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Analysis on the key construction technology of steel structure in prefabricated high-rise building-A case study of Pingshan new energy vehicle industrial park in Shenzhen

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Abstract. Prefabricated steel structures are more energy efficient and adaptable than ordinary structures. The characteristics of prefabricated steel structures can better meet the needs of modern buildings, such as diversification, large space, and high strength. At the same time, it has the advantages of shortening the expected construction period and improving the construction efficiency. In this paper, the plant of Pingshan new energy automobile Industrial Park in Shenzhen is taken as a case to study the key construction technology of steel structure in prefabricated high-rise building. Firstly, the plant of Pingshan new energy automobile Industrial Park in Shenzhen is compared with the ordinary plant, and the advantages and disadvantages of the first "skyscraper" workshop are analyzed. Then, section construction technology of steel structure plant members, high-rise steel structure lifting technology, green building technology are analyzed, respectively. Finally, the prospect and development of prefabricated building are expounded. It is suggested that the prefabricated high-rise building can be used in more architectural designs.

Keywords: prefabricated steel structure, high-rise factory, prospect analysis.

1. Introduction

With the rapid development of China's construction industry and the country's promotion of prefabricated steel structure buildings, steel structure has gradually developed in the direction of specialization, complexity and efficiency [1-3]. Among them, prefabricated building construction has gradually gained market recognition for its advantages of low energy consumption, high efficiency, fine management, green and low carbon, and has become the trend of future building development. According to the opinions of relevant state departments, the application of steel structure in prefabricated buildings is strongly supported. The standard system of prefabricated buildings has been gradually

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improved [4]. Prefabricated steel structure building, is all the components are processed in the factory first, so that the work of site construction is greatly reduced. As a result, the pollution to the environment is reduced and the construction period is accelerated. Through standardized design and construction, the safety and quality of construction projects are fully guaranteed. This architecture and construction model fits in with the current concept of green, innovative and harmonious development. It is compatible with the current concept of green, innovative and coordinated development. Promoting prefabricated steel structure buildings conforms to the concept of green, recyclable and sustainable development, which is conducive to providing strong support for the national development strategy. Prefabricated steel structure also has high efficiency, energy saving and good adaptability. It can not only better meet the needs of diversified, large space, high strength and high efficiency of modern buildings, but also give full play to the mechanical properties of building materials, shorten the expected construction period, improve the construction efficiency and reduce the production cost [3]. Therefore, the application of prefabricated steel structure in plant construction has gradually become one of the key contents of scholars. Based on the plant of Pingshan new energy automobile Industrial Park in Shenzhen, this paper compares it with ordinary prefabricated plant, and studies and analyzes the construction technology of prefabricated steel structure. Finally, the prospect and development of prefabricated building are expounded.

2. Engineering background

2.1. Project overview

As shown in Figure 1, Shenzhen Pingshan New energy Automobile Industrial Park is more than 90 meters high. The project which covers a total area of 107,800 square meters can provide 321,000 square meters of industrial space. It is also 3 times the floor area ratio of general plant. The project team adopts the new technology of fully prefabricated construction. By prefabricating construction components and accessories in the factory and then transporting them to the construction site for assembly and installation one by one, the on-site construction is free of formwork and support, which effectively improves construction efficiency and shortens construction time. In order to ensure the stability and safety of the project's bearing capacity, the project team independently completed the full scale test of the most unfavorable loading of prefabricated continuous composite slabs, and confirmed that the maximum loading weight of a single storey floor of 180 square meters could reach 164 tons. By applying this test result, the main structure of each tower of the project has achieved large span, high floor and heavy load, with the maximum span reaching 12 meters, and the first three floors of the workshop reaching 10 meters. After enterprises settle in, the load of each floor can reach 2.5 tons/square meter. These indicators are sufficient to meet the equipment upstairs and production requirements of new energy vehicle manufacturers.

Figure 1. Plant of Pingshan New energy Automobile Industrial Park in Shenzhen [5].

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2.2. Comparison with ordinary prefabricated plant

2.2.1. Improvement of land utilization rate. As the design parameters of this project shown in Table 1, it covers a total area of 107,800 square meters and can provide 321,000 square meters of industrial space [5]. As an assembly-type plant, Xiamen Times lithium-ion Battery Production Base Project (Phase I) has a total construction area of 460,000 square meters [6].

Table 1. The design parameters of the project [5].

Number of layers	Story height (m)	Load (t/m^2)	Area (m^2)
First floor	8	2.5	
The second and third floors	6	0.8	＞3000
Above four levels	4.5	0.65	

2.2.2. Condition of car going upstairs. Each plant is equipped with an oversized truck cargo elevator with a load capacity of up to 5 tons, as shown in Figure 2. Large trucks can be loaded and unloaded directly on the third floor, 66% higher than the freight elevator of general prefabricated plant [5].

