Research on Technological Innovation of Super High-rise Buildings

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Abstract. As China enters a new era of socialism, the economy is developing at a high speed, and the urban population density is increasing rapidly. The development of cities is facing the problem of land shortage. Therefore, the development of super high-rise buildings has become an inevitable means of urban development and construction. However, the construction of super high-rise buildings is difficult and complicated, and there are many factors need to be considered. If the construction technology, structural design method and materials adopted in the construction process are too old or inappropriate, it will cause unnecessary economic losses and even potential safety hazards. Therefore, it is urgent to summarize and find more novel and appropriate construction methods for super high-rise buildings in China. In this paper. the literature method is used to discuss and explore the structural design, material selection and construction technology of super high-rise buildings. The results summarized can provide references for designers and engineers.

Keywords: Super High-rise Buildings; new material; technological innovation.

1. Introduction

In the early 19th century, iron cast multi-storey building structures appeared in Britain after the industrial revolution. In the United States, forged iron beams gradually replaced cast iron beams around the 1840s. The cage structure composed of cooked iron frame, cast iron column and masonry bearing wall is considered to be the most important first step in the history of high-rise building development.

The home insurance building, built in 1885, is the first skyscraper in the world. It is located in Chicago, Illinois, USA. The building had a total of 10 floors and was 42 meters high. The designer was American architect William Jenney. In 1890, two more floors were added to the building, rising to 55 meters. Pig iron columns are used for the lower 6 floors, and the cooked iron beam frame is used for the upper 4 floors. The wall only bears its own weight. It was finally dismantled in 1931.

From the late 19th century to the 20th century, steel structures were widely used to increase the height of buildings to 100 meters. The park building in New York, built in 1898, was the tallest building in the 19th century. Then, in 1903, the first reinforced concrete high-rise building appeared in Britain, called the Ingers Building. In 1931, the Empire State Building, which dominated the height of high-rise buildings in the world for more than 40 years, was built in New York, USA, with a height of 381 meters. In 1974, the United States completed the World Trade Center building, breaking the height record of the Empire State building. Two years later, Chicago's Sears Tower replaced the World Trade Center building as the tallest building in the world. In 1976, the Toronto tower, built in Canada, became the new world's tallest building.

In the past, the buildings built in China which had higher height were Pagodas. After the founding of new China, the development of high-rise buildings began to enter a real development period in the 1980s. The representative building is Shenzhen Development Center building, which is 146 meters high. It is also the first steel structure building in China. Since the 1990s, the construction of super high-rise buildings in China has entered a peak period, high-rise buildings have sprung up like bamboo shoots after a spring rain, and the height records are also being refreshed at a very fast speed. In 2008, Shanghai World Financial Center, a landmark building in Shanghai, was completed. It was 492 meters high and was the first in China and the third tallest building in the world at that time. In 2009, Guangzhou tower, the tallest tower in the world at that time, was completed. Another landmark

building, Shanghai center, was built in 2015, with a height of 632 meters. So far, the building is the first in China and the third tallest in the world.

By 2017, there were 870 super high-rise buildings with a height of more than 200m in China. Among them, there are 777 super high-rise buildings of 200-300m in total; The rest are 76 buildings within 300-400M; There are 6 buildings 500 ~ 600m in total. China has a total of five super high-rise buildings ranking among the top ten in the world height rankings, and is a real super high-rise building country [1].

With the continuous development of super high-rise building construction technology in China, the requirements for construction are getting higher and higher. It is urgent to explore new materials and new building methods. Based on this kind of demand, the purpose of this paper is to summarize, analyze and summarize the existing relatively new super high-rise building methods, structures, materials, etc. This paper will use the literature method to research and analyze the development history of super high-rise buildings, innovative materials of super high-rise buildings, super high-rise building structures, etc. for the reference of readers.

