of load-bearing capacity) when a component burns in a special furnace according to the simulated fire temperature flame.

7.2. Fire Prevention

During maintenance, we should not forget the principle of fire protection design, and pay attention to the fire resistance and combustion performance of components. Pay attention to the fireproof distance between adjacent wooden structures, and pay attention to the fireproof performance of indoor decoration materials, pipes, cladding materials or lining in accordance with relevant regulations during maintenance.

8. Current Situation of Oak Wood Structure Products Consumption Market

At present, China is in the historical period of urbanization and rapid development of new rural construction. Oak structure has unique advantages in energy conservation and

environmental protection, earthquake resistance and fire prevention, and housing industrialization. However, in the current age structure of timber forest in China, the young forest age is relatively large, which makes the forest resources available for cutting and utilization in the near future less. In addition, there is few high-quality oak wood in China, and most of them are imported oak wood, so the price of using oak wood is relatively high. Imported oak wood is still mostly used for interior decoration in China, and there are few materials for wood bans and wine barrels. The development of oak wood structure building still needs to make a lot of efforts. We should actively study the suitable areas for domestic oak wood planting, and learn the reasonable planting technology abroad. In line with the principle of sustainable utilization, we should develop and plant high-quality oak species that can be applied to wood structure, improve the output, strive for self-sufficiency of oak logs and reduce the cost. The government should vigorously promote the relevant policies of oak wood structure construction, and encourage design firms and construction enterprises to actively participate in the design and construction of oak wood structure, We should be good at combining oak structure with other building materials, reduce the comprehensive construction cost, and improve the design, construction and maintenance standards of oak structure.

9. Summary

In all, Oak is a type of useful wood species. Based on the principle of sustainable utilization, we should develop and plant high-quality oak varieties that can be applied to wood structure, improve yield, realize self-sufficiency and reduce cost. Meanwhile, our government should actively promote the relevant policies of oak wood structure building construction, encourage design units and enterprises to participate in the design and construction of oak wood structure building, combine oak wood structure with other building materials, reduce the comprehensive construction cost, and improve the standards and specifications of oak wood structure design, construction and maintenance, so as to better promote the application of oak in wood structure building.

Conflicts of Interest

The authors declare that they have no competing interest.

References

- [1] Fallis A. G., S. Gagnon, C. Pirvu. (2011) CLT handbook: cross-laminated timber [M]. FP Innovations. Vancouver, Canada.
- [2] Wang H. Y. Li X. Qin Z. Y. (2020) Green energy saving technology and design in super high-rise building. *Intelligent Building & Smart City*, 11: 48-49.

- [3] Werner F, Richter K (2007) Wooden building products in comparative LCA. *The International Journal of Life Cycle Assessment*, 12 (7): 470-479.
- [4] Liu X. T. Xi F. Yang X. L. (2017) Research progress of wooden structure construction sound insulation technology. *China Forest Products Industry*, 58 (3): 67-69.
- [5] Hou X. Y. Fei X. (2018) Design points of prefabricated wooden structure building. *City Weekly*, 38: 6-7.
- [6] U. S. Department of Agriculture, Forest Service, Forest Products Laboratory. *Wood Handbook Wood as an Engineering Material [M]*. General Technical Report FPL-GTR-190. 2010. Madison, WI.
- [7] Yin J. (2020) Application and development trend of key technologies for building energy conservation in China. *Science and Technology & Innovation*, 22: 6-9.
- [8] Zeng J. Yu, H. Y. Zhang, D. D (2018). Comparison of carbon emission between wood structural materials and other building structural materials. *Wood Industry*, 32 (1): 28-32.
- [9] Ren H. Q. Shang G. W. (2015) Research and current situation of wood structure building development in China. *Construction Science and Technology*, 3: 12-16.
- [10] Jungmeier G, Werner F, Jarnehammer A (2020) Allocation in LCA of wood-based products; experiences of Cost Action E9; part I. methodology. *The International Journal of Life Cycle Assessment*, 7: 290-294.