Design and Research on Full Bolt Connected Box Beam-Column Joints of Cantilever Short Beams with Attachments Connecting Plate

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Abstract. Aiming at the assembly connection of box beams and columns, this paper proposes a connection that can realize rapid on-site assembly. The joint is mainly composed of two parts, a box-shaped column welded with a short cantilever beam and structural reinforcement measures and a box-shaped beam attached with connecting plates. The connecting plates are used as accessories of the box beam and shipped with the box beam. When installing, the outer connecting plate is rotated by 180° to the designated position, the inner connecting plate is slid into the designated position, and then these members including the box beam and the short cantilever beam are connected by bolts. The joint is simple and easy to install. It can not only realize rapid assembly on site, but also transmit force directly and reliably. It is an excellent joint for assembled steel structure.

Keywords: Full-bolt connected; Double-shear; Rotate.

1. Introduction
In the field of assembly fabricated connections, many scholars have carried out numerical, theoretical and experimental research and have achieved tremendous results. Wang Yan[1] et al. studied the mechanical properties of the inner sleeve connection combined by bolts (high-strength bolts + opposite tension bolts). The joint stiffness increases with the increase of the sleeve thickness, but the sleeve gap will reduce the stiffness. It is believed that the manufacturing accuracy should be improved as much as possible to reduce the gap. Li Liming[2] et al. designed a fully bolted outer sleeve H-shaped steel beam-column joint. They found that the joint has good seismic performance and energy dissipation capacity by researching on the seismic performance of the joint. To a certain extent, increasing the thickness of the outer sleeve can effectively improve the seismic performance and stiffness of the joint, but because this joint is restricted by the closed section of the square steel tube column, it is necessary to open installation holes in the column and sleeve to complete the installation so that the degree of assembly is not high. Liu Xuechun[3] et al. studied the seismic performance of a modular joint connected by a square steel tube column and H-section steel beam with full bolts. The joint was tested and studied by changing the thickness of the flange plate, the bolt diameter, the number of cover bolts and the gap between the bolt rod and the bolt hole. The results of finite element analysis show that the number of cover bolts is the main factor that affects the energy consumption of the joint. The more the number of cover bolts, the stronger the energy consumption of the joint. Based on the theory of damage control, Zhang Ailin[4] and others designed a beam-column connection joint (semi-rigid node) that can realize full bolt connection with a cantilever short beam. They adjusted the thickness of the flange connection cover, the middle row bolt spacing and other parameters to control the stiffness of the flange cover plate, so as to use the flange cover plate to dissipate energy and ensure
that the main components of the beam and column maintain elasticity without damage, which can realize rapid repair after the earthquake.

Prefabri cated buildings have the advantages of convenient and fast installation, high degree of industrialization, green and energy-saving. The state attaches great importance to the development of prefabricated buildings and vigorously promotes prefabricated buildings. The box-shaped column has the same moment of inertia in the two main axis directions and has good bending resistance. It is widely used in the frame structure system. Under the same geometrical dimensions, the box-shaped beam has better bearing capacity than the H-shaped beam. The smooth surface of the box-shaped beam have great advantages in fire protection and decoration. At present, the box-shaped column-box beam connection is mainly be welded, which cannot meet the requirements of prefabricated buildings. The box beam-column connection proposed in this paper has the following advantages: the full-bolt connection can achieve full assembly; As an accessory, the connecting plate is shipped with the box beam components, which reduces the types of components and is conducive to rapid assembly; because the box beam section is closed, the bolt is generally single-shear, but the joint realizes double-shear, which can greatly reduce the number of bolts and component materials.

2. The Structures of the Full-bolted Connected Box Beam-column Joint

2.1. The Details of the Beam End

The beam end mainly consists of two parts. The first part is a box-shaped beam with installation holes and bolt holes at the corresponding positions. Besides, the channel steel structure prepared for the inner connecting plates is welded on the inside of the beam. The second part is the connecting plate, including the inner connecting plate and the outer connecting plate. The inner connecting plate is placed on the welded channel steel structure and temporarily fixed with bolts. The outer connecting plate is fixed on the surface of box-shaped column with temporary fixing bolts. The fixing bolts are arranged on the center of the bolt group, so that the outer connecting plate can be connected to the column end by rotating 180°. The inner and outer connecting plates leaves the factory as a whole part with the box beam, which is conducive to the integration of components and resource allocation, and speeds up the construction. Figure 1 is a detailed display of beam end parts. Figure 2 is the rendering picture of the beam end.

