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The Development of Chinese Glass Buildings

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This paper introduces the development of Chinese glass building, discusses the problems in the development, and forecasts the future of glass building in China. There is a short but leap-forward development of Chinese glass buildings. The paper, which uses the methodology of history research, takes Beijing as an example to research the development of Chinese glass buildings. It divides the development into three stages: function stage, aesthetic stage, technology stage, and describes each stage with practical examples. It supports an objective analysis of the development with the context of culture, economy, society's status and technology. Finally, the paper concludes the opportunities and challenges in current China, and proposes that the future of Chinese glass building is integrated design.

Keywords: Glass Building, Function Stage, Aesthetic Stage, Technology Stage, Integrated Design

1. Introduce

Glass is an ancient material, while it is one kind of modern building material. After crystal palace, glass became a kind of indispensable building material, and glass buildings appear more and more prevalent due to modular design, modern form and transparency.

Throughout the development of glass buildings, there are three main stages generally: function stage, aesthetic stage and technology stage. The function stage could date back to 1620s, the first "glass house" built by Salomon de Caus. In this stage, the requirements of sunshine and protecting wind in winter are the mainspring, so glass played an important role in the thermal and luminous environment of the building. The aesthetic stage originated from Glass Chain, which maintained that the transparent and smooth character of glass could represent the industry aesthetic. Mies Van der Rohe is the heirs of this idea, and he designed a set of classical glass buildings which are considered as the pioneer of Minimalism. Since 1970's, there were two trends of building development: one was the energy saving caused by the Oil Crisis; the other was the integrated design following the development of building medium tool-computer. Glass building design begun to pay much more attention to how to integrate physical, visual and performance, and it entered into the technology stage. Of course, the three stages are not unattached but superimpose.

China is not the original place of glass, so there is a short history of Chinese glass building. In general, the development could be divided into two parts: the initial part was from 1676 to 1980, and the second part began after 1980, which is real sense of glass building time.

2. The Initiate Development of Chinese Glass Building

2.1. From Glass to Glass Building

In ancient China, glass was not widespread and precious material compared to jade. Glass was introduced into China as utensils filled with water and special ornaments in Western Han Dynasty (BC 202~AD 9), following the Silk Road. So there was nothing different between Chinese glass and Mediterranean glass in form and producing process. At the beginning of Tsing Dynasty, Kangxi Emperor was enchanted with western Optical Physics, so he ordered to found the first regular glass factory in China in 1676, which provided specifically for the royal tribute. At that time, western missionaries mastered the core skills of glassmaking, such as glass blowing, glass casting and glass patterning. The major productions were used as optical glass, but building glass was rare. The first building glass appeared in Forbidden City. It was only a “window eye”, and the other part of the window was closed over by paper. Qianlong Emperor, who is the successor of the throne, liked glass very much. He made a poet named “Glass Windows”, and commended the building craft to patch up the windows by small pieces of glass which was similar with the craft of color windows in Gothic church. After 1909, the Boxer Rebellion Indemnity Scholarship Program unded outstanding Chinese students to learn western culture and technology. The returned students introduced the modern architecture concept to China, including the modern material - glass.

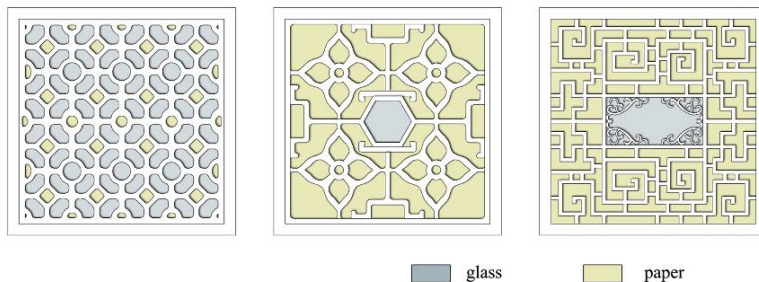


Figure 1: The traditional window frame in Tsing Dynasty.

However, there were no real glass buildings in china until 1980. This period, from 1676 to 1980, was the preparation phase of Chinese glass building development, and it had the following characteristics:

- Building glass was building appendage, without the any pragmatic functions.
- There was no construction design for the building glass.
- Glass was too expensive to replace window paper.

2.2. The Function Stage

After World War Two, the requirements of rebuilding home were imperative in China. However, the traditional building construction had been lost, all the new brick buildings need a kind of economic and transparent material for the luminous environment urgently. Based on the principles of architecture in the early days of New China foundation, those were practical, economy and under the conditions of attention to aesthetic, the function of glass windows in the top priority, little attention was paid to the last point of the principles. Chinese glass building entered into the Function Stage. Glass windows were widely used in China, but the glass constructions were too simple and crude to meet the requirement of aesthetic. Glass building design only followed the function.

