A REVIEW OF PRECAST CONCRETE BUILDING DEVELOPMENT IN DIFFERENT COUNTRIES

[1]WANG HE, [2]ZHANG YINQI, [3]GAO WEIJUN

[1, 2]Doctor Student, Professor
E-mail: [1]344305710@qq.com, [2]yinqiz90@gmail.com, [3]weijun@kitakyu-u.ac.jp

Abstract - In recent years, many Chinese enterprises have imported the precast concrete (PCa) methods, which includes different kinds of formed diversified construction method systems. However, it is difficult to form generality of these methods. additionally, there is no relevant and suitable regulations or standard drawings providing guidance for precast concrete methods in China nowadays. It causes a lack of unified module for structure systems and space design. At the same time, the one-sided emphasis on the rationality of the technology and many restrictions of the diversification of architectural design lead to house types and building appearance monotonous. This paper aims to provide realistic suggestions for the current situation and future development direction of prefabricated construction in China. The development history of prefabricated construction buildings in Japan and European countries has been reviewed. Combining with the current development of Chinese prefabricated building and housing industrialization, different construction methods of cases has been investigated systemically.

Index Terms - Construction methods; precast concrete building; Prefabricated Concrete; Housing industrialization

INTRODUCTION

1.1 Features of precast concrete building

Precast concrete building, also known as prefabricated concrete building, is a new kind of architecture with a special construction product produced previously. The construction process is firstly splitting the traditional building products into precast reinforced concrete member produced in the factory. After the factory prefabrication, they are hoisting transported to the construction site and then assembled into a whole building. Prefabricated Concrete structure (hereinafter referred to as PC or PCa structure), is a kind of concrete structure which uses prefabricated members as main component, and is produced through assembly, connection and cast-in-situ partly[1].

In addition, it makes use of modern management mode to achieve generalization of architectural structure members and assembly and mechanization of site construction by architectural design standardization and factory production.

1.2 Classification of precast concrete building

The precast members of precast concrete building mainly include prefabricated wall, precast beams, precast column, prefabricated shear wall, floor, stair, and prefabricated terrace, etc. According to various prefabricated applied position, it can be classified into full-prefabricated assembly concrete structure and precast integral concrete structure.

II. PRECAST CONCRETE BUILDING DEVELOPMENT IN DEVELOPED COUNTRIES

2.1 Japan

There are 4 stages of precast concrete building development in Japan.

2.1.1 The first stage (1955-1965): development period of prefabricated house technology[2]

In this period, the demand for housing increased dramatically in large-size and medium-sized cities in Japan. However, the architectural engineers and project operators were not enough. In order to shorten the construction period, reduce construction staff and improve the efficiency of construction, it began to build houses massively.

2.1.2 The second stage (1965-1975): Prosperous period of prefabricated house

Lots of large enterprises cooperated to be involved in the housing industry in this period. They created and built majority of new housing forms, such as box housing, unit residential housing, etc. During 1967-1974, a series of full scale structure tests were conducted. It fully verified the seismic performance of PCa structure system

2.1.3 The third stage (1975-2000): Re-development period of prefabricated house

In 1975, reinforced concrete structure was precast, which means the cast-in-place concrete was transformed to precast concrete. The purpose and technique of PCa construction method have great changes since 1980s. by the 1990s, the prefabricated houses accounted for 25%-28% of total completed residential area.

2.1.4 The fourth stage (2000 up to now): Promotion period of prefabricated house quality

Since 2000, it began to pay more attention to the construction of long life residence in Japan. The Hundred Year Housing Scheme was proposed. In order to solve the problem that house types monotonous because of the housing industrialization, occupants were able to decide the interior design. In addition, the structure strength and integrity can be

kept by the pre-stress of the wire rope. Therefore, there is not necessary to use steel to connect structure members.

2.2 Europe

2.2.1 France

In 1891, Ed. Coigent company used prefabricated concrete members for the first time in the project of Biarritz Club in Paris[2]. So far, prefabricated concrete structure has developed over 130 years. French tectonic system is given priority to prefabricated concrete system, complemented by steel, wood structure system.

2.2.2 Germany

Germany built large numbers of residential buildings with precast concrete large slab technology[3]. The precast concrete slab technology is built in a way that is more expensive and less personal than the conventional one. It is difficult to meet the social aesthetic requirements of today and is not used after 1990. Concrete laminated wallboard technology has developed rapidly and applied more.

2.2.3 Denmark and Sweden

Since the 1950s, under the influence of France, Sweden started to develop prefabricated housing system with large concrete slab by private enterprises[4]. Then general components-based system was developed vigorously. Nowadays, Swedish new residential building which using general components accounts for more than 80% of the total new residential building. The energy consumption per unit area in new residential building is over two-thirds less than traditional one. Denmark is the first country in the world that legalized the construction module. The standard for modular coordination is established by the International Organization for Standardization (ISO) based on the Danish standard. The approach that implement construction industrialization in Denmark is developing general system using 'Protect Catalogue Design' as its key point. At the same time trying best to achieve modules diversification based on generalization.

