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THE PURSUIT OF NEW CHINESE TIMBER STRUCTURE ARCHITECTURE TECHNOLOGY

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Abstract

Ancient Chinese timber structure architecture technology in the past thousands of years has reached the pinnacle of the state, which also had a profound impact on that of other countries in the world. Unfortunately, the sophisticated technology has not been inherited and improved in the development of Chinese modern architecture, while the reinforced concrete construction has become the main body of the city. Nowadays, Chinese timber structure architecture has a chance of recovery under the language environment, in which new technology and conception of timber structure architecture are being popularized on the global stage. People come to realize the characteristics of timberwork building, namely, energy conservation, environmental protection and good seismic performance, which has a great significance for the future construction of sustainable urban environment. The study of new timber structure architecture technology is the excavation and reapplication of Chinese timber structure construction, which has great theoretical and practical value to the development of timberwork in China. The author will discuss the development history of timber structure architecture in China and main classification of timber structure system. A detailed analysis technological achievements and classic case (Zhongjia Ecology Model District of Exhibition Center in Tianjin, Changzhi Cultural and

Creative Industrial Park in Shanxi, etc.) of Chinese new timber structure in the design field will be held in this paper to sum up advantages, problems and countermeasures. This paper also discuss the past and present of timberwork in order to enlighten future application fields and technical route of new timber structure architecture in China.

Keywords

New Timber Structure, China, Development History, Main Classification, Classic Case, Architecture Technology

1. Overview of Chinese timber structure architecture

Timber structure architecture refers to one engineering structure, which takes the timber as the main stress system. Timber is a building material that is sustainable, reproducible, recyclable, light and solid (Fei Benhua & Liuyan, 2011). At the same time, Timber structure architecture consumes less energy during production and manufacturing (Figure 1), produces fewer emissions and waste water, and has the least environmental and ecological impacts (Figure 2). It helps humans cope with the threats posed by climate change. With the development of times, science and technology, it uses the new materials, new processes and accurate factory production (Zhu Jingxiang, 2014). Compared with traditional timber structure architecture, the modern timber structure adopts industrialized design, modular production and quick on-site assembly to construct, whose construction period is short, on-site pollution is small, quality is controlled, it is a new type of timber structure (Figure 3).

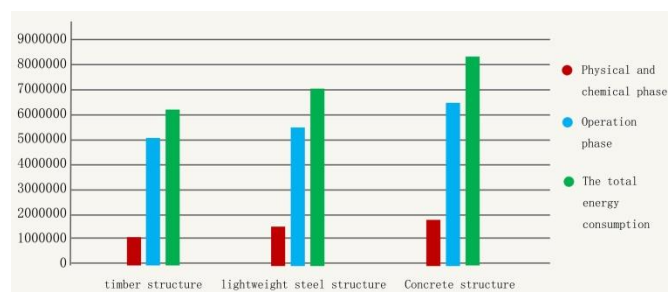


Figure 1: Energy consumption

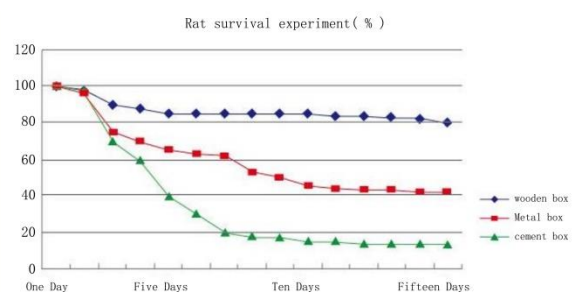


Figure 2: Ecological impact



Figure 3: *New type of timber structure*

In recent years, China's Ministry of Housing and Urban-Rural Development has formulated and perfected a series of standards and norms related to timber structure architecture (Table 1), which has gradually formed a relatively complete technical system.

