Application of prefabricated building in emergency rescue project construction —— Taking Wuhan Huoshenshan Hospital Project as an example

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Abstract. In recent years, various natural disasters and health events have caused huge losses of people's lives and properties. Because these events have the characteristics of force majeure, it is necessary to focus on the emergency relief after the disaster, with the development of industrialization of construction industry, the modular building provides strong technical support for the construction of emergency rescue projects. In late 2019, the super-efficient construction of Wuhan Huoshenshan Hospital became an example of the application of Modular Assembly building in the rescue of the new coronavirus epidemic in Hubei Province, it provides a new idea for building industrialization and sustainable development

Keywords: Assembly Building; Emergency Rescue Project; Construction Technology

1. Introduction
At the end of 2019, the outbreak of pneumonia in novel coronavirus in Hubei Province of China touched the hearts of the people of the whole country. Behind the fight against the epidemic, besides the frontline medical workers, construction workers are also contributing their own professional strength to the control of the epidemic. Wuhan Huoshenshan Hospital, which was designed in 24 hours and delivered in 7 days, has become a national attention project because of its efficient construction efficiency, which has been praised and recognized by the international community, and also reflects the construction and production level under the superiority of China's system.

2. Assembly modular building characteristics and development trend
Prefabricated building is a new building mode that promotes the concept of sustainable building in China in recent years. Through industrialized and standardized production mode, prefabricated components are assembled on the construction site to realize integrated production and rapid construction.[1] According to the form of construction structure, there are three types of prefabricated buildings: concrete structure, wood structure and steel structure.[2]

Among the prefabricated buildings, there is a modular building derived from the steel structure, which is called container building (box building). Since the 1940s, container building has been practiced and explored. As a temporary building for disaster relief, the movable disaster relief house designed by architect Sean in 1995 is used as a temporary housing project for disaster relief materials and victims, and it is the embryonic form of a temporary building for disaster relief.[3] In the Wenchuan earthquake in 2008, China used container-type construction of Yanmen Central School in Wenchuan County as a temporary school, which solved the learning and living space needs of about 1,000 students, and was also the practical application of prefabricated modular buildings in emergency
rescue projects. During the Ya'an earthquake in Sichuan in 2013, the "General Practice Box Hospital" jointly developed by Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences and CIMC realized the mobile miniature hospital to meet the disaster relief needs. The container hospital has complete functions, and all medical equipment and functional partitions are modularized and prefabricated in the factory. After arriving in the disaster area, it can be directly connected with water and electricity to put into emergency rescue.

![Figure 1. Inside and Outside of an Assembly-type Modular Hospital.](image)

In order to standardize the design and construction of prefabricated container buildings and other related industry standards, the Technical Specification for Modular Container Building (CECS334:2013) [5], which was approved and issued by China Engineering Construction Standardization Association, provides executable relevant regulations for the design, construction and supervision of prefabricated container buildings. The main contents of the regulations include modular design, exterior structure construction, interior decoration, building protection, structural design, foundation, construction and acceptance, etc. For light modular composite houses, China's Ministry of Housing and Urban-Rural Development has also issued the industry standard Technical Specification for Light Modular Steel Structure Composite Houses (draft for comments) to solicit opinions on relevant technologies and standards of light modular steel structure composite houses.

In terms of policy incentives, China has successively issued relevant policy documents since the beginning of this century to promote the development of sustainable buildings and the promotion of new light steel technology. For example, in 2005, the Ministry of Construction issued the "On the Development of Energy-Saving and Land-Saving Housing The new buildings proposed in the "Guiding Opinions on Public Buildings and Public Buildings" should aim to save energy and materials [6]; the "Green Building Action Plan" formulated by the National Development and Reform Commission in January 2013 also proposed to accelerate the development of building prefabrication and assembly technology [7]. In October 2013, the "Guiding Opinions of the State Council on Resolving Serious Overcapacity Contradictions" (Guo Fa [2013] No. 41) issued by the State Council,
in particular, proposed that light steel structure prefabricated houses should be vigorously promoted in areas where earthquakes and other natural disasters are high Earthquake-resistant building. [8]

3. Project analysis of Wuhan Huoshenshan Hospital

3.1. Project Overview
With the expansion of the epidemic, Wuhan City, Hubei Province, as the hardest-hit area of the new crown pneumonia epidemic, under the condition that the medical acceptance capacity reached the upper limit, the Wuhan Municipal Government proposed to follow the model of "Xiaotangshan Hospital" built-in Beijing during the SARS period in 2003. A medical point with a capacity of about 1,000 beds will be constructed next to the Wuhan Staff Sanatorium near Zhiyin Lake, with a construction area of about 34,000 square meters.