2.3 Prefabricated Concrete Building development situation in North America

The North America here mainly refers to the United States and Canada. Thanks to the Precast/Pre-stressed Concrete Association (PCI) long-term research and precast construction extension, precast concrete related standards is perfect[5]. Therefore, the prefabricated concrete application is widespread. North American prefabricated buildings including prefabricated wall of building and prefabricated component of structure. The common characteristic of prefabricated component is the combination of large-scale and pre-stressed. It can optimize the structure reinforcement and connection, reduce the production process and installation work, and shorten the construction period, which fully reflect the industrialization, standardization and technical economic characteristics.

In the 20th century, prefabricated buildings are mainly used in low-rise non-earthquake-resistant areas in north America. Due to the earthquake influence in the California region, the engineering application technology of seismic design and mid-high-rise precast structure has been attached great importance in recent years. The book of Precast Concrete Structure Seismic Design analyses the aseismic design of prefabricated building systematically from the perspective of theory and practice. It concludes lots of latest scientific research achievement in precast structure seismic design, which has a strong guiding significance for the design and engineering application of precast structure.

2.4 Key factors of prefabricated concrete structure building and the development of housing industrialization

2.4.1 State Steering

The housing industrialization of Japan and Europe has different technical characteristics, but both of their government has played and irreplaceable role in promoting the housing industrialization. In terms of the overall situation of industrial development in various countries, it is basically the government that plays the leading role[6]. The United States has successively introduced the housing law to promote the housing industrialization. Japan introduced 'Public Housing Act' since 1950s. Apart from legal aspects, there are numbersof administrative regulations to ensure the healthy development of industrial houses in developed countries. There are series of industrial standard and regulations coming on stage in France which are also driven by the government. 'Construction System' introduced by French Ministry and the 'Construction Logic System' are the government behavior in the role as well.

2.4.2 Attaching Importance to Standard

One of the reasons for the rapid industrialization in countries is that they are more mature in industrial technology and have basically formed their own technological system. HUD standard implemented in 1976 was a milestone in the development of American housing industrialization. It standardized the production and sales of industrial housing. The Japanese product design list, residential parts directory, modular coordination regulations, etc. played a key role for promoting industrial housing. It promotes the industrial production of the residential part, ensures the quality of residential products and components, and protects the rights of the buyers. 25 industrialized building standards had been established until 1981.

2.4.3 Technological Innovation

Countries attach great importance to technological innovation and application. Since 1965, the housing corporation has developed a series of PCa methods. such as W-PC engineering, R-PC, HPC, and the application of pre-stress in precast concrete structures. France has developed a 'Structural Logic System' G5 software system.

2.4.4 Scales Benefits

According to the current situation of industrialized countries development, if the industrialization housing did not reach enough scale, the cost of using industrial production mode to build residential will higher than that of traditional way. Whereas, after reaching a certain scale that large enough, industrialization way will be cheaper than traditional way. In developed countries, such as Japan and Europe countries, at very beginning, the government has used industrializationconstruction way to build a large amount of residential buildings, which can reflect the advantage of industrialized housing on cost.

2.4.5 Large Enterprises Conglomerate

The production enterprise organization form of housing industrialization plays an important role in the construction of industrial housing. In 1995, Japan founded Large Enterprises Conglomerate，namely housing cooperation. Similarly, France has founded the industrial construction group to manage the whole process of industrialization.

III. PRECAST CONCRETE BUILDINGS DEVELOPMENT SITUATION IN CHINA

3.1 Prefabricated concrete buildings development situation in mainland China

3.1.1 The first stage (1950s-1980s): the creation and start-up period

In the 1950s, China put forward to learn industrial construction experience and design standardization, industrialization and modular from the Soviet Union. A lot of industrialization and standardization issues have been discussed and practiced in the aspect of development of prefabricated construction and precast component. Since 1950s, China began to study the design and construction technology of prefabricated concrete building. A series of prefabricated concrete building system was formed. Typical building systems includes a prefabricated monolayer industrial workshop, prefabricated multilayer frame building system, prefabricated large slab building system, etc. In 1960s, drawing lessons from other countries and combining with national conditions, Yugoslavia pre-stressed slab-column system, namely the post-tensioned pre-stressed fabricated structure system, was introduced in China. It further improves the standardized method whose construction technology, construction speed and some other aspects are all improve. In 1980s, a policy, which is to achieve design standardization, components production industrialization, construction mechanization and construction wall modification, was put forward. Following that appeared residential construction form using large block fabricated slab, cast-in-situ large template and so on. However, due to the products monotonous, high cost and some key technical problems unresolved, the construction industrialization comprehensive benefit is not good enough at that time[7]. This period can be regarded as a period in which the government promotes the construction of residential structures in the form of planned economy.

3.1.2 The second stage (1980s-2000):Exploration Period

Since 1980s, it started to carry out housing market supply. The housing construction increased dramatically. In this period, there are lots of significant exploration of building industrialization in China. For example, modulus standard was related to industrialization closely. In 1987, 'Standard for Modular Coordination of Building (GBJ2-1986)' was issued in China, which mainly used for the unity and coordination of the modulus[8]. Product integration appeared in the residential areas in 1990s as well. In this period, compared to the industrialization of building structure, the construction components industrialization is much more outstanding. Meanwhile, with the housing system reform, studies the theory of housing industry increased, represented by a well-off residential system research. However, the housing industrialization in this period was disjointed from real estate construction.

