

Research Status of Self-locking Connection Joints in Steel Structure Modular Buildings

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Abstract

Steel structure module building can greatly shorten the construction progress, improve the construction quality and reduce the waste of resources through factory prefabrication and on-site installation. Modular steel structure has become a development trend in the future. However, at present, the connection between the upper and lower module units generally adopts bolt connection or welding connection. These connection methods have high requirements for construction time and operation space, and the new self-locking or even detachable nodes can solve this problem, so as to promote the development of modular construction. Therefore, this paper summarizes the self-locking connection nodes and classifies the nodes according to the form of self-locking, which is convenient for people to have a new and convenient understanding of the nodes of modular steel structure. Finally, aiming at the shortcomings of current nodes, node innovation is discussed.

Keywords

Steel Structure Module Building; Node; Self Locking Connection Node.

1. Introduction

The construction industry is the pillar industry of China's national economy and has a great impact on China's society. However, the traditional construction methods have some problems, such as destroying the environment, wasting resources and difficult to control the construction quality, which goes against the general direction of vigorously developing green and sustainable in China. Modular steel structure is a highly integrated prefabricated building form, which can significantly shorten the construction period, reduce the waste of resources and reduce the project cost, which is in line with the current national policy of our country.

Steel structure module building refers to a building that transfers a large number of on-site operations in the traditional construction method to the factory, processes and manufactures each module unit in the factory, transports it to the site, and assembles and installs it on the site through reliable connection. As a highly integrated fabricated building, modular steel structure can greatly shorten the construction time, improve the quality of building components, and reduce the waste of resources and project cost. Steel structure modular building is in line with the background of vigorously developing green buildings in China. In response to the call of national policies, it is gradually becoming a hot spot in academia and construction.

The connection node is the key to the performance of modular buildings. The reliability of the connection node will directly affect the performance of the whole building. Moreover, in the specific construction, it is limited by the operation space and construction time. The connection of some parts inside the building is still a difficult problem to be solved. Therefore, a reliable and convenient node form, that is, self-locking connection node, is designed, It is a problem that we can study in depth at

present. This paper systematically analyzes and summarizes the research results of self-locking steel structure module building connection joints in China, so as to provide reference for the development of self-locking steel structure module building connection joints in China.

2. Classification of Nodes

The nodes of modular steel structure are classified according to the form of self-locking, which can be divided into sliding block self-locking connection node, plug-in self-locking connection node, snap type self-locking connection node and torsional self-locking connection node. For different types of nodes, domestic scholars have proposed different connection nodes through a large number of experiments and innovations.

2.1 Slider Type Self-locking Connection Node

Sliding block type self-locking connection node refers to the node form that generally reserves a hole at the unlocking device in the upper member or lower member, connects the spring with the sliding block, and then connects the upper and lower modules together through a certain mechanical structure. This kind of joint has the advantages of simple principle, uncomplicated structure and reliable structure, which is helpful to improve the vertical uplift capacity of members.

Wen [1] proposes a prefabricated steel structure pop-up self-locking column connection node. The connection node is composed of upper steel member, lower steel member, inner sleeve standard part and self-locking device. During assembly, only the upper and lower modules need to be aligned and installed. The trigger ejector rod will be butted with the spring trigger device in the self-locking device after installation, so that the insert rod in the self-locking device pops up and is stuck with the reserved hole of the upper member, Complete the assembly. The connection node realizes on-site welding and bolt free operation, and greatly improves the assembly speed and quality. During disassembly, only remove the clamp outside the reserved hole of the upper steel member, take out or push back the inserting rod in the inserting rod hole along the sleeve, and then remove the upper module to complete the disassembly. The node is characterized by convenient assembly, reliable structure and disassembly.