Table 1: *Standards Related to Timber Structure Architecture*

Number	Standards	Contents
1	National Standards	<i>Technical code of glued laminated timber structures</i>
2	National Standards	<i>Code for design of timber structures</i>
3	National Standards	<i>Code for acceptance of construction quality of timber structures</i>
4	National Standards	<i>Standard for test methods of timber structures</i>
5	National Standards	<i>Technical code for maintenance and reinforcement of ancient timber buildings</i>
6	National Standards	<i>Technical code for partitions with timber framework</i>
7	Standard Design Atlas of National Building	<i>Timber Structure Residence</i>

8	National Standards	<i>Technical code for light timber trusses</i>
9	National Standards	<i>Steel nails for timber structures</i>
10	Jiangsu Local Construction Standards, Procedures	<i>Technical specification for in-site testing of timber structures</i>
11	Standards and Procedures of Jiangsu Local Construction	<i>Technical specification for timber frame construction</i>
12	Standards and Procedures of Shanghai Local Construction	<i>Technical specification for timber frame construction</i>
13	National Standards	<i>Oriented Strand Board</i>
14	National Standards	<i>Structural glued laminated timber</i>

2. A Brief History

China is one of the earliest countries to apply timber structure. In the history of architecture in our country, it has a history of more than three thousand years for the application of timber. From the stilt style architecture in the early period of civilization to the Yingxian Wooden Tower (1056) in Liao Dynasty (Figure 4), to the resplendent and magnificent Forbidden City whose beams are painted and carved, the dominance of timber structure architecture has almost never been shaken in the history of Chinese architecture. In Tang Dynasty, a rigorous production methods of Chinese timber structure has been formed, but it appeared in the literature of Yingzaofashi edited by Li Jie. In China, also in the world, the book is the first regulation of timber structure architecture in design, construction, materials and quotas. Chinese timber architecture, which is integrated with beams and columns, has a unique style. From the emperors' palaces, altar temples, temples and gardens, to the palace of the prince, residential buildings and public buildings, timber structures are adopted generally.



Figure 4: *Yingxian Wooden Tower*

3. The Main Classification of Timber Structure System

At present, the common form of timber structure is mainly divided into heavy timber structure, light timber structure and log structure. Heavy timber structure is generally glued timber structure, which is jointed by timber totally or, timber and plywood in the method of adhesive with timber efficiency as a whole. Structure foundation generally uses reinforced concrete structure, and wall adopts light timber structure, glass curtain wall, masonry walls and other structures (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2012).

Light timber structure is formed by timber frame wall, timber floor or timber roof using stock lumber, timber-based plate or gypsum plank. Log structure is piled by mortise and tenon structures which use log processed by log house moulder. Tall and majestic heavy timber structure is suitable for the large column span, high image open public building types, such as leisure clubs, school, gym, library, exhibition halls, conference rooms, restaurants, churches, train station, aisle front porch, bridges, outdoor landscape facilities, etc. Light timber structure could be seemed as the wall bearing system, not suitable for large open space. It is often used in

residential construction. Log structure technology is more traditional, which has higher requirements on construction technology. It has a higher cost and is common in the construction of scenic area, tourist attractions, leisure places and hotel facilities.

3.1 Heavy Timber Structure

3.1.1 Definition of Heavy Timber Structure

Heavy timber structure refers to the large span beam structure which adopts the engineering timber products, the processed log or the log as bearing component. For the characteristics of exposure, it can fully embody the natural color of timber and beautiful decorative pattern (Figure 5).



Figure 5: *Heavy timber structure*

3.1.2 Characteristics of Heavy Timber Structure

- Heavy timber structure are mostly adopted by public facilities, because of the majestic appearance and a large amount of timber exposed in a visible place. It takes timber as load-bearing and beams, and other part does not use timber.
- Fire prevention design of heavy timber structure exposed all the components mainly through stipulating the smallest size of structural elements, taking advantage of the fire resistance of wooden parts itself to meet the fire endurance. Large timbered parts have good capability of refractory because of the carbonization of timber. When they are exposed to fire, carbonized layer of timbered surface formation will play a very good heat insulation effect.
- To heavy timber structure, the indoor area is commonly large, the storey height is usually high. To highlight the characteristics of the heavy timber structure, the timbered beams

and timbered bearing column of the ceiling are not hidden. Metope and the other part of the ceiling are usually filled up with the concrete, the rock, the glass window or other building materials (Figure 6).



