Characteristics and Application of Modular Integrated Construction

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Abstract. The modular buildings technology is a new type of construction technology, and it is officially called modular integrated construction. It is a new type of construction technology, this system treats each room as a separate module, all prefabricated in the factory. After the factory production, the rooms are transported to the site and assembled into the whole building through reliable connection. This paper discusses the advantages and disadvantages of modular building technology, and describes the development prospect in future. Compared to the traditional way of building, modular buildings have fast construction speed, environmentally friendly construction process, high construction quality and broad development prospects. At the same time, it has some aspects that are not mature at this stage, like the incomplete production chain and low freedom caused by high-degreed standardization. Modular buildings have been applied in many field, and it can be used in cooperation with existing computer technology like building information model. The main development direction of modular architecture in the future is digitalization, intelligence and integration.

Keywords: Modular building, BIM, prefabricated building, building industrialization, Emergency building.

1. Introduction

With the rapid development of the world construction industry, the industrialization and greening of buildings have become mainstream. The traditional building construction starts from laying foundations on site, which creates a lot of waste and costs too much time and money. Compared to traditional technology, the modular building has an excellent design concept, environmental protection type of construction process, and convenience. So it has been increasingly concerned by the construction industry all over the world

MIC (Modular integrated Construction) is also called modular integrated architecture, which is a building form composed of several functional modular unit components. According to the different uses and degrees of prefabrication, the prefabricated units of prefabricated buildings can be generally divided into rod units, plate units and module units. The corresponding building structure system includes direct prefabricated structure system, prefabricated large slab structure system and modular building structure system [1].

In the grim situation of the global COVID-19 epidemic, rapid construction technology is becoming an urgent need. Benefits from the convenient construction mode of modular technology, the construction of the makeshift hospital was completed in just a few days, making a huge contribution to epidemic prevention and control. Besides this, it also has environmental protection and energy-saving features.

This study focuses on MIC, discusses its advantages and disadvantages, and describes the development prospect in future by using some examples.

2. The advantages and disadvantages of MIC

2.1. Advantages

The advantages of MIC include fast construction speed, environmentally friendly construction process, high construction quality and broad development prospects.

2.1.1. Fast construction speed

In the traditional field construction process, each construction link is a single-line production process, which may cause a waste of time. For example, a functioning hospital can take up to three years to build, but Leishenshan hospital, which uses modular technology, took just 12 days. This large gap is due to the excellent construction process of modular buildings.

The production process of prefabricated modular buildings is relatively simple and time-consumed. It mainly divided into factory prefabrication and on-site assembly [2]. All prefabricated modules are carefully designed and carefully reviewed prior to production, so they only need to be assembled in the field according to the relevant instruction. According to the relevant statistical data, the construction time of modular buildings is about 50 percent of that of traditional poured in situ buildings [3].

2.1.2. Environmentally friendly

The traditional construction produces a lot of pollutants such as dust, waste, noise, and sewage. In recent decades, green and environmental protection has become a part of people's daily life.

MIC buildings have more advantages in energy and water saving. As a construction method with high prefabrication rate and volume delivery, it effectively reduces waste generation [2]. This is mainly due to the convenient installation process, without laying foundations and other construction links that always produce a lot of pollutants. Besides these, because of the short construction time, most energy consumption comes from module production in the factory but not the construction site. According to the Institute of Building Sciences, the average UK construction industry spends 13 per cent of all waste on-site. In contrast, modular construction greatly reduces on-site waste, with about 98 percent of steel recycled nationwide. In daily life, one of the leading roles of energy in a building is to provide heat or cooling. Modular buildings usually have high insulation and leakage rates of less than 2 $m^3/m^2/hr$ [4].

2.1.3. High construction quality

The construction quality of the traditional in-situ casting mode can be affected by many factors, such as rain, snow, wind and other extreme weather. The properties of building materials may be affected. For example, the concrete affected by the uneven humidity and temperature could cause the mechanical performance of the building structure to decline because of the inconsistent solidification speed [2].

Compared with traditional in-situ casting mode, modular buildings have higher quality than their standardized manufacturing processes. The room of modular buildings are produced from the factory, and these modules would not be affected by season and weather. In addition, the quality of rooms produced by proper processing procedures and strict product manufacturing standards is less variable and more stable [5].