Liu [2] proposed a sliding block type modular building self-locking connection node. The connecting node is composed of an inserting rod, a side baffle, a sliding block, an upper slide plate, a lower slide plate and a return spring. During the assembly of the connecting node, only the upper and lower modules need to be aligned and installed in place. The sliding block in the slide will pop up under the action of the spring and cooperate with the notch of the inserting rod to complete the assembly. During construction, there is no need to weld or bolt connection on site, and all components are prefabricated in the factory. The connection node is mainly used to connect the upper and lower modules in the module building. It has the characteristics of simple structure, reliable connection, but it is not removable.

Liu [3] proposed a latch type modular building self-locking connection node, which includes an upper connector and a lower connector. The upper connector is hollow and a hole matching and opposite to it is opened on the side wall. The lower connector includes a slide channel plate, a spring and two locking tongues. The slide channel plate is matched with the hollow part of the upper connector, and the size of the lock tongue is smaller than the hole size of the side wall of the upper connector. During the assembly of the node, only the upper and lower modules need to be aligned and installed. The upper connector retracts the sliding tongue in the lower connector under the action of its own weight. After the installation is completed, the sliding tongue will pop up automatically under the action of the spring and cooperate and clamp with the reserved holes in the upper connector to complete the assembly of the upper and lower modules as a whole. During construction, there is no other operation on site. All components of this node can be prefabricated in the factory. It has the advantages of simple structure and reliable connection, but it can not be disassembled.

2.2 Plug in Self-locking Connection Node

Plug in self-locking connection node refers to the connection mode of self-locking or unlocking through tenon and mortise structure or plug-in structure and spring to connect the upper and lower module units as a whole. This type of joint has simple and reliable structure, which is helpful to improve the horizontal shear capacity of members.

Chen [4] proposed a self-locking mortise and tenon modular building connection joint. The connecting node is composed of a self-locking mortise piece, a self-locking mortise piece and a mortise piece sleeve. The surfaces of the upper and lower mortise heads in the self-locking mortise piece and the upper and lower mortise heads of the self-locking mortise piece are stepped and can cooperate with each other. When assembling the connecting node, it is only necessary to insert the tenon into the self-locking mortise of the upper module or the lower module, and the tenon and mortise are clamped with each other, and then align the upper and lower modules for installation. The connection node can be used at any corner position in the module building, including the corner column "two columns and four beams", the side column "four columns and eight beams" and the middle column "eight columns and sixteen beams". It has the characteristics of simple and reasonable structure, and can achieve fast and convenient installation, but it can not be disassembled.

Zong [5] proposed an unlocking modular steel structure insertion self-locking joint, which is composed of upper steel members, lower steel members and connecting devices. Before the node assembly, the conical clip in the connecting device cannot be closed due to the restriction of the limit block. In the assembly process, just install the inserting rod on the lower module through bolt connection, and then align the upper module with the lower module for installation. When inserting into a certain depth, the inserting rod pushes the limit block in the connecting device away, and the conical bamboo shoots are closed to realize self-locking connection. The assembly is completed. During disassembly, the unlocking plate can be pushed by unlocking the kilogram item, and then the unlocking rod can drive the sleeve to move to realize unlocking. At this time, the upper module can be lifted away to complete the disassembly operation. The node has compact structure, fast, convenient and detachable construction. The node also uses the friction self-locking principle, so that the closed conical bamboo shoots can not be opened, so as to realize reliable pull-out connection, which is a significant advantage of the node.

Chen [6] proposed a modular building connection node, which is composed of corner pieces and clamping pieces. The clamping piece includes the clamping piece body and the clamping structure arranged on the clamping piece body; The clamping structure can extend from the connecting interface to the interior of the cavity and be clamped by the clamping device. During the assembly of the node, only the clamp needs to be inserted into the upper corner piece or the lower corner piece first, the clamp will push the upper limit part and be clamped by the clamping device, and then the upper and lower corner pieces can be aligned and installed. The node is mainly used for the connection between the upper module and the lower module in the module building. The construction operation of this node is simple and convenient, and the connection is safe and reliable, but it cannot be disassembled.