The project adopts the integrated reinforced concrete movable slab house, which is equipped with toilet and bathing facilities inside and adopts the pre-processing standardized production mode, which is a single-layer or partial two-story building. The project is organized by Wuhan municipal government, the construction unit is Wuhan municipal construction group, and the design unit is CITIC Architectural Design Institute; in response to the emergency epidemic, China Construction Third Engineering Bureau Co., Ltd. (hereinafter referred to as China Construction Third Engineering Bureau), which is headquartered in Wuhan, was entrusted to organize the construction force. China Construction Third Engineering Bureau organized four units including Wuhan Construction Engineering Group, Wuhan Hangfa Group and Hanyang Municipal Construction Group to participate in the joint construction. More than 1,500 construction personnel and 500 construction machinery and equipment were constructed at the same time, and a reserve team of about 2,000 people was deployed to ensure that the construction was carried out 24 hours a day, which was put into use on February 2, 2020.

3.2. Project construction difficulty
As an important project in a special period, the project is short of time and heavy in the task. In addition to running against time, it also poses a great challenge to the organization and construction units in terms of multi-disciplinary coordination of the project. The main characteristics of this project are as follows:

(1) Time is running out. In the context of public health emergencies, time means life. When Huoshenshan hospital was completed and put into use one day earlier, more patients with epidemic diseases were admitted and treated, which is of great significance to the development of epidemic control. Therefore, in the special period, the project adopts the "three sides" mode (i.e. survey, design and construction), which greatly reduces the processing time of each stage.

(2) The construction specialty is complex. In order to improve the construction efficiency, the project adopts the method of prefabricated movable board house, which will produce prefabrication, transportation, installation and other work; and in order to minimize the pollution and damage to the surrounding environment, it is necessary to do a good job of sewage disposal; the completion of the project within 7 days requires multi-disciplinary flow construction at the same time, involving multi-unit and multi-disciplinary organization and coordination work.

3.3. Project construction scheme and disposal measures
(1) For rapid construction, a large number of products or semi-finished materials are used. The prefabricated movable board house has been equipped with basic decoration, suspended ceiling and ground PVC, and reserved wires and cables. During site construction, only site hoisting and positioning is needed. Workers connect the corner column of the prefabricated house with the ground floor through bolts, which greatly improves construction efficiency. From January 27, the first batches of box type prefabricated houses were hoisted. On January 31, the hoisting of all prefabricated houses was basically completed, and more than 600 box type prefabricated houses were installed in about 100 hours, ensuring the smooth development of other supporting facilities.

(2) Foundation and sewage discharge.
Huoshenshan Hospital is located in the west of Wuhan City, which is a hilly lake plain area. The underground rock stratum is relatively stable and hard, and the geological conditions compound the needs for rapid construction. Combined with the regulations in the Code for Design of Building Foundations (GB50007-2011)[9], the strip foundation is selected, which is convenient for construction. The foundation should be higher than the ground to meet the structural requirements of the overhead floor. Masonry should be used to block the periphery of the bottom plate, and square steel should be used to pad up the bottom of the box to facilitate moisture-proof and waterproof to form overhead. In virtue of Huoshenshan Hospital is a highly contagious patient with pneumonia in novel coronavirus, special attention should be paid to sewage disposal. On the one hand, attention should be paid to sewage treatment, and on the other hand, isolation should be done in the foundation to prevent sewage from penetrating the natural soil layer and affecting the surrounding ecological environment and water source. In the process of foundation treatment, after leveling and backfilling, the ground is paved with high-density polyethylene pre-laid anti-adhesive membrane waterproofing membrane (HDPE membrane), and the non-trench area is paved with polyethylene membrane (PE membrane) to effectively isolate the infiltration of pollution sources.