3. Glass Building Time

3.1. Background of the First Glass Building Time

The real sense glass building time begun from 1980 in China, and the major driving forces were government policy, western architectural concepts and the promotion of glass producing.

Firstly, Chinese government's policy advanced the development of Chinese glass building. In 1980s, there was an earthshaking change – Reform and Opening up policy China opened the door to foreign advanced technologies, which ensured high quality and safe glassmaking; China opened the door to western ideas, which made Chinese modern aesthetic more inclusive. And China opened the door to the foreign architects, who active the design inspiration. So glass buildings, as the symbol of fashion and modern, were accepted by public.

Secondly, lots of glass buildings, as a main kind of modern styles, were designed by foreign architects in China. In the period, from 1960 to 1980, architects showed solicitude for the promotion of manufactory and information technology. Glass building became a typical architecture for its high degree of accuracy and module. With the growth of foreign design studios, glass buildings became much more famous in China.

Finally, much more glass factories, which had advanced technology, were founded. Before the Reform and Opening up policy, there were only 3 glass factories all over the country, and produced little plate glass per year. It seemed vacant in the glass manufacturing industry. After 1978, many glass factories were founded to meet the needs of economic reform, which made a major breakthrough in glass industry. The glass factories could either produce a large variety of glass or support glass deep processing to meet the requirement of energy saving. The rapid development of glass industry laid a physical foundation for glass building design. The first Glass Building Time was coming.

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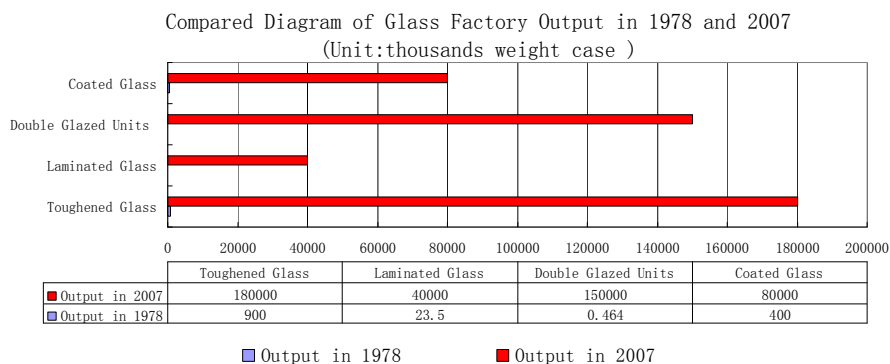


Figure 2: The compared diagram of glass factories in 1978 and 2007.

3.2. The Aesthetic Stage

After 1980, there was a breakout of architecture, and Chinese glass buildings entered into the aesthetic stage. From 1980 to 2000, hundreds of glass buildings were founded in Beijing, and the main changes of the glass buildings focused on color, transparency and form. The architects always took the responsibility of the skin-deep form, but need not master the construction and detail node which was designed by the Curtain Wall Manufacturers. (Figure 3 shows the main glass buildings in the last 30 years, taking Beijing as an example.) The first true sense of glass building is The Great Wall Restaurant which was designed by the American Beckett International Corporation and finished in 1983. This giant building startled the whole nation with its application of glass curtain wall to the main building. It set off wave of glass building in China, and curtain walls became the most famous and simplest modern building component. However, it also took a serious of threats to the personal characters and detail design of architecture. Throughout the research, the miss of construction detail is the gap. So the development of Chinese glass buildings must turn from aesthetic to technology.