2. Structure Design of Super High-rise Buildings

2.1. Structural Design Requirements for Super High-rise Buildings

Because super high-rise buildings usually exceed 100 meters, their structures must be complex. At the same time, because of its particularity for urban development, super high-rise buildings need to be deeply designed and considered in terms of practicality, ornamental, comfort, etc. On the other hand, the design of super high-rise buildings needs to conform to the laws of the times. In today's era, the world advocates energy conservation and emission reduction, and implements the concept of green buildings. In addition, the safety of super high-rise buildings also needs to be considered. In the design, due to the particularity of the super high-rise building itself, it is necessary to focus on the three aspects of earthquake resistance, wind protection and fire protection. To sum up, the design of super high-rise buildings needs to consider many aspects such as environment, practicality, materials, ornamental, comfort and safety [2].

2.2. Mechanical Structure Form of Super High-rise Building

In the structural design of super high-rise buildings, there are mainly the following structural systems with different advantages and disadvantages: tube structure, steel structure, frame shear wall structure.

2.2.1 Cylinder structure

Tube structure refers to the high-rise building system with one or more tubes as the load-bearing structure, which is applicable to high-rise buildings with more floors. Under the action of lateral wind load, the windward side is tensioned and the leeward side is compressed. The tube structure can be divided into a series of systems, such as frame tube system in Fig. 1, tube in tube system, truss tube system, bundled tube system, etc. The disadvantage is that there is structural load, and the structural frame is heavy, and the manufacturing cost is high.

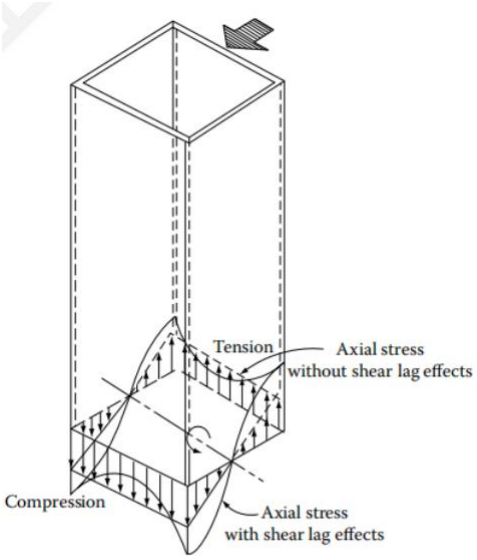

Fig. 1 Frame tube structure

2.2.2 Steel structure

The steel structure is characterized by its good recyclability. The steel frame used in the construction of super high-rise and high-rise buildings can be recycled. In addition, it has less emissions during manufacturing and is more environmentally friendly. The use of steel structure in structural design can reduce the use of concrete and protect the environment. In terms of structural stress, due to the strong ductility of steel, the seismic performance is excellent. The steel structure construction technology used in the construction of super high-rise buildings is relatively simple and fast, which can effectively shorten the construction time. In the construction process, it can not only save most of the labor force, but also improve the comprehensive economic benefits accordingly. Therefore, as a new structural form, steel structure has been paid more and more attention and used in high-rise buildings and super high-rise buildings.

Its disadvantage is that the welding place is easy to cause hidden danger, and if the building catches fire and burns for a long time, the fireproof material will be invalid. After reaching the melting point of steel materials, the structure will quickly deform and melt [3].

2.2.3 Frame shear wall structure

The material of shear wall is reinforced concrete, which is mainly used for vertical load bearing and earthquake resistance of buildings. It can be seen from Fig. 2 that the shear wall uses the internal wall or external wall of the building for horizontal resistance and can bear part of the vertical gravity. Its advantage is that the shear wall structure is not easy to cause subsidence and deformation, and its integrity is good. Because there is no prominent beam and column, it is convenient for the layout of rooms in the building [4]. Its disadvantage is that it cannot provide large space houses, and its structure has poor ductility.