2.1.4. Broad development prospects

The digitalization and informatization of the construction industry is the primary way in the future, and each company and units involved in the construction need to achieve data interoperability.
MIC has a high degree of adaptation with information and intelligent technologies, and the entire production process can be digitized using BIM and other information technologies. Therefore, combining new technologies and modular design can improve the degree of standardization of modular buildings and promote the long-term development of construction enterprises [6].

2.2. Disadvantages

Besides the advantages, the modular building has some aspects that are not mature, like the incomplete production chain and low freedom caused by high-degreed standardization.

2.2.1. Incomplete production chain

The idea of modular design has been proposed for a long time, the modular architecture has been used in architectural design since Le Corbusier envisioned 'if houses could be industrially mass-produced like car chassis' [7]. However, the technology that can be used on a large scale is new. It leads to many supporting facilities, the combined technology and design are incomplete, and many countries and regions do not have a complete industrial chain to support the large-scale application of this technology [2].

2.2.2. Excessive standardization

Standardized production is obtaining the best order within a certain scope and formulating common and reusable rules for real or potential problems. As the product of standardized design and production, modular architecture does not possess strong individuation, which means that ordinary customers prefer traditional building patterns to modular buildings because the traditional building has higher degrees of freedom for them to design.

Considering the above two major reasons, current technology development is slow, and public recognition and acceptance are low. The general public knows little about modular buildings, and the construction way of the technology is too different from the traditional way, which leads to a lack of confidence and acceptance in the technology. Besides these, the development of the new technology requires a large amount of capital, which is complicated for small and medium-sized enterprises to afford, and many enterprises are afraid to try the emerging technology, so the development of modular construction-related industries is slow under the influence of these factors [8].

3. The engineering application of modular buildings

This study introduces some typical cases of modular buildings to discuss their application effects in different application scenarios. These cases are typical and cover many different periods since the advent of modular buildings and modular integrated construction.

3.1. Student Housing in Wolverhampton, England

The background of this building is that the University of Wolverhampton needs to provide accommodations for its growing student population in a short time. At that time, it was a difficult problem to build a large and excellent student apartment in a short time, so the construction company started to use the modular integrated construction to ensure that high-quality tasks were completed on time [9].

The building is a 25-storey modular architecture in Wolverhampton, UK, with a concrete core in the middle and modular units around the core. For this building, only the ground floor was built on-site. The remaining 24 floors were assembled from many individual modules built hundreds of miles away in Ireland. The Irish factory started modular production in July 2008, three out of the four buildings were finished in 10 months [9]. The three buildings have a total floor area of 2,703 ㎡. The total floor area of the modules is 16,340 ㎡. The average module size is 21 ㎡ and the maximum size is 37 ㎡[4]. It was completed in August 2009, and the total construction took 12 months [10]. The total module installation time is 32 weeks, and the average installation rate is 7 modules per day, up to 15 modules per day. During the entire production and construction process, it takes 16 man-hours to complete one square meter of floor, which is 80 percent more efficient than traditional construction [4].

This case is a daily application mode. It shows that modular buildings can meet the needs of daily life.

3.2. Wuhan Leishenshan hospital

In the winter of 2019, the Chinese city of Wuhan was hit by the COVID-19 virus. Wuhan Leishenshan hospital, a MIC building, was urgently established to share the huge medical pressure in a short period of time.

The total construction area of Leishenshan hospital is about 79,000 square meters, and the total construction time is only 12 days. The main important guarantee factors are modular design, standardized production and assembly production [11]. The concept of modular is the core of the project. The entire isolated medical ward area was divided into two types of containerized slab housing skeleton modules with different size, A and B. The total number of modules reached 990, and all the modules are prefabricated in the factory, transported to the perimeter of the site for off-site assembly, and then lifted into place on site. The hospital ensures excellent quality as well as speed of construction. This is the profit from the standardized production with modular technology. More than ten factories jointly produce the whole module production, and all the data have corresponding standards so that the final modules are not different [12].

Besides these, Leishenshan hospital is a collaborative application of BIM and modular building. Building information model is a multi-dimensional building model information integration management technology [13]. The large-scale construction projects need the cooperation of all functional departments, and there is often a clear division of labor but poor communication between different departments. However, the project of Leishenshan Hospital has been well-organized as a whole, with different functional departments fulfilling their respective responsibilities. The collaborative management function of BIM greatly improves the collaborative efficiency of design and construction. In addition, relying on the simulation function of BIM, the lighting, noise and other functions are optimized [14]. Figure 1 shows the construction process of the hospital.