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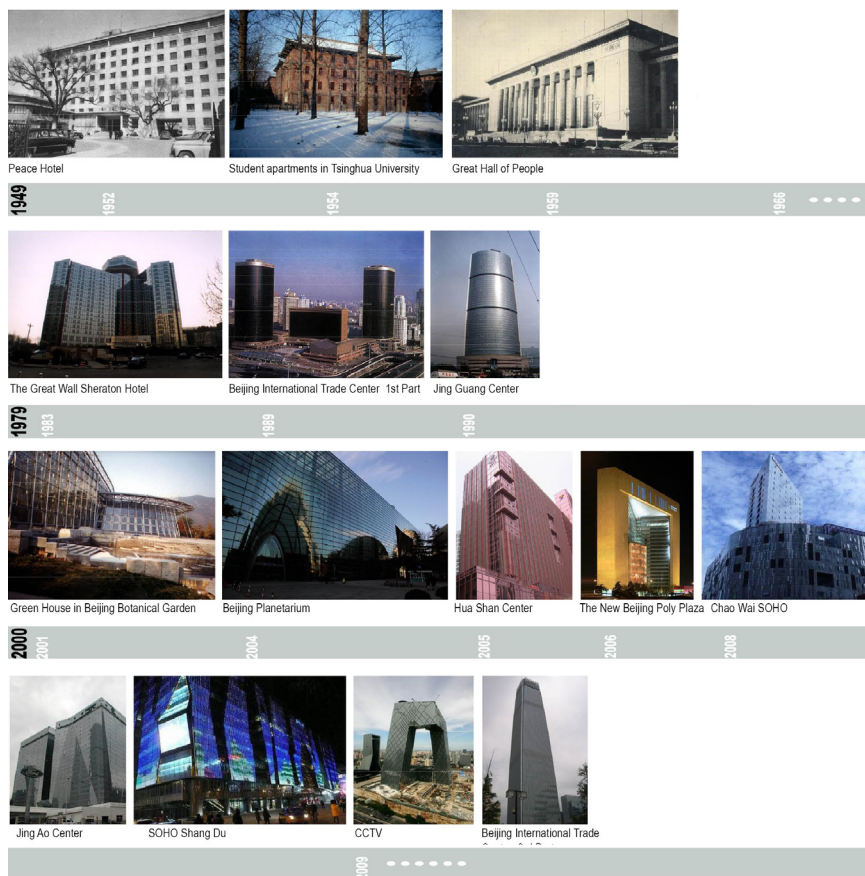


Figure 3: The diagram of glass buildings development in Beijing from 1950 to 2008.

3.3. From Aesthetic to technology

Not only the need of the modern form but also the requirement of energy saving and safe, the technology stage of glass buildings started from 2000 in China. It is considered that excepting for safe glass building also should possess of both diaphanous detail design that presents the structure logic and the effect of energy saving.

In China, the pioneer of the technology stage is Beijing Planetarium which was designed by China Space, Civil, Building, Engineering, Design & Research Institute and an American architect Nonchi Wang. The planetarium's forms represented essential concepts in physics and cosmology, like relativity, warped space, and string theory. The 210,000-square-foot building is an extended rectangle with a long, north-facing glass wall. To represent the warps and curves of outer space, the entrance was designed with distinctive saddle-shaped curves depicting half of a "wormhole", the term for a "shortcut" in Einstein's space-time continuum. And RHINO software was used to build virtual models of the building using to enable their manufacture. The double-curved glass walls were of two types, one more complex than the other. Inside, the tubular "strings" are detailed like shingles, with each course of glass slightly overlapping the one below. But the external curtain walls had to be weathertight and double-glazed for

thermal insulation, and thus the glass was designed to fit into metal T-bar frames with gasketing. In the curved segments, each frame and pane (approximately 3 feet by 10 feet in size) has a unique shape. To complicate matters further, a tight schedule dictated that the glass and frames be fabricated simultaneously, rather than by the usual method of building the frames first and then cutting the glass to fit. Beijing Planetarium present the technology aesthetic by construction.

After 2000, the architects increasingly concerned the technological approaches integrated with the complete building's context, not only the nature context but also the culture context. Amount all the new glass buildings, Forbidden City Meridian Gate exhibition design is a special one. Meridian Gate, which is the main entrance to the Forbidden City, was built in Yongle 18th years (1420). It reflects Chinese long-term construction-type system, and it has the preservation of Tsing Dynasty's painting within the canopy. As early as in 2000, National Palace Museum planed the Meridian Gate Exhibition Hall project to find the possibilities of modern exhibition in traditional building. How to balance between preservation and showing is the core. It must either present the original style and the traditional culture as much as possible or reduce the burdens coming from the new exhibition hall in weight, temperature and humidity. The architect chose glass as the building material because of its transparency and light weight. An approximately 1000 square meters "Glass House", the main structure of which is the self-balance cable system, was designed in the Meridian Gate-hall. And air-condition is controlled tightly to prevent mold and other microorganisms. The project was completed in 2005, and won he UNESCO Prize for cultural heritage protection. It is a model of integrated design. Glass building development has entered into the technology stage which should be compatible with the aesthetic and function.



Figure 4: Beijing Planetarium.



Figure 5: Forbidden City Meridian Gate Exhibition.