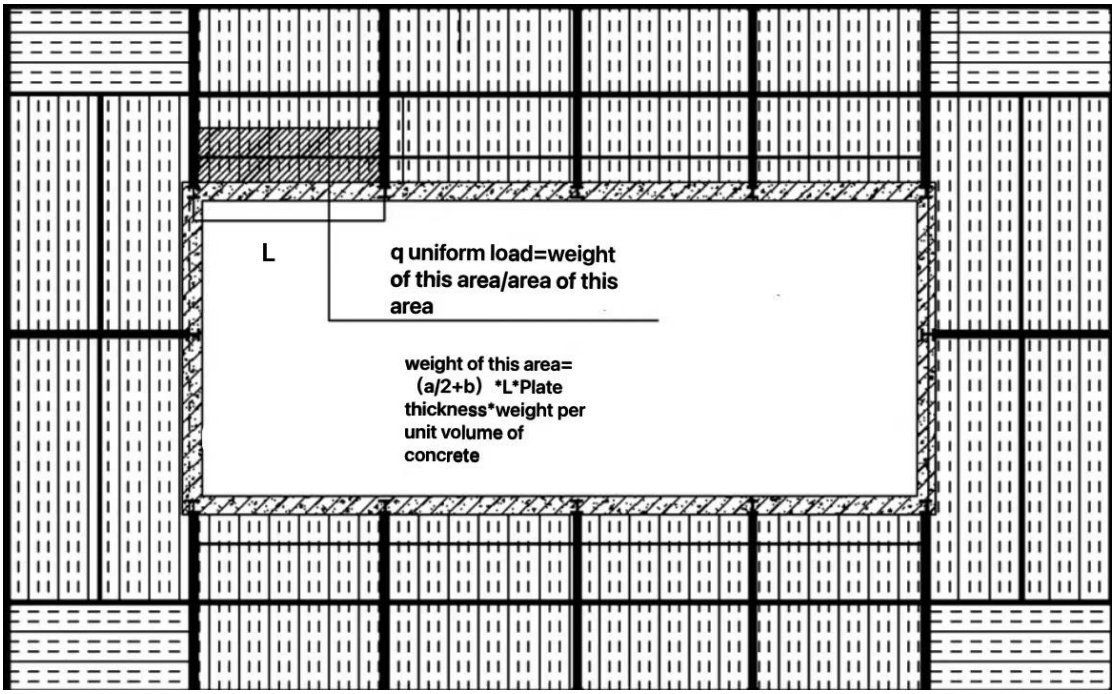

Fig. 2 Shear wall structure [5]

3. Common and Innovative Structural Materials for Super High-rise Buildings

3.1. Common Structural Materials

In the common construction materials of super high-rise buildings, the most important ones are steel structures and concrete structures. The advantages of steel structure are environmental protection, easy assembly, good ductility and strong seismic resistance. The disadvantage lies in its poor fire prevention ability and high comprehensive cost, which makes the use of steel structures more limited in the process of high-rise building construction.

The manufacturing process of concrete structure is relatively mature, with less maintenance cost in the later period and convenient materials. But it is too heavy, and the components built with concrete will be huge and occupy more space. At the same time, the ductility of concrete is also poor.

3.2. New Structural Materials

In essence, new materials do not explore new materials, but can perfectly replace the materials of the previous generation. On the contrary, many new materials developed today are mostly upgrading and remanufacturing of older generation materials. In this paper, new materials developed based on steel structure and concrete structure will be described.

3.2.1 High performance steel

In today's super high-rise buildings, the more important and novel steel is low yield point steel, SN steel and so on. As the name implies, low yield steel has a low yield point. In this way, it has a very good deformation ability to consume external energy. Because of this, low yield steel is often used in shock absorption members. It is difficult to manufacture low yield steel, and low yield steel in China is mainly obtained through import channels. Low yield steel is an essential material for designing shock absorption structures [6].

SN steel is a kind of product manufactured by new technology, which greatly enhances the toughness and strength of ordinary steel. Because of its good toughness and strength, it is also one of the new materials commonly used in super high-rise buildings.

3.2.2 High Performance Concrete

Concrete is an indispensable building material for super high-rise buildings. With the development of construction and manufacturing, concrete has also been innovated many times.

Active micro powder concrete building material, shown as Fig. 3, is a new type of concrete material. Compared with traditional concrete, the indexes of reactive micro powder cement concrete are higher. It has strong compressive capacity, its compressive strength index, tensile strength

The strength indexes are 200~800 MPa and 25~150 MPa respectively. Its improvements on traditional cement concrete are roughly as follows:(1) The particle size of concrete is improved to make the concrete more uniform and improve the tensile strength and tensile strength index. (2) The density of steel fiber is improved to make it have better ductility. (3) Adjust and control the water volume, and maximize the use of non hydration type. (4) Cement particles, effectively increasing the bulk density index. (5) The strengthening and hardening treatment is carried out to improve the strength index of the material by means of heating and pressurizing [7].