This case is typical of modular construction in the area of solving medical problems and the area of rational application of electronic information technology. It shows that the modular building can solve the large demand for high-quality buildings in the short term.



Fig. 1 The construction process of Leishenshan Hospital.

3.3. Habitat67, Montreal, Canada

The house was a major showcase for the 1967 Montreal World's Fair. It uses MIC, and pioneered three-dimensional prefabricated living units. The building consists of 365 building blocks to form 158 homes (Figure 2). Each module is 12 m × 5.33 m × 3 m and weighs 90 tons. Habitat's modules were all built and assembled on site: an on-site factory was used to produce concrete, which was then applied to prefabricated steel cages that later became Habitat's signature modules. The modules are then hoisted onto the main structure by crane and arranged in one of 16 different configurations. The outer surface of the concrete was sandblasted without further surface treatment [15].

In response to the Expo's theme of "Man and the World", the authorities of the 1967 World's Fair decided to build a new residential district to showcase the economic, ecological and environmental development trend of modern urban housing. This building was selected as one of the exhibits, and this building is a great attempt of modular building technology by early architects. At the time, this new and environmentally friendly building attracted attention. Today, a large number of people still live in that, and the strength of the buildings is still very high. It is a case that is typical and has been recognized over time. It shows people the advantages of modular buildings and modular integrated construction.



Fig. 2 Aerial view of Habitat67

4. The trend of future development

As an emerging technology, modular construction has been applied in many countries and regions by virtue of its convenience, environment-friendly, high degree of standardization and so on. In the context of global resource depletion and environmental deterioration, green and energy-saving

buildings have become a common demand of the world. Many countries and regions have introduced laws to limit the construction of highly polluting buildings. Therefore, modular buildings would have great development space and opportunities for a long time in the future.

The main development direction of modular architecture in the future is digitalization, intelligence and integration.

As a highly industrialized building technology, the production process must be inseparable from the management and planning of information systems. The standardized production of modular buildings requires extremely accurate data. In the field assembly process, there are a large number of various subcontractors involved, which requires excellent collaborative management ability. The existing relatively mature information management technology is BIM technology [14]. There would be more mature and practical technologies in the future, and modular technology could be combined with these information management technologies, to promote the development of modular technology and realize digitization. The main role of digitization is management and planning, and intelligence is to improve production efficiency and quality. For example, the module unit and the core tube need to be connected with steel components. After assembling, there will be some voids, and the holes in the building are the primary way of fire spread. The intelligent system can take more advanced fire prevention measures for the relevant module rooms, and it can automatically alarm and take appropriate measures to improve the safety of the overall production process [16].

The second direction of development is integration, which requires a complete industrial chain and related infrastructure. The Integration mainly refers to industrial integration in this paper. The integration of modular construction industry refers to the integration of the five key blocks in the traditional industry of construction design, material transportation, enterprise construction, sales operation and after-sales service into a large and complete industrial chain, which makes the whole process more efficient [7]. To be truly successful, an engineering technique usually needs to be used on a large scale, which means it needs to improve on all sides, from demand to supply. When the technology is truly integrated, there would be a complete industrial chain covering all aspects of production and supply.

5. Conclusion

This paper introduces an emerging building technology, modular integrated construction, discusses its advantages and disadvantages, and describes the development prospect in the future.

Modular building is a new construction system compared to traditional building techniques. It has a high degree of industrialization, which is more convenient, environmentally friendly, resource-saving, and has broad development prospects. This technology is in line with the development of green buildings in the world, so it needs to be valued and promoted by society to address existing disadvantages like incomplete production chains and a low degree of freedom in design.

Modular buildings have been applied in many fields and buildings, such as student housing in Wolverhampton of England, Wuhan Leishenshan hospital and Habitat67 in Montreal of Canada. As an emerging technology, modular construction has been applied in many countries and regions by virtue of its convenience, environment-friendly, high degree of standardization. The main development direction of modular architecture in the future is digitalization, intelligence and integration. The MIC still has a lot of deficiencies to improve. In the future, with the cooperation between this technology and information technology, MIC could be used by more countries and regions and gradually become the mainstream technology.

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