Applicability Analysis of the Self-pierce Riveting Connection of Assembled Light Steel Structure

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Abstract: The connection process of traditional assembled light steel structure is complicated and the efficiency is low. The introduction of self-pierce riveting connection technology for component assembly can effectively improve the work efficiency. When studying the applicability of self-pierce riveting connection, the mechanical properties of the self-tapping screw and self-pierce riveting are compared. This paper takes the truss beam performance of traditional self-tapping screw as the standard, and analyzes the feasibility of the self-pierce riveting connection of assembled light steel structure. The results show that the mechanical properties such as the bending resistance and rigidity of the self-pierce riveting connection are better than those of self-tapping screws, so it is more suitable for fabricated cold-formed thin-walled steel modules with higher rigidity requirements.

During the "13th Five-Year Plan" period, our country has vigorously promoted the development of prefabricated buildings and proposed the industrialization of buildings. The cold-formed thin-walled steel module structure can not only make the building return to industrialization, but also has the advantages of light weight, high strength, high degree of industrialization, fast and convenient assembly, and convenience for rapid reconstruction after disaster. It has been widely used and developed in low-rise buildings in recent years. In the fabricated light steel floor system, the truss beam structure is widely used because of its small span limitation and effective increasing of the height of the room. Self-tapping screws are the commonly used connection method between the components. But in actual use, its operation process is complicated, positioning, drilling and screw thread are required, and the working hours are long, so it is difficult to give full play to the advantages of rapid assembly of prefabricated structure. In addition, it is also discovered that there are risks of screw tilt, pull-out and shear in the cold-formed thin-walled steel module structure, and its performance has a great impact on the traditional connection mode.

1. The Significance of Assembled Light Steel Structure Buildings

With the continuous progress of society, people have begun to pay attention to the impact of human activities on the environment. Faced with problems such as resource consumption and environmental pollution, our country's research on assembled steel structure buildings has also continued to be deepened, which has brought certain basic support to the assembled structure building and laid the foundation for the formation of new building mode. Traditional reinforced concrete buildings not only have a long construction period, but also have problems such as high noise and large floor space on the construction site. While consuming a lot of natural resources, it also has a certain impact on the surrounding environment and endangers the ecological environment. And this kind of reinforced concrete structure cannot be reused after use, and it will also pollute the environment when it reaches the demolition period. In contrast, the assembled light steel structure is much more environmentally friendly and faster.

2. Experimental Study on Bending Performance of Truss Beams

According to the current research situation, this paper mainly studies the mechanical properties and forming principle of the lock riveted joint, as well as the truss beam with self tapping screw. There are few research on the mechanical properties of the truss beam with self-pierce riveting connection. Therefore, this paper makes a more in-depth analysis on the applicability of the self-pierce riveted connection and the cold-formed thin-walled steel truss beam with self tapping screw connection in the assembled light steel structure. Through the bending performance test of truss beam, the mechanical properties of different connection modes are analyzed and compared to provide experimental basis for self-pierce riveting connection in cold-formed thin-walled steel structure.

2.1. Test Analysis of Failure Mode

In the early stage of failure mode test, the truss beam components of the self-pierce riveted connection specimens are in linear elastic state. When it increased to 7 kn, the extension of the top chord between the inclined bar and the vertical bar at both ends begins to expand and bend, and local deformation began to appear. With the further increase of load, the expansion bending situation has further appeared, and the inclined bar at both ends and the upper bar between the vertical bar has began to bend downward, and the shape is further destroyed. The reason of bending is that the spacing is set in the inner part of the bar to avoid the space interference problem of riveter, and the force is not in the same position, so the local top chord is staggered and bent. With the increase of load, the bending of the top chord becomes more and more obvious, and the serious expansion phenomenon appears, and the deformation is more and more large, which finally leads to the fracture of the middle part of the upper chord and the shear buckling failure. During the test, the self-pierce riveting connection is complete. In the final failure mode, the final test result is local shear buckling failure.

At the initial stage of failure mode test, the self-tapping screw connection specimens does not show obvious changes. When it increased to 5 kn, the self-tapping screws of connecting rods and top chords at both ends have gradually inclined. With the further increase of load, most of the self-tapping screws incline, and the self-tapping screw connection specimens have entered the elastic-plastic state. And when the load continues to increase, the upper chord around the self-tapping screws begin to expand and bend, and the self-tapping screws appear to be further tilted, and the self-tapping screw protrudes outward. When the load is increased, the self-tapping screw connection specimen is similar to the self-pierce riveting connection specimen, and there is serious dislocation and downward bending. With the increase of load, the self-tapping screw tilts extremely seriously and can not connect the parts. The top chord is bent seriously and finally breaks. In the final failure mode, the final test result of self tapping screw connection specimen is connection failure, and the upper chord is local shear buckling failure.

Through this test, it can be concluded that the different stress conditions of the self-pierce riveted connection specimen and the self-tapping bolt specimen lead to different ultimate failure modes. In the process of increasing the load, the self-pierce riveted joint is always elastic, and the bars are stable. The deformation of the top chord leads to local buckling. In the loading process, the self-tapping screw begins to tilt, and then the rods bend, resulting in the deformation of the specimen.