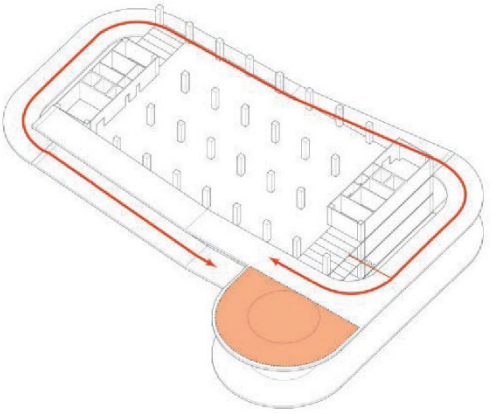

Figure 2. Diagram of "The Car goes Up the Stairs" [5].

2.2.3. Functional recombination. As the first fully assembled "industrial upstairs" project in China, Shenzhen Pingshan new energy Automobile Industrial Park integrates research and development, office and living. The first to third floors are industrial plants, and the third floors are office and living areas, which meet the needs of diversified industrial space. Xiamen Times lithium-ion Battery Production Base project (Phase I) is divided into two sections. The first section is the production area, with 13 buildings including two main plants, static workshops, and raw material warehouses. The second section is the living supporting area [5].

2.2.4. Cost increasing. According to the comparison table of steel consumption in Table 2, this project adopts the long-sided hollow floor scheme with a short span of 8.4m, a long span of 12.6m and a storey of 6m. The unilateral cost increases by 270 yuan and the monthly rent increases by 10 yuan /m2 [5].

Table 2. The comparison of steel consumption [5].

Span (m)	Story height (m)	Usage of steel beam (t)	Usage of column steel pipe (t)	Amount of steel brace (t)	Amount of plate reinforcement (t)	Total steel used (t)	Steel consumption of every square meter (kg)
8.4	4.5	1261	1043	203	272	2779	82
12.6	4.5	1807	1330	298	305	3740	98
8.4	6	1035	950	246	204	2436	96
12.6	6	1426	1184	345	229	3185	111

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3. Construction content of steel structure key technology in prefabricated building

3.1. Segmental construction technology of steel structure plant members

The practical application of components needs to be determined according to the site. It is also necessary to constantly study the construction of segment technology, ensuring the reasonable and scientific assembly of each part through advanced technology innovation. Relevant technical personnel should pay attention to the deployment of the capacity of the tower crane on site, ensuring the reasonability of design, the optimal range of lifting, and the safety of construction. To carry out reasonable transportation of ring parts and ensure the transportation conditions and efficiency, scientific design and route division are must be done, such as decomposing different parts and choosing the optimal segment plan for processing and lifting.

When the steel structure is operated in sections, the weight of the steel components should always be kept within the lifting range of the tower crane or crane. The storage yard of the steel components should be managed well. The stacking standards of the components should be kept in accordance with the construction sequence, and the detailed information and identification should be registered for easy search and use.

3.1.1. High-rise steel structure plant laminated plate construction process technology. Laminated plywood is one of the key links, technical standards require less than 6 layers, so as to ensure safe transport distance. In the actual transportation process, it is often necessary to add a square timber between each laminated board to ensure the matting effect. The laminated panels are large in area and thin in body, which are easily damaged during transportation, then it is necessary to strictly control the transportation link. Special attention is paid to the rational design of the path when transporting to ensure rapid transportation. In order to ensure the reliability of transportation, it is necessary to do a good reconnaissance of the route in advance, to understand the surrounding situation. Since road width and turning radius both affect transportation, special treatment is required for special routes to ensure smooth and safe transportation.

Construction of exterior wall panels and nodal joints must ensure uniformity. The entire connection is made with full penetration welding, and use high strength bolts to ensure the strength of each structure. The maximum single weight of the exterior wall panel has reached 350kg, according to the actual requirements of mobile operation, The plate needs to be smooth after lifting, adjust the position of the wall panels by using the crowbar, and make the prefabricated components and the embedded parts on the column fixed.

3.1.2. Key construction techniques for steel column components.

(1) Positioning of steel columns

Before construction, collision checks should be carried out according to the relevant code standards, and the construction process should be appropriately modified to ensure that the steel columns are of the right size and position when installed. When positioning the steel column, the positioning of the first section of the column must be precise, the purpose of which is to reduce the difference between the value of the upper part of the column in verticality and the specified value.

The specific measures are as follows:

Section I steel column: A level was set up on both sides for the first inspection and measurement; at the same time, a total station was used to locate and measure the center point of the top of the steel column and the top corner around the column [7]. Above the first section: placement of lines in multiple locations on each floor to reduce the error caused by excessive measurement angle, the laser plumb bob is used to ensure the verticality of the four corners of each floor. Use anchor bolts at the foot of the column during construction and design anchor column support platform, angles steel were used as supports around the perimeter to ensure stability, as in Figure 3 [8].

