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MECHANICAL PROPERTIES TEST OF MODULAR STEEL STRUCTURE NODES

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Abstract: Modular steel structure is a highly integrated prefabricated structure. With its factory-based production and modular assembly characteristics, it has been widely used in the construction industry. This article analyzes the advantages and construction points of steel structures, and explains the advantages of modular steel structures and the classification of modular nodes. Finally, it analyzes the shortcomings of existing modular nodes and the development trend of future modular steel structures.
Keywords: Modular building; Steel structure; Mechanical nodes

1 INTRODUCTION TO STEEL STRUCTURE BUILDINGS

In the construction industry, steel structure buildings are an emerging construction model. Compared with previous concrete structures, this model uses steel instead of concrete, which has greatly improved construction and mechanical properties.
Among them, the steel structure is mainly a structure composed of steel, generally composed of steel beams, steel beams, steel frames and other components cast from shaped steel. Each of the accessories is connected by welding, bolts or rivets, etc., which has the advantages of low weight, simple and fast construction, and good mechanical properties.
Steel structures are prone to rust, so it is generally necessary to carry out anti-rust treatments such as rust removal and surface coating on the steel.
During the project construction process, the steel structure technologies used generally include: selection of steel materials, anti-rust treatment of steel materials, construction of steel structures, etc. The use of steel structures for construction is environmentally friendly, low-cost, and can also significantly reduce the construction period. Therefore, steel structure technology still needs to be researched.

1.1 Some Advantages of Steel Structure Buildings

Generally speaking, steel structures have the following advantages: (1) strong structural stability (2) high safety (3) flexible use (4) high cost performance.

1.1.1 Strong structural stability

The traditional concrete model uses concrete to build the main structure of the building. Although this structure has high strength, as time goes by, the concrete will develop problems such as cracking, which is caused by the instability of the concrete. In steel structure buildings, steel is used as the main frame. Due to the high strength and strong deformation performance of steel itself, the stability of the structure is stronger.

1.1.2 High security

The steel structure has excellent ductility and toughness. Before damage, the steel structure has more obvious deformation, which can detect problems earlier and persist for a period of time without damage, which is of great significance to safety.

1.1.3 Convenient construction

The traditional construction method uses materials such as sand and stone, which is inconvenient during the construction process, and may affect the progress of the construction period due to bad weather and other influences. When carrying out steel structure projects, steel components are generally transported to the construction site by the manufacturer and assembled on the construction site. This process is low-cost and fast. Moreover, it is easier to preserve steel, which can keep the construction period from being affected by external factors.

1.1.4 High cost performance

The construction industry likes to complete the same project at a lower cost and with fewer resources and manpower. Concrete requires a lot of energy during the manufacturing process, and the requirements for manpower and material resources are higher than those of steel structures. Due to the flexibility of the steel structure building itself, the cost of manpower and material resources is lower. In terms of time, due to the fast assembly speed of the steel structure, the time cost is lower than that of concrete construction. Therefore, it is more cost-effective to use steel structures in buildings.

1.2 Construction Points of Steel Structure

1.2.1 Selection of steel materials

Steel is generally divided into four types: plates, profiles, metal products, and pipes. In general civil engineering, ordinary carbon steel and low alloy steel are generally used. During the construction process, I-beam and cross steel are generally used for columns [1].

1.2.2 Anti-rust process

Painters are generally used as anti-rust methods for steel structures. The processing of paint can be roughly divided into the following steps: (1) Remove rust from the surface of the steel; (2) Use steel balls and gauze to polish the steel. Make the steel surface bright (3) When painting, pay attention to the paint spraying evenly and the paint cannot agglomerate (4) Carry out further smoothing treatment (5) Finally, apply primer to the steel and wait until it is completely stable. Clean the residue

1.2.3 Stacking and loading and unloading of steel

In large-scale projects, more steel is required, so a larger open space is needed to stack steel. Also pay attention to the environment around the steel.

Such as humidity, etc., to prevent steel from rusting. During the loading and unloading process,

It is necessary to ensure that the steel does not deform, and if deformation occurs, it must be corrected in time. During the installation process, construction workers must pay attention to safety.