Figure 6: *Heavy timber structure*

3.2 Light Timber Structure

3.2.1 Definition of Light Timber Structure

Light timber structure is a timber frame structure whose structure specification interval is thick (0.3m, 0.4m, 0.6m) and the outer is filled with structure wall panel (OSB board, plywood). Light timber structure can be used in factory production, its light weight greatly improves the construction speed and accuracy, reduce costs and infrastructure construction difficulty.

3.2.2 Characteristics of Light Timber Structure

Compared with the steel structure and the reinforced concrete structure, it has a large structural damping which consumes a large amount of seismic energy in the earthquake, thus, its seismic performance is good (He Minjuan & Frank Lam, 2004). However, due to reasons such as fire prevention, the inside or outside of the framework needs to be laid fire gypsum board, so the natural texture material could not be revealed. To light timber structure construction, the area of

is between 100m² to 600m², the number of floors is generally one to three, the roof is usually slope structure. It is also known as the box frame, the load is supported by the outer wall (load).

3.3 Log Structure

3.3.1 Definition of Log Structure

The construction of the whole house is generally made of logs, which minimizes the use of other building materials and highlights the color of timber whose color and lustre are close to nature. But because log material is huge, it is not common in large buildings of the public place.

3.3.2 Characteristics of Log Structure

- The thickness is not less than 70mm, which can be used for sealing wall groove and crack pointing groove, mainly for building walls.
- Log structure house is a new type of building with timber as the wall material. The timber come from the natural green plant of nature and is the best living material for human.
- The log houses in North America and Eastern Europe are mostly log structure, so their appearance is more rugged. The roof of the log house is pitched to prevent the collapse of snow and rain storage. The log is largely retained in the original color, so that the timber house could be better integrated into the surrounding environment. The corner of the timber house uses the splicing interface, which has a great diversity also leads to different results in appearance.

4. Showroom Design of Tianjin Chinese-Canadian Ecological Demonstration Zone

Showroom of Tianjin Chinese-Canadian ecological demonstration zone is located in Chinese-Canadian ecological demonstration area of Binhai New Area in Tianjin. The base is a piece of reclaimed land to be developed, adjacent to the national maritime museum. It takes the Chinese-Canadian cooperation development as the background. The design concept of the demonstration center aims to further highlight the application of timber in contemporary architecture, thus, to present building characteristics of zoology and livable. Its building area is 3419m², the building materials are red cypress timber, carbonized anticorrosive timber, pure timber surface resin board, fair-faced concrete and so on.

4.1 Design Philosophy

Under the condition of covering an area of less than 5000 m², according to owner's preliminary idea, three parts have been set up, namely, experience exhibition area, activity area and residential sales area. These three parts did separation according to the principle of form following function. After that, each volume is cut and rotated, and the main entrance and central courtyard of each direction are returned (Figure 7).



Figure 7: *Main entrance of exhibition hall*

It is the first time that Canada and China developers cooperate together to build new timber structure with the design concept of low carbon, and environmental protection. In order to fit this design concept, some builds will be sold in sales center are light timber structure residence. The exhibition hall at the southeast corner is designed as the heavy timber structure architecture (Figure 8) which also becomes a unique timbered exhibit of itself at the same time of displaying exhibits. The positioning of this structural form reflects the design concept of "manifesting style with structure, highlighting the application of timber in the building, expressing characteristics of ecology and livable" (Sunyuan, Meiyang & Xuyue, 2017).



Figure 8: *Exhibition center*

4.2 Structural Performance

The outer door platform of sales center's third layer and roof deck of the exhibition hall are connected by an aerial outdoor corridor. This aerial corridor is also connected to the outdoor platform on the second floor stairs by the steel structure stair. Corridor and stair not only solve the problem of the sales center's evacuation, also become the path to the exhibition hall roof. In the process of stress calculation, corridor will be affected by the wind load of large displacement and release force, at the same time, structure rigidities of steel and wood differ to a large extent. So these two kinds of structure, steel and wood, cannot be connected directly. A special processing method would be adopted, otherwise, wood structure which has a weak rigidity will be severely damaged (Sunyuan et al., 2017). Eventually, one-way sliding bearing is implanted after repeated comparison of schemes. This special structural connection component will transmit wind load force that aerial outdoor corridor takes to the timber beam of the exhibition hall.