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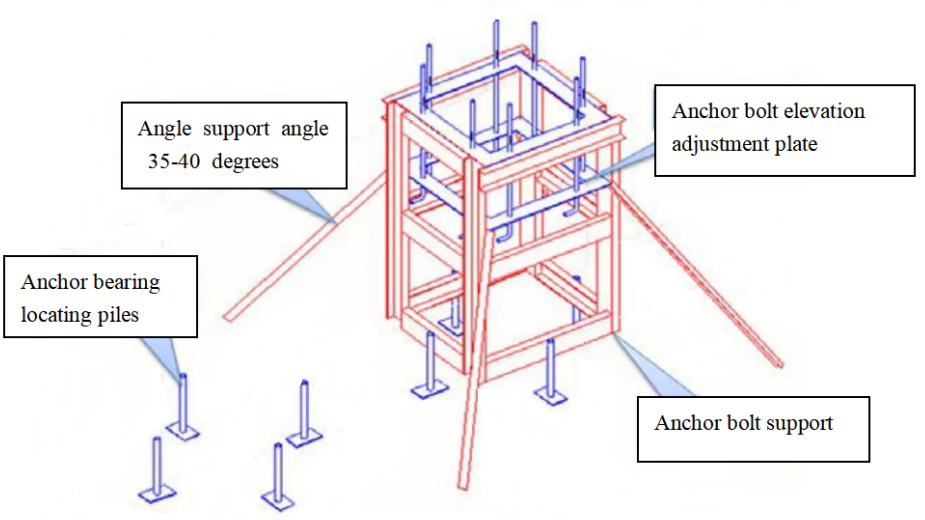

Figure 3. Anchor bolt installation measures bracket platform diagram [8].

(2) Lifting of steel columns

One end of the steel column needs to be protected by matting before it is lifted mechanically, when lifting the steel column, the crane should be lifted on one side to ensure that the steel column lift vertical. In order to ensure the verticality of the steel column, it should be made stable when it rises to the 200 mm area, tested with a special angle ruler and adjusted accordingly [3].

3.1.3. Steel beam construction technology. Steel beams are delivered to the site for installation, The crane was used to carry out the turn-over operation steel beam righting operation and tied the sling for trial lifting. Before formal lifting, a fall arrest plate should be welded in the center of the upper flange of the steel beam. When lifting, the lifting points should be placed on both sides of the center of gravity of the steel beam, and the interval between the two points should be more than half a meter, which should be adjusted according to the actual situation, and then slowly lifted with the slide rope [9]. The installation of the steel beam is shown in Figure 4.

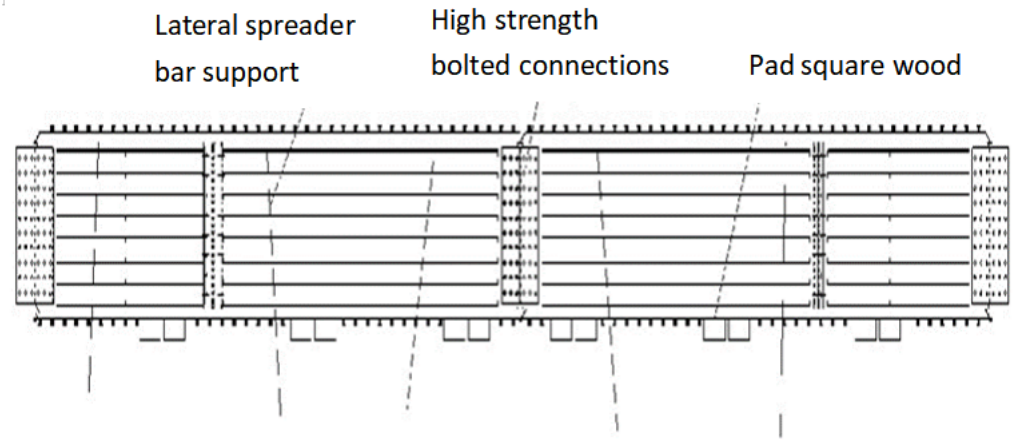

Figure 4. Installation of steel beams [9].

3.1.4. Exterior wall panel construction technology. The nodes of exterior wall panels are connected by full penetration welding and high strength bolts are used to ensure the strength of each structure. After lifting the panels should ensure their smoothness and adjust the position of the wall panel using a pry

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bar, make the prefabricated elements and the embedded parts on the columns fixed. For the maximum single piece of exterior wall panel that has reached 350kg, the operation should be moved according to the actual requirements [10].