1.3 Generally Applicable Types of Steel Structures

1.3.1 Long-span structure

The larger the span of a building, the greater the proportion of its own weight in the load, so reducing the self-weight of the structure is the primary issue. Steel has the advantage of high strength and low self-weight, which is very suitable for long-span structures, so steel structures have been widely used in long-span buildings. General long-span structures include: trusses, grids, suspension cables, etc.

1.3.2 Structures subject to dynamic loads

Steel has good toughness, so it performs relatively well under dynamic loads. In some factories that often use forging hammers or have power functions, and in some buildings that require strong earthquake resistance, steel structures are generally used.

1.3.3 Multi-storey buildings

Steel has excellent properties, and steel structures are often used in multi-story buildings in recent years. The structural forms generally include: multi-layer frame, frame tube, suspension, etc.

1.3.4 Industrial plants

The main load-bearing frame in industrial plants is steel structure. Not only does it perform well in terms of load-bearing, but its performance remains stable under the influence of strong radiant heat.

In recent years, with the emergence of various materials, industrial plants with light steel structures have changed greatly. Nowadays, its structural form is generally a solid-web variable-section portal steel frame.

One of the great advantages of detachable structural steel structures is that they can be

Connection construction, so some structures need to be relocated, such as: mobile factories, construction sites, production and living buildings for field operations, etc.

1.3.5 Light steel structure

Steel structures are not only used in large-span structures, but also in small-span structures with light roof loads. When the roof load is not large, the self-weight of the small-span structure is also an important factor. The dead weight of cold -formed thin-walled steel is smaller than that of reinforced concrete.

1.3.6 Steel and concrete composite structures

Steel must also require stability when under pressure, and often cannot show its advantage of high strength. However, the compressive strength of concrete is greater than the tensile strength, so combining steel and concrete to complement each other is a very ideal structure. This structure has been widely used this year. The main components include steel and concrete composite beams and concrete-filled steel tube columns. 1.4 Current application status of steel structures

With the development of science, the technologies required for civil engineering construction are also increasingly improved. The emergence of steel structure frames has excellent performance in theory and actual construction. Therefore, steel structure technology has been widely used in construction in recent years, gradually replacing traditional concrete buildings. However, there are still many problems to be overcome during the specific construction process. For example, the steel structure is relatively complex, so the consequences of its destruction are very serious. Therefore, research on steel structure technology is still a task that cannot be ignored.

In summary, we can conclude that steel structure buildings are a better building solution. At present, the mainstream of steel structure buildings is prefabricated steel structure, and the most important thing is the connection between various components.

2 ANALYSIS OF MODULAR NODES OF STEEL STRUCTURE BUILDINGS

2.1 Introduction to Modular Construction

Modular construction is the only way for construction industrialization, modularization

It refers to decomposing the building into multiple standard three-dimensional space modules.

The factory is prefabricated and transported to the site for assembly [2]. The overall structure, decoration, water and electricity facilities, equipment installation and other steps of the module can be completed in the factory. On site, only the installation of the module and the connection of water and electricity pipelines are required. That's it. Compared with the construction mode of traditional buildings, the biggest feature of modular buildings is that they adopt factory assembly line design, that is, most of the work is completed in the factory, and it is highly repeatable and facilitates assembly operations.

2.2 Advantages of Modular Buildings

2.2.1 Quality assurance

In the construction of modular steel structures, 95% of the work in modular buildings is completed in the factory [3]. The environment of the factory is more stable than the construction site, and the construction process of each module is consistent and less prone to errors. At the same time, the inspection and supervision of product quality in the factory are also more convenient to prevent the occurrence of substandard quality. Therefore, the quality of modular buildings is more reliable, and there is less possibility of quality defects caused by worker misoperation or environmental impact.

2.2.2 Speed up construction

The modular building design process is standardized, product production is factory-based, and on-site construction and assembly are standardized, which effectively improves the construction time of modular buildings; the basic construction and assembly at the construction site can be carried out simultaneously with the production and processing of building modules, improving efficiency and significantly reducing costs. construction time and speed up the return of funds. According to statistics, the construction period can be shortened by about one-third to one-half on average [4].

2.2.3 Green environmental protection

Since the processing of modular buildings is all done in the factory
Completed, only the assembly and connection work of modules and the connection work of pipeline equipment need to be carried out at the construction site, so there is no need to sprinkle water and dust at the construction site, and the generated construction waste is small, the dust is small, and the noise is low, which is in line with the concept of green construction.