In the design of interior space in timber structure exhibition hall, architect simplifies the constituent elements of space, cuts functional or transition space which has nothing to do with the scene. Such as a hallway, bathroom, lounge, etc. Structure, space, transportation and furniture which could not be reduced are made full use of to constitute a clear meaning space. Most of the space in the exhibition hall has two floors and an open staircase connects the main entrance to

the second floor. The stair takes the transportation function already, also it is the rest place and showcase space. An umbrella timber structure is designed around the center of the space (Figure 9), and the six oblique columns diverge to the top and link the main and secondary beams of the roof, thus, a rectangular lighting skylight is made.



Figure 9: *The umbrella timber structure*

As part of the structure calculation, the timber column is not only a structural unit, but also a display of spiritual symbolism. Skylight is made of by the main beam, second beam and red cedar plank. The architect do not make suspended ceiling underneath beam structure. To follow Chinese ancient building roof, they expose the beam frame structure completely, so people standing anywhere in the interior can see clearly and read transition logic of the whole building structure. Lack of suspended ceiling keeps its interior height, which makes the inter space tall and spacious. The connection of beam and column becomes one way of decorating indoor top space. The sunshine pours into the indoor space of two-layer height through the window. Indoor light is scattered by beam columns and umbrella columns and a mottled dream experience of light and shadow is created. Due to the good thermal insulation performance of the timber structure, the design logic of exposing beam columns is also applied to the external facade. And the facade panel is also "filled" in the frame of the beam column. The exterior wall panels of the exhibition hall are designed to be a timber veneer with the feeling of massiveness.

And light and shadow are made with different angles of cutting surface to further strengthen the feeling of wooden massiveness (Xie Lisheng, 2013).

4.3 Light and Skin

Timber has a high degree of flexibility and plasticity, so many attempts have been made in the facade form. In the facade of children's activity center and sales center, the grate of pure timber face resin board is adopted. The multivariate light and shadow effect could be made by changing plate size and installation angle. Parapets of the exhibition hall and the sales center also use pure timber veneer resin board, but the shape and installation of the plates are very different from those of the grate. The shimmering texture is created through the design. The exterior wall of the exhibition hall uses outer wall panel whose material is Canadian red cedar. The thickness and texture of the timber are reflected through the cutting of different angles (Kong Yuhang & Christian Schittich, 2014).

5. Changzhi Cultural and Creative Industrial Park in Shanxi

5.1 Project Summary

Changzhi Cultural and Creative Industrial Park is located in Changzhi, Shanxi Province, which includes the recreation club of more than 7000 square meters (Figure 10, Figure 11) and the diamond structure report hall of 2, 000 square meters (Figure 12).





Figure 10, Figure 11: *The recreation club*



Figure 12: *The diamond structure report hall*

The project design is positioned in green and low carbon, low energy consumption and zero emission, cultural creativity, scientific and technological intelligence. It is established in high starting point planning and high standard construction. The park covers cultural products trading, film and television shooting, cultural exhibition, education training, new media, information service, ecological leisure and other fields. The first phase of the project covers 122667m². The project is a green building and eco-city pilot project jointly built by the government of Changzhi city and the government of Singapore. It is the first industrial park integrating green ecology and creative culture in China.

Main road system of the project is presented in the form of butterfly, which divides the area into three regions: the middle part is the body of the butterfly and wings are on both sides. The whole building is willing to dance and fly from the view of the air. The diamond report hall not only has the grand scale of the large span of the glued timber structure, but also has the

transparency and lightness of the glass, which gives consideration to the texture and aesthetic feeling of various building materials.

5.2 Timber and Sustainable Utilization

The thickness of the column, the length of the nails and the thickness of the wall are not the basis for evaluating the building performance and strength. What counts is the overall loading bearing strength of the building. Structure method of connecting timber frame by metal has effective utilization of timber processing technology characteristics and uses the advanced timber mechanic technology to build solid, durable timber architecture. The metal fittings are embedded in the beam end and shall be spliced in the construction site. Construction plywood are labeled on the outside of the wall construction to make column, beam and slab form an organic whole, which can effectively inhibit the distortion and deformation. Not only that, this project adopts the same method in the floor and roof construction to spread outside force, reduce the node location stress intensity, and make whole bearing strength of the construction reasonable, effective and balanced. Less energy consumption than other materials in timber election and processing leads to the result that the use of timber to build houses has less energy consumption and better durability (Zhanghong, 2012).