Fig. 3 Reactive micro powder cement concrete materials [7]

4. New Construction and Management Technology

4.1. BIM Building Information Model Technology

BIM technology was proposed by Autodesk in 2002 to help realize the integration of building information. From the design and construction of buildings to the end of the project, all information will be collected in a 3D model information database. BIM technology makes up for the lack of contact in the original CAD technology. It shows a very complete integrity in the construction process.

The application advantages of BIM technology in super high-rise building construction are mainly reflected in the following three aspects. First, promote the use of CAD technology. The application of BIM technology can realize the digital transformation of building information and create building information models. 2D design drawings still have their own advantages in current construction projects, but the actual application process faces many limitations and problems. The application of BIM technology can further simplify the application of CAD through format conversion. Second, improve the quality of construction. As BIM technology is a complete whole, all parties involved in the construction can coordinate well and carry out the construction of super high-rise buildings. Third, improve the comprehensive benefits of the project. Through the preliminary virtual construction, the problems in the construction process can be reduced, so as to achieve progress, quality and cost control [8].

4.2. Super High Pumping Concrete Technology

How to transport concrete to high-rise buildings is a difficult problem in the process of super high-rise building construction. In China, the relatively new method is the ultra-high pumping concrete technology. This technology, as its name implies, uses the pumping method to transport concrete to a high place for pouring. China's technology in this field is relatively mature and in the leading position in the world.

This technology has also been successfully applied in engineering projects, creating a world record of 621m pumping height on the Tianjin Gaoyin 117 Building, which was built in 2008 [9].

4.3. GPS and BDS Survey Technology in Super High Level Survey

Because the height of super high-rise buildings is too high, it is difficult to accurately measure the building height with traditional measurement technology. Therefore, the height measurement technology of GPS came into being. Its main advantages are fast, convenient and accurate. In China, we independently developed the Beidou Satellite Navigation System, which was first used by Shenzhen Ping An Financial Center. It is mainly used to determine the corresponding monitoring scheme according to the position of the welding antenna (Fig. 4), and to store the data in real time and finally record all parameters of the measuring point in the whole process and in all directions.[10]

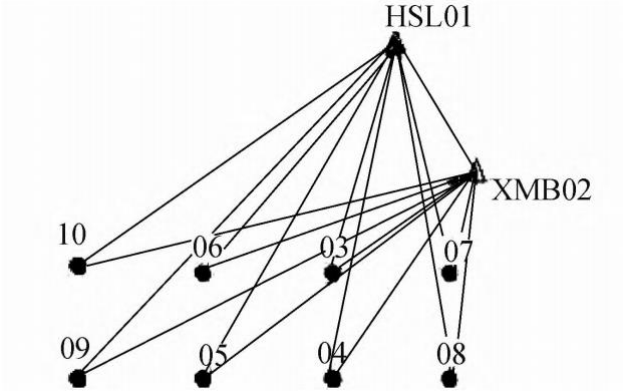

Fig. 4 Plane position of datum point and monitoring surface [9]

5. Conclusion

The construction of super high-rise buildings is a large and difficult project. In the process of design and construction, the selection of materials and construction methods should be considered again and again. All projects have their own unique significance, especially for super high-rise buildings. In the construction of such buildings, after the purpose is clear, the compatibility between the building and the environment should be considered first, and the materials and basic methods should be selected based on this, and then the saving of human resources and the protection of workers should be considered.

With the development of modern science and technology, new materials and high-tech methods emerge in endlessly, but the fundamental of building construction is the mutual blend and communication between people and the environment. In this era, cities are under rapid development every day, so super high-rise buildings will have a very broad development prospect in the future. This also means that there will be more new materials and new methods that can be selected during construction. Select the most appropriate method and material according to the actual situation, so that the construction of super high-rise buildings can get twice the result with half the effort.

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