2.3 Snap on Self-locking Connection Node

This kind of joint can be connected with the self pulling locking rod through the principle of small friction angle, which can help to make the self pulling locking structure. It can be used to make the joint with the self pulling locking rod, which is simple and reliable.

Ding [7] put forward a rotary snap in self-locking connector between modular steel members, including upper steel members, lower steel members, inserting rods, rotary snap in, rotating shafts, stiffeners, limit pins and return springs. During the assembly of the node, only the inserting rods need to be fixed on the lower steel members through bolt connection or other connection methods, and then the upper steel members can be installed in alignment with the lower steel members, When the inserting rod is inserted into a certain depth, push the rotating card shoot away, and then go deep for a certain distance. The rotating card shoot resets and blocks the inserting rod, and its trapezoidal

flange matches with the necking section of the inserting rod to complete the assembly operation. During construction, the plug-in only needs to be bolted with the lower steel member on site, and all components of the node can be prefabricated in the factory. It has the advantages of fast and convenient installation, simple structure and reliable connection, but it can not be disassembled.

2.4 Torsional Self-locking Joint

Torsional self-locking connection node generally refers to that the self-locking device is twisted and clamped with the connector through the spring. This kind of joint has simple principle and complex structure, which is helpful to improve the bending and torsion resistance of members.

Lu [8] proposed a fabricated steel structure torsion self-locking column connection node, as shown in Figure 8. The node includes upper section steel column, lower section steel column, upper section steel column end plate, lower section steel column end plate, lower section steel column diaphragm, torsion spring triggering rotation device, inserting rod and ejector rod. During assembly, external force needs to be applied to make the limit ball on the torsion spring pass through the limit hole to complete the preparation before self-locking, Then, the upper steel column and the lower steel column can be aligned and installed. After the inserting rod completes the insertion of the lower column, under the action of the spring, the rotating gasket will automatically rotate and snap with the inserting rod to complete the assembly operation. All components of the node can be prefabricated in the factory, and the welding part is also completed in the factory. There is no other operation on site. It only needs to be hoisted and assembled. It has the characteristics of convenient construction, good bending resistance and stress performance, but it can not be disassembled.

3. Comparison of Connection Methods

When selecting the appropriate connection method, we mainly consider four aspects: safety, convenience, fault tolerance and cost. Among them, safety mainly requires its stress performance, whether the force transmission path is clear and whether the connection node is reliable. Convenience mainly considers whether the installation and disassembly of node connection are simple and fast during construction and whether it is easy to place in the transportation link, The fault tolerance rate mainly refers to whether the size deviation of the connecting node during construction or the installation deviation during assembly will affect the reliability of the node connection, and the cost. The main consideration is the manufacturing cost of the connecting node in the factory and the construction cost of on-site installation. Advantages and disadvantages of each node form.

4. Conclusion

By sorting, classifying and summarizing the existing self-locking connection nodes in China, this paper hopes to lay a foundation for future work.

(1) At present, modular steel structure has received extensive attention from all walks of life because of its advantages of high construction efficiency, high construction quality and low project cost. However, the domestic node related research is still a blank, which is still in its infancy, and there are few forms of self-locking connection nodes. We urgently need to carry out the innovation, theoretical analysis, numerical simulation and experimental research of connection nodes.

(2) Compared with traditional connection, self-locking connection is convenient and fast; To complete the self-locking, it often needs a spring or rotating shaft, and uses a simple mechanical structure; The rotating shaft is better than the spring, which is mainly reflected in good durability, high fault tolerance rate, good force transmission path, etc; The field of detachable self-locking connection node is still blank, which is in line with the national green and sustainable policy and is a potential area.

(3) Sliding block type self-locking connection node and snap type self-locking connection node can effectively enhance the pull-out capacity of components; The plug-in self-locking joint can effectively enhance the shear capacity of the member; Torsional self-locking connection joints are

mainly used to enhance the torsional capacity of components. The above joint forms can be used for the corner column connection of upper and lower modules.

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