2.2. Analysis of Each Stage of the Test

The specimens of cold-formed thin-walled steel truss beams with self-piercing rivets and self-tapping screws will go through four stages in the failure mode test, but there are quite different for the time points to reach each stage. The first stage is the elastic stage. The strength of the self-pierce riveted connection specimen is significantly greater than that of the self-tapping screw connection specimen. The chord bar maintains the linear elastic state at the initial loading stage, while the self-tapping screw connection specimen shows a certain degree of inclination at an early stage. The second stage is the elastic-plastic stage. The self-pierce riveting connection specimen enters later. After increasing the load, there is only a small local bending deformation, while the self-tapping screw connection specimen appears bending deformation and self-tapping screw

protruding in this stage. The third stage is the plastic stage. The plastic stage of the self-pierce riveting joint is longer than that of the self-tapping screw connection specimen. The self-pierce riveting connection specimen can maintain the overall stability even if the bending deformation occurs. However, the self-tapping screw connection specimen inclines rapidly after bending, resulting in the connection losing its function. Consequently, it is unable to maintain the overall stability and quickly enters the failure stage. The fourth stage is the failure stage, that is, the rapid deformation intensifies the final failure.

3. The Applicability of Self-Pierce Riveting Connection of Assembled Light Steel Structure

Compared with the traditional concrete building, the assembled light steel structure can greatly shorten the construction period, but the self-tapping screws are still used to connect the components when the assembled light steel structure is used in our country. This connection method has more processes and longer working hours. It does not give full play to the advantages of assembled light steel structure. The self-pierce riveting connection structure commonly used in the automotive field can greatly improve the connection efficiency. Self-pierce riveting connection is a commonly used technology in thin plate connection. By pre-tightening the plate to be connected, the upper die presses the rivet into the lower steel plate, which deforms the rivet under the action of the lower die, and forms an internal lock structure in the lower steel plate to connect the two layers of plate. This connection method is convenient to operate and fast in connection, and it also has the characteristics of high flatness, high strength and high rigidity on the surface of the connection node.

3.1. Analysis of Mechanical Properties

From the test analysis of the bending performance of truss beam, it can be seen that the bearing capacity and bending resistance of the truss beam connected by the self-pierce riveting are higher than that of the truss beam connected by the self-tapping screw. There are quite different in mechanical properties of the self-pierce riveting connection and the self-tapping screw connection, resulting in different failure mode. The self-pierce riveting connection specimen always maintains linear elasticity during the test process, and finally the bending of the chord leads to the deformation and destruction of the entire specimen. The components are the main parts that bear external forces, not the connection parts between the components. Therefore, the feasibility of the application of self-pierce riveting must be evaluated on the structure. According to the experimental analysis, the mechanical properties of the self-pierce riveting connection are stronger than that of the self-tapping screw connection. In the structure that requires higher rigidity, the self-pierce riveting connection can be used to replace the self-tapping screw connection, such as in the application of cold-formed thin-walled steel truss beam.

3.2. Analysis of Processing Convenience

When the self-pierce riveting is connected, only the clamp needs to be extended into the position to be riveted, and the switch is pressed, and the riveting can be completed by clamping the steel plate by the punch and the female mold. Compared with the self-tapping screw connection, this riveting method eliminates the steps of positioning and punching, the processing is quick, the node surface is flat, and solves the problems of tedious process and long working hours of self-tapping screw connection. However, because the self-pierce riveting connection requires specific equipment for connection, the space interference of the riveting gun needs to be considered during construction. There are certain limitations in the actual scope of use, and the current technology cannot achieve the full lock riveting building connection. But in the modular fabricated light steel structure system, the walls and floor slabs have standardized modules, and the self-pierce riveting connection of the components in these modules can be completed in the factory, which greatly improves efficiency and shortens the construction period. Therefore, the self-pierce riveting connection method is more suitable for the modular riveting of the floor and wall panels of the assembled light steel structure system.

4. Conclusion

Through the failure mode experiment of truss beam, it can be seen that the self-pierce riveted connection belongs to local shear buckling failure, while the failure mode of self-tapping screw connection appears connection failure. And the result shows that the truss beam with self-pierce riveting connection is more stable. In the mechanical properties of bending resistance, rigidity, and ductility, the self-pierce riveting connection is stronger than the self-tapping screw connection, and the bending rigidity of the self-pierce riveting connection is particularly significant. Therefore, it is feasible to replace self-tapping screw connection with self-pierce riveting connection. It is especially prominent in the cold-formed thin-walled steel structures with high requirements for stiffness. However, the self-pierce riveting connection is affected by the connection process, which requires special equipment for riveting. It has certain limitations in the actual application scenarios, but it is more suitable for modular riveting of floor and wall panel of assembled light steel structure system. It greatly shortens the construction period and plays a great role in reconstruction after disaster.

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