3.1.3 The third stage (2000-now): fast development period

Policies and measures on housing industrialization were introduced in succession in this period. In 2006, the ministry of construction issued 'National Housing Industrialization Base Implementation Outline'. SI housing technology research and 'Development and Technology Integration Demonstration Project between China and Japan' were explored from 2008. In terms of decoration construction, full housing decoration was promoted. In recent years, local government policies on housing industrialization have also been introduced, including Beijing, Shanghai, Shenzhen and Shenyang. In January 2013, the National Development and Reform Commission (NDRC) and the Ministry of Housing and Urban-Rural Development (MOHURD) jointly issued the 'Green Building Action Plan (No. 1, 2013)', which clearly that to promote the industrialization of construction is one of the top ten tasks. In the background of pushing the transformation of the pattern of economic development, adjusting industrial structure and promoting energy conservation and emissions reduction, local governments of Beijing,

Shanghai, Shenyang, Shenzhen, Jinan, Hefei, etc., beginning with affordable housing, issued policies to support the development of housing industrialization. Many large real estate development enterprises, general contractor enterprises and prefabricated component manufactures in China have started to increase investment in construction industrialization as well. From the view of the whole country, the construction industrialization which is represented by the new precast concrete assembly structure has entered a new period of high speed development. This period is the time for China's housing industrialization process accelerating gradually. However, the gap is still large compared with developed countries.

3.2 Prefabricated concrete buildings development situation in Hong Kong

The prefabricated concrete building applications in Hong Kong are very common because of the construction site limitation and strict environment protection requirements[9]. The regulations of prefabricated building design and construction that implemented by Hong Kong Building Department is perfect. Generally, high-rise residential buildings are constructed with composite floor slab, prefabricated stairs and walls. Industrial buildings are made use of prefabricated frame structure or steel structure.

3.3 Prefabricated concrete buildings development situation in Taiwan

Prefabricated concrete building applications in Taiwan are common as well[10]. The building system is close to that in Japan and South Korea. The research and application of prefabricated structure node connection structure and seismic isolation technology are fully developed. Prefabricated frame beams and column, precast wall hangs and other components are applied widely. The professional construction management level is higher. The advantages of prefabricated building that high construction quality and short construction duration are fully embodied. Most of the multi-stories industrial and civil buildings adopt the cast-in-situ concrete structure system. The housing industrialization is carried out based on this system as well. The development of commodity concrete is the typical representative. It is no doubt that all innovations will help the construction industry. However, due to the characteristics of the cast-in-situ concrete structure system, a great deal of manual labor is inevitable. Form work, reinforced binding, vibration and maintenance of concrete, etc., are still carried on in the construction site. All of them are manual operation, which is not possible to achieve industrial production fully.

CONCLUSION

Although there are still many problems in the assembly structure, in the long run, itconform to the development of industrial production.It is necessary to realize that the construction industrialization is a long process of development in China. It is essential to carry out the key technologies such as component, structure, connection node and structural integrity from easy to difficult, from low to high. The design and construction of professional integration requirementsshould be achieved as well. Meanwhile, it should be considered to establish a professional integration of management idea that is from the pilot study to theproject design, production, construction and installation.

REFERENCES

[1] Jiang Qinjian, “Summary on development of assemble concrete building both home and abroad,” Architecture technology, vol. 41, pp. 1074-1077, Dec2010.

[2] Wei・Jiangyang, “The Development and Application States of Precast Concrete in Civil Architecture,” Master,Nanjing University, 2016.

[3] Liu Kang, “Development and outlook of assembled precast concrete building in housing industrialization,” Building Technique Development, vol. 42, pp. 7-15, Jan. 2015.

[4] Yu Tianyi, “The Development and Application States of Precast Concrete in Civil Architecture,” MasterDalian University of Technology, 2015.

[5] PCI Design Handbook[M]. 6th Edition. Precast/Prestressed Concrete Institute

[6] YanWei,Cao Yong-hong,LiGuo-rong“Development of Assembly-Type RC Structure and Building Industrialization”Journal of Chongqing Jianzhu University, vol.26, pp. 131-136, Oct2010.

[7] “Standard for Modular Coordination of Building (GBJ2-1986) (GB/T50878-2013)”, Ministry of Housing and Urban-Rural Development of the People’s Republic of China, 1986.

[8] Jiang Qinjian, “Summary on development of assemble concrete building both home and abroad,” School of Urban Construction and Safety Engineering, vol. 15, pp. 357-361, Decr2015.

[9] Xu Jialin"Study on Detailed Design for Prefabricated Construction ", Master, Jilin Jianzhu University, 2015.

[10] Qi Baoku,Zhang Yang “Research on the Development of Fabricated Buildings”Journal of ShenyangJianzhu University, vol.17, pp. 156-159, Apr2015.

★★★