3.2. High-rise steel structure lifting technology

High-rise steel structure lifting adopts the method of one lifting position every four floors. Since the steel structure is harder than concrete, the installation method of four layers a lifting position will directly affect the verticality control. The position and twist of the bottom of the steel column is adjusted to observe and control the column direction and elucidate the height of the column with a meridian, and this is used as a basis for the calibration and marking of the steel wedge [10].

3.3. Green building technology

With the application of green building and the promotion of green building technology, people also have higher requirements for the steel structure of assembled buildings. Combining green building technology with assembled steel structures, not only can the construction technology of assembled steel structures have good environmental characteristics, in line with the popular green concepts and standards of the day. More so, the quality performance of the building can be maximized. The project independently developed" Photovoltaic, energy storage, direct current and flexibility" technology applied to the temporary office area, the rooftop photovoltaic power generation can meet most of the project's temporary building electricity demand.

3.4. Current development of assembly type architecture

This advantage is mainly concentrated in tall buildings, and in the process of prefabricated steel structure application, will not be affected by the weather and construction environment. If ordinary concrete is used at this point, the main structure of the building will exhibit extremely unstable characteristics and be susceptible to weather changes and environmental influences. Compared with the concrete structure, the whole space occupies a relatively low degree, allowing the internal space of the building to be fully utilized. In addition, the relatively short time consumed during the operation of concrete and steel construction, while ensuring a shorter construction period, can also reduce the project cost to a certain extent. In the operation process of the whole prefabricated steel structure building, it is mainly to transport the components that have been handled well to the construction site, and then carry out the specific construction operation with the help of the relevant processes, which can shorten the construction period to a certain extent and make the sense of space better expressed.

At present, the country's construction industry is growing at an increasing pace and the corresponding construction projects are also increasing, which has led to a dramatic change in the surrounding construction environment and brought the issue to the attention of the whole society. When the prefabricated steel structure is used in building construction, it can show better environmental protection effect.

3.5. The BIM technology optimization

Building Information Modeling (BIM) integrates project information into a spatial model database based on open standards and interoperability. BIM technology simulation of the construction process of work space and layout proved that the use of BIM technology can effectively reduce the occurrence of space collision in the construction process. Applying RFID and BIM technology to the risk control of prefabricated building construction, it is found that infinite RFID technology improves the visibility and traceability of information to a large extent, and helps to control the progress of prefabricated buildings. As a new software, BIM has won the recognition of the industry through continuous promotion, and has been applied more and more widely, with more and more research results. From the regulatory point of view, through project studies, a BIM based quality and safety supervision system for prefabricated construction supervision was constructed, which includes functional modules such as data management, process control, field quality control and document management to improve quality control for

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prefabricated construction supervision. BIM technology is integrated with 3D scanning technology to quickly obtain bias in the construction of prefabricated buildings, which helps to improve the accuracy of construction.

Using BIM technology and lean production technology system, the last planning system (LPS) in lean construction can be developed to improve the construction environment, and the construction error visualization can be implemented to optimize the construction environment. BIM combined with lean manufacturing tools can improve design efficiency and enhance customer value. The use of lean management, BIM techniques to improve the management system of prefabricated buildings, and mechanical and personnel procedures to propose quality management measures for the construction quality control of prefabricated buildings set the stage for further research.

Research has focused on the combination of BIM technology and lean production techniques. However, case practice studies on the combined application of BIM techniques and lean construction and construction quality control are not very rich from the perspective of the construction quality of prefabricated construction projects.

4. Conclusion

Prefabricated steel structures have become an effective way to realize the transformation of the construction industry from single-storey development to green and high-quality development, due to its advantages such as light weight, well earthquake resistance, strong bearing capacity, large effective use area and benefits to the integrated economy. Prefabricated steel structure buildings have various types of structural system, enclosure system and floor cover system, and each has its own advantages. Through the description of the plant in Pingshan new energy Automobile Industrial Park in Shenzhen, the construction technology of steel structure plant components segment, composite plate construction technology of steel structure plant components, column and beam wallboard components and other key construction technologies are analysed.

The development and popularization of prefabricated buildings is the inevitable result of transformation and upgrading of construction industry. Whether from environmental protection, resources, and the future development of the construction industry, assembly technology has incomparable technical advantages. The fact is that assembly technology started relatively late in many countries, develops slowly, and hasn't been accepted by the mainstream of the market. In the coming years, prefabricated buildings will be the main direction of the construction industry. With the guidance of national policies, it can be predicted that prefabricated buildings will become the main direction of future engineering construction. However, there could be a lengthy process, given the low starting point for technology in various aspects of the country. It is hoped that construction industry will grasp the new development opportunities and take the significant step of industrializing construction at an early date.

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