![Figure 2. HDPE on the ground.](image)

(3) Joint construction and sealing. The box room adopts steel structure, with four corner columns for the support of the house, and the connection between the side beam and the corner column adopts bolt connection to ensure the stability of the box structure, and strengthen the joints of the steel framework to prevent the occurrence of joint failure. In order to ensure the use safety of the hospital and meet the building design standards, the design checking calculation should also be carried out
according to the provisions of code for design of steel structures (GB 50017-2017)[10] and code for seismic design of buildings (GB 50011-2010 (2016 Edition))[11]. After the modular box is installed in place, the gap between the outermost enclosure structures should be sealed tightly to prevent the external cold air, rainwater and debris from entering the cavity, and the water seepage will affect the stability of the module structure. Flexible materials should be used for plugging.

(4) Application of BIM technology

China Construction Third Engineering Bureau makes full use of BIM technology in the construction project of Huoshenshan Hospital. The main application points are the use of BIM for modular design, which is convenient for the standardized production and processing of prefabricated components. Secondly, the construction site layout is realized through the BIM model, which is scientific and reasonable. Arrange the functional partitions of the construction area; the BIM model can also simulate and display the complete picture of the completed project through its visual characteristics, which is convenient for finding design errors and design clarifications, speeding up the communication between the construction and the design unit, and improving the overall construction efficiency[12].

![BIM Model and Scene in the Ward](The picture is from Chinese architecture).

(5) Heat preservation and heat insulation of enclosure structure

In accordance with the regulations in CECS334:2013, lightweight, efficient materials with heat preservation and heat insulation functions that are convenient for prefabrication and assembly are suitable for the maintenance structure of container composite houses, and the requirements for fire resistance rating of buildings and fire resistance limit of components should be met. The thermal and combustion characteristics requirements of the envelope structure materials are as follows, in addition to the "Building Structure Insulation Composite Board"(JG/T 432-2014)[13] and "Technical Regulations for the Application of Fabricated Glass Fiber Reinforced Inorganic Material Composite Insulation Wallboard"(CECS 396-2015)[14]:

![Figure 3. BIM Model and Scene in the Ward](The picture is from Chinese architecture).
Table 1. Thermal Performance Requirements for Thermal Insulation Materials used in Projects.

| Category                  | Material name                        | Apparent Density(kg/m2) | Thermal Conductivity(W/m·K) | Combustion performance |
|---------------------------|--------------------------------------|-------------------------|-----------------------------|------------------------|
| Common materials          | Expanded polystyrene foam board(EPS) | 18-22                   | ≤0.041                      | B1, B2                 |
|                           | Extruded polystyrene foam board(XPS) | ≥25                     | ≤0.030                      | B1, B2                 |
|                           | Rigid polyurethane foam(PU)          | 35-65                   | ≤0.025                      | B1, B2                 |
|                           | Phenolic resin foam(PF)              | 50-80                   | ≤0.025                      | B1                     |
|                           | Mineral wool, rock wool board        | 80-200                  | 0.045                       | A                      |
|                           | Glass wool felt                      | ≥16                     | 0.050                       | A                      |
|                           | Wood                                 | 500-700                 | 0.170-0.30                  | B2                     |
|                           | Plasterboard                         | 1050                    | 0.330                       | B1                     |
|                           | Cement fiberboard                    | 1000                    | 0.34                        | A, B1                  |
|                           | Lime cement mortar                   | 1700                    | 0.87                        | A                      |
|                           | Thermal insulation mortar            | 800                     | 0.29                        | ——                     |
|                           | Closed air layer (standard state)    | ——                      | 0.024                       | ——                     |
| Structural measures       | Aluminum foil reflective material    | ——                      | Radiation reflectivity ≥85% | ——                     |
|                           | Ventilation double roof and wall     | ——                      | The surface temperature difference can be increased 10°C-15°C | ——                     |

Due to the high demand of fire-proof material, the fire-proof board can be produced quickly for the construction of Wuhan.

4. Conclusion

Wuhan Huoshenshan hospital has created "China speed", and has given full play to China's infrastructure construction level and capacity in the process of emergency relief. Prefabricated modular box and container (box) buildings have shown their advantages of high efficiency and safety in many emergency projects at home and abroad, such as military mobile command center, field operation room, construction site mobile office, etc. On the one hand, it has the characteristics of high turnover and easy construction, on the other hand, it is easy to transform and reuse, which provides a way of thinking for low-carbon and sustainable development of buildings.

Acknowledgement

Under the supervision of 2018 Guangxi’s middle-aged teachers 'basic ability improvement project: Application and Practice of BIM in Information Treatment of Quality Control in Assembly Construction(2018KY1010) and Application and Research of DMBP Intelligent Building Technology In Guangxi(2021KY1098).

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