6. Chengdu Pihe Civil Square

6.1 Project Overview

Chengdu Pihe Civil Square belongs to glued timber monospar structure with the maximum span in China, established by using the variable cross section column. The project is located in the south bank of Pihe in Chengdu, two-story building, a total construction area of 3560.2 m², the seismic fortification intensity of 7 degrees, and the building function is for the restaurant. The architecture adopts varying curved beams with different radians to build an eggshell-shaped structure. Its single span of glulam beams is 16.7m and the whole building consumption of glulam is 235m³ (Figure 13).



Figure 13: *The eggshell-shaped structure*

6.2 Architectural Style

This project is located in Chengdu, which uses large span glulam to reflect the majestic and wide characteristics of the public architecture. In addition to that, other buildings which create an idyllic simple folk customs with culture stone walls and thatched roofs shorten the distance between human and nature. Glulam is widely used in buildings of large span and large space. Nowadays, it is extensively applied around the world. And glulam beams and columns in the building structure can fully reveal the beauty of the timber. This kind of structure in Europe and the United States has a history of nearly a century. The glulam component can be customized and prefabricated according to the requirements of the user (Zhu Jingxiang, 2014), such as the curved beam, and can be connected with the concrete or steel structure through metal fittings.

7. Conclusion

7.1 Research Limitations

There are many restricting factors of developing new timberwork building in our country, such as restricting usage of domestic land, high cost of the construction, low social recognition of timberwork building, the key technology needed to be researched, backward standard, unfinished timberwork building construction management system, weak industry ability and foundation of timberwork building, imperfection of talents reserves and cultivation mechanism, and so on (Xu Hongyuan & Wu Jianmei, 2014). The field of architectural design, the author engages in, has the following limitations. To standards and specifications of wooden construction, there is still a gap between our country and the developed countries. Foreign practice has proved that modern timberwork technology in the production of bearing component can be built multilayer large-span buildings. While for our country, timberwork building could not have more than 3 layers. There is no clear regulation on size and span, and in application scope of timberwork, wood products that can be used and construction size have many restrictions. The current safety rules for fire protection is conservative, which limits the size of wood construction scale and scope of application.

7.2 Advantages of Development

- The application of ecological and sustainable building materials to build houses becomes the theme of the times. China advocates vigorously the architecture development of low energy consumption and green ecological health and new timber structure meets the requirement of our country. Its rich variety of architectural form and structure can satisfy multi-dimensional and multi-level demand of real estate market and provide consumers with more choices.
- The supply and demand contradiction between the huge domestic market demand and the limited forestry resources makes the sustainable development of the timber industry in China objectively and inevitably. The new timber structure can provide a wide market for China's artificial rapid growth forest, which is suitable for China's forest structure. In this structure, there are less natural forest, less large diameter and high quality timber, and more man-made forest. The new development of timber construction gives the future to man-made forest in China. At the same time, it will help adjust the unreasonable

consumption structure of man-made board in our country, expand the scope of use and promote timber industry.

- The epidermis of new timber construction generally has natural timber color, material, texture and natural affinity. Furthermore, it has excellent mechanical property, which provides more possibilities for architects to better shape artistic image. Because of that, there will be rich and varied facade image, warm and pleasant interior space, and perfect match with the natural environment (Hong Yucheng & Chen Peiyu, 2013).

7.3 Scope of Future Research

It is thought that on the base of architectural design, the renewable work of research on new timber construction in China includes:

- The research of composite laminated timberwork system. Laminated wood can largely overcome natural unfavorable factors in restricting the wood used in construction design, which has a great significance to the development of the timberwork building. Wood skeleton composite wall body and light wood truss system could be considered in the application of reinforced concrete structures, expanding the use of the artificial board.
- The research of building materials recycling. It includes: the reuse of building components, transformation of large component to small component, processing to a variety of artificial wood products by abandoned components as raw materials, etc.
- The deep research of wood used in the design of building structure and construction method (Xu Hongyuan & Wu Jianmei, 2014).
- Pay attention to the inheritance of traditional culture, and develop the new timber structure building system in China according to local conditions.

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