2.2.4 Save resources

Modular buildings adopt a streamlined manufacturing method, which has a high utilization rate of factory production materials and is conducive to resource conservation. There is no need to sprinkle water and dust during on-site construction, which can also save the waste of water resources to a large extent. In addition, modular buildings also have the advantages of convenience The advantage of disassembly is that it makes recycling of resources more convenient.

2.2.5 Little impact on the environment

Compared with traditional construction methods, which require outdoor work most of the time
In the industry, most of the work on modular buildings is completed in the factory, ensuring that the construction progress will not be stalled due to bad weather conditions, and that the product quality will be stable and will not be affected by environmental factors.

2.3 Introduction to Modular Building Nodes

The connections in the modular building structure system can be divided into modular units
There are three types of connection forms: connection between internal structural components, connection between module units, and connection between module units and external support structures [5]. This article focuses on the nodes connected between module units.

The most critical part of the modular steel structure is its nodes, which play the role of connecting and fixing the entire structure. They should be safe and reliable, have clear force transmission, reasonable structure, good durability, and are easy to construct, install and inspect; at the same time, the nodes The structure should have a certain degree of ductility, and the stress distribution on the nodes should be as uniform as possible to avoid stress concentration; during design, the principle that nodes are stronger than components should be followed [4].

2.4 Existing Modular Building Node Classification

According to the direction classification of nodes, they can be divided into vertical connections, horizontal connections, vertical-horizontal connections, etc. Among them, the combined use of vertical connections and horizontal connections can greatly improve the efficiency of construction, especially for non-permanent temporary building structures; while vertical-horizontal connections have more application scenarios and a wider scope of application.

According to the number of connected modules, it can be divided into 2-module nodes, 4-module nodes, 6-module nodes, and 8-module nodes. In special cases, there are 3-module nodes, 5-module nodes and 7-module nodes. The nodes between modules are constructed in a "multi-column and multi-beam" manner, as shown in the figure below: "two columns and four beams" for the corner columns of module 2, "four columns and eight beams" for the side columns of module 4, and "eight columns and sixteen beams" for the middle columns of module 8. Liang"[6].

Generally speaking, the connections between modules should be located at the corners of the modules; when specific requirements arise, such as the module box is too long or the mechanical properties of the module require it, additional nodes can be set in the unit length direction of the module.

According to the on-site assembly form of modular units, it can be divided into component-level assembly nodes, structural-level assembly nodes, and building-level assembly nodes. The assembly node at the component level refers to the production of each component in the factory and assembly on site, which is suitable for situations where the components are not resistant to bumps and poor road conditions; the assembly node at the structural level refers to the assembly of the structural system (including beams, columns, wall panels) completed in the factory or load-bearing wall), the assembly of structural modules such as the envelope system is completed on site, which is suitable for the connection of large, high-rise buildings and 6,8 module nodes; the building-level assembly nodes refer to the completion of full decoration in the factory, or the completion of maintenance systems and The connection method of pipeline connection is fast and efficient in on-site assembly. It is suitable for situations where high efficiency is pursued and the lifting equipment can bear the weight of the complete module.

According to the connection form, the node connection between module units can be divided into welding, bolt connection, pad connection, flat dowel connection, prestressed connection and other methods. For steel structures, welding is the simplest connection method. It has the advantages of simple processing and low error sensitivity. But at the same time, welding has a great impact on the environment, the total project volume is large, and welding is easy to produce residual stress, which affects the quality of the nodes; in addition, the modules connected by welding are not easy to disassemble, making it difficult to reuse modular buildings, resulting in waste.

Bolt connection is currently the most widely used connection method in engineering. The advantage of bolted connection is that it is simple and convenient to connect, easy to install and disassemble, and easy to position. The disadvantage is that it is sensitive to factors such as positioning accuracy, bolt tightness, and hole size, which increases the requirements for processing accuracy.

It is a non-permanent building, usually with low floors. Therefore, the node connections usually use the connectors used in shipping containers: that is, the vertical connectors are twist locks and the horizontal connectors are bridge lock connection nodes. This kind of connection has high construction efficiency, facilitates installation, disassembly and reuse of modules. It is compatible with non-permanent modular buildings and is suitable for situations where the number of floors is not high (generally ≤3 floors).