![Figure 1. Schematic diagram of beam end structure.](image1)

![Figure 2. Beam end renderings.](image2)

2.2. The Details of the Column End

The column end is composed of a box cantilever short beam, a box-shaped column and strengthening structural measures which consists of flange reinforcement and web reinforcement. First, the box-shaped short beam with bolt holes and installation hole is welded to the box-shaped column. And then the stiffening plate(stiffener) is welded on the inner side of the column at the flange position of the box-shaped short beam. At the same time, reinforcements including flange reinforcement and web
reinforcement are arranged at the junction of the cantilever short beam and the box column to ensure that structural damage does not occur here. The details are displayed in Figure 3.

2.3. Splicing and Installation
The first step is to splice the beam end and the column end and place them in the designated position which is showed in Figure 4. The second step is to remove the non-center temporary fixing bolt, rotate the outer web connecting plate with the center bolts center by 180°to the designated position, remove the center bolt, and slide the inner web connecting plate to the designated position through the installation hole, so that the bolt holes of the outer web connecting plate, box beam, cantilever short beam and inner web connecting plate are aligned. This step can be seen in Figure 5. The third step is to install high-strength bolts through the installation hole. The box beam can be safely fixed on the column end after the inner and outer web plate is installed completely and the corresponding auxiliary equipment is removed which is showed in Figure 6. The installation method of the inner and outer flange connecting plates is the same as that of the web connecting plates. The installation completed by finishing the flange connecting plates. The final step is to weld the cover plate at the installation hole to prevent the inner side of the box beam and short box beam from rusting. Figure 7 is the finished status of installation.

Figure 3. Schematic diagram of column end structure.

Figure 4. Schematic diagram of the first step.

Figure 5. Schematic diagram of second step.
3. Conclusion

Nowadays, prefabricated buildings are developing vigorously. Steel structure has huge advantages as an excellent structural form of prefabricated buildings. The connection of steel structure is big problem of fabricated steel structure which is worthy of in-depth study and exploration. The connection between box column and box beam needs to be developed and researched. Based on previous research, the connection in this paper proposes a fabricated connection suitable for box column and box beam. The joint mainly has the following advantages:

1. The structure is fully connected by bolts, which can realize rapid assembly, shorten the construction period and speed up the construction progress.
2. The connecting plate is shipped with the main part, which is conducive to component protection, processing and transportation. At the same time, it reduces the types of components and facilitates.
3. The connecting plate can be positioned by rotating 180° or sliding, which is convenient.
4. The key parts are welded in the factory, which can guarantee the welding quality.
5. The force transmission is direct and reliable.
6. Although the section is closed, double-shear is realized, which can greatly save materials.

But there are also the following problems:
1. The junction of joint are relatively weak, which is harmful to structural stability and the torsional stiffness.
2. Factory production requires high precision.
3. The installation hole weakens the cross section and reduces the integrity of the component.

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References

[1] Wang Yan, Ma Qiangqiang, Yang Songsen 2016 Mechanical Properties of Beam-Column Joints Using Inner Sleeve Composite Bolts in Fabricated Steel Structure *Journal of Tianjin University(Science and Technology)* vol 49 p 73-79

[2] Li Liming, CHEN Yi-yi, Li Ning, CAI Yu-chun 2010 Seismic performance of outer-shell connection of cold-formed square tubular column and H-shaped beam *Journal of Jilin University(Engineering and Technology edition)* vol 49 p 67-71
[3] X.C. Liu, Z.W. Yang, H.X. Wang, A.L. Zhang, S.H. Pu, S.T. Cai, L. Wu 2017 Seismic performance of H-connection beam to HSS column connection in fabricated structures. *Journal of constructional steel research* vol 138 p 1-16

[4] Zhang Ailin, Li Ran, Jiang Ziqin, Yang Xiaofeng 2018 Finite element analysis of static behavior of PBCSC with double flange cover plates. *Industrial construction* vol 48 p 30-36