4. Opportunities and Challenges

4.1. Opportunities

In recent years, integrated building design, future of the architecture, promotes rapidly. It concerns that all the approaches in the building design should be thought of in the context of the complete building. Glass building is one of the best common and practical approaches for integrated design. From the point of function, the property of transparent could provide enough sunshine in the daytime, and the advanced glass has good thermal insulation and sound insulation performance. So compared to the other building materials, such as concrete timber and stone, glass could meet all the requirements of interior physical environment. From the point of construction, curtain

wall is so light that could save much more structural material. And glass components of the facade are rapid and economic, because they are modular and manufacture, and labor costs are saving largely. Additionally, glass buildings could integrate into the surrounding environment and have culture value. In modern metropolis, glass windows in the commercial centre express the symbolic value of goods in the consumer society most vividly. In the ancient town, glass buildings seem a mirror of the history. One side, they deal with the problems of new function, on the other side, they effort to maintain the authenticity and integrity of the old building and continue the heritage of traditional culture. So Chinese glass building will become more and more popular. And architects have rare opportunities to design a masterpiece in China.

4.2. Challenges

Chinese glass building faces four major challenges currently: energy saving from the point of LCA; security design for the user; detail design for the hi-class quality architecture; the distinguishing feature of the glass building.

Firstly, glass is not an energy saving material from the view of LCA. Table 1 shows the energy consumption of 1 kg glass production. And Figure 6 shows the environmental load of glass production. And it is known that the process of glass production can not break off, which means that energy is consumed at all times. From the view of LCA, glass does cost a lot of energy to produce it. And the thermal insulation of glass needs to be improved, although insulated glass is used as building material widely. So the embedded energy will be part of the integral design.

Table 1: The Energy Consume of Pronouncing 1kg glass.

	1990	1995	2000	2001	2002	2003	2004	2005
Electricity (KWh)	0.1224	0.1229	0.1613	0.1757	0.1901	0.2045	0.2189	0.2334
Coal (Kg)	0.3088	0.1969	0.1426	0.127	0.1119	0.0977	0.0843	0.0718
Fuel oil (Kg)	0.3487	0.287	0.28	0.2751	0.2694	0.2634	0.257	0.2507
Natural gas (m ³)	0.0072	0.0092	0.0118	0.0118	0.0117	0.0115	0.0114	0.0112

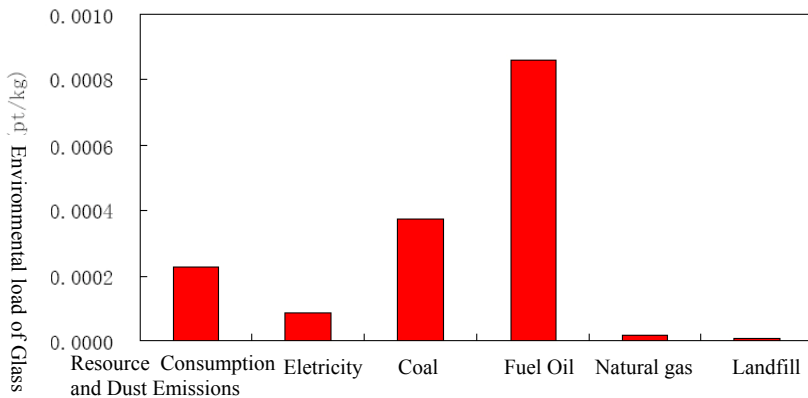


Figure 6: Environmental load of Glass Production.

The second, security design is still a large problem for glass building. *“A 5-by-13-foot glass panel detached from the 51st floor of the Bank of America tower Tuesday, sending pedestrians and workers across W. 42nd Street scrambling.”* New York Daily News reported on Aug. 13, 2008. Compared to beauty and economy, security is the most fundamental principle. However falling glass from the high tower threatens urbanism. There are always two methods to deal with the problem: one is flexible construction design for stability of the facade; the other is enhancing the strength of the glass through physical way or chemical way. Currently, the tempered glass and wire glass are common in China, and there is greater development space for safety glass.

The third point is how to design the glass building much more deep. During the past 30 years, Chinese glass building has a leap-forward development. Lots of components of Glass building are designed by curtain wall manufacturers, and the job of architects is collage, not to mention the technology aesthetic is lost. The best methods to deal with the problem are adjusting the process of the design and helping the architect make up the missed technological knowledge.

The last challenge is how to keep the distinguishing feature of the glass building. It is taken by the standard in modern industrial production, not only for glass building but also for all the modern architectures. Facing this problem, the scale of the standard components of building is core. If the standard component is a wall, there will be no different absolutely. If the standard component is a door, there will be some similar characters. And if the standard component is a nail, maybe it is hard to construct the same buildings. So the architects' new responsibility is to balance the relation of components and whole building, which must base on the context of each building.

5. The Future of Chinese Glass Building

Integrated design is a new concept of architecture with the development of culture and technology, especially for glass building. And glass building integrated design should meet all the needs of function, aesthetic technology, and the context. The function and technology should meet the basic physiological needs and security needs. The aesthetic

should meet social needs. And the integration with context should meet self-actualization needs and respect the needs. From the present situation of glass building, Chinese glass building is coming into the integrated stage.

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