According to the degree of rigidity, modular nodes can be divided into rigid connections, semi-rigid connections, and articulated connections. For example, mortise and tenon connections should be simplified to hinged connections, bolt connections should be simplified to semi-rigid connections, and welding should be simplified to rigid connections.

3 RESEARCH TRENDS AND PROSPECTS OF STEEL STRUCTURE MODULAR BUILDINGS

3.1 Shortcomings and Solutions of Existing Modular Nodes

3.1.1 Physical performance limitations of steel structures

The main components of steel structures are steel parts, and their physical properties will decrease or even melt under high temperature conditions. In a humid environment, steel structural components are prone to rust, which reduces the strength of the building structure more easily than concrete, which will increase later use and maintenance costs. At the same time, the experimental structure shows that the welds in the steel structure have stress concentration, are prone to fracture and other problems, and have poor seismic performance. If measures are not taken to solve these problems, steel structure modular nodes will not be widely promoted.

3.1.2 Modular structure has single node components

Due to the existence of partition walls, floors, etc., most of the current basic modular units only contain structural components such as beams and columns, which have higher requirements for construction space. A certain working plane is required during the installation process, and other building functions are implemented. The mold must be completed before components

Block unit connection work. Therefore, only by developing new building node forms with more building functions can it be possible to realize and promote modular operations at the functional level of fully decorated buildings.

3.1.3 Node connections are weak

At present, steel box-type modules have been applied and promoted to a certain extent in low-rise buildings at home and abroad. However, because their connection form is derived from the connection form of containers during ship transportation, the disadvantage is that the seismic performance of its connection nodes cannot be improved. Meet earthquake resistance fortification

The application requirements of the district make it more difficult to apply to high-rise buildings. The new version of the earthquake parameter zoning map in my country has canceled the unprotected areas and requires earthquake-resistant equipment.

Full coverage will seriously restrict the promotion and application of modular steel structure buildings in my country [7].

3.1.4 Insufficient depth of node research

At home and abroad, modular steel structure building connection nodes have been

Some experimental research and numerical simulations have been carried out, and certain results have been achieved in establishing an overall structural analysis model, but the research depth is generally insufficient. The node structure and

connection methods of modular steel structure buildings are often relatively complex mechanical structures, which are difficult to simulate accurately. Therefore, analysis should be carried out in terms of mechanical principles and model simplification. Further research. The design theory research on its bending stiffness, bending resistance and shear strength needs to be put on the agenda as soon as possible, otherwise the actual construction process will lack theoretical support and technical guidance.

3.1.5 The cost of steel structure modular construction is relatively high

At present, the project cost of using reinforced concrete shear wall structure is still much lower than that of using steel structure modular building.Book. At the same time, the production of building modular prefabricated parts, the timely assembly of prefabricated parts at the construction site, and the integrated implementation of construction all require professionally trained and skilled construction workers and technicians. Projects using steel structure modular buildings require high-quality construction workers. construction team, leading to further increase in labor costs.

3.2 The Future Development Prospects of Steel Structure Modular Buildings

As a basic industry, the development of the construction industry will affect the economic development of a country to a certain extent. Nowadays, science and technology are developing by leaps and bounds, and more and more new technologies and methods should be introduced into the construction field.

To promote the modern development of the construction industry. With its technical advantages such as good (green and environmentally friendly, excellent quality), fast (parallel operations, efficient construction), economical (manpower and material resources, optimized configuration), and flexible (convenient disassembly, flexible combination), prefabricated buildings have become an important factor in the development of construction. one of the main areas. We can learn from advanced foreign technologies and management methods to increase the development of prefabricated buildings in our country. In the process of making prefabricated components, the relative position of the formwork and the accuracy of the overlap are strictly controlled to ensure that the

The size and shape of the components must meet the construction requirements to prevent the overall quality of the building from being affected by substandard quality of the components themselves. In addition, in terms of on-site installation, we should also take effective measures to improve the actual installation level of the project and increase the requirements for post-installation verification and quality inspection of components. Only in this way can we effectively ensure the quality of prefabricated buildings and better promote construction Standard development of assembly [8].

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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