The study of steel transfer parts in assembled building connection

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Abstract. At present, most prefabricated components in the assembled buildings could be assembled at the construction site. But the connection method is still of traditional nature, such as steel connection and seam filled with cast-in-place concrete. So, our research group proposed a series of different new types of connection schemes based on the idea of connecting steel transfer parts. According to the different parts of the connection, including how to connect the assembled shear wall and the coupling beam by the U type bar connector, how to connect the shear walls by the method of mortise joint in the horizontal direction and how to connect the shear wall with the columns and beams in the frame-shear wall structure by the keyways. As compared with the traditional way, the following observations can be made: By using the steel transfer parts to connect prefabricated components, the internal force can be transferred effectively and the connection reliability is ensured. The design requirement of “strong connection” is easy to be achieved, which can increase the seismic performance of the structure. The field wet operation can be reduced and connection parts no longer need to be welded. The assembly rate is raised greatly in the whole structure. In the meanwhile, the proposed schemes still exhibit some drawbacks which need to be improved by finite element simulations and experimental studies.

1. Introduction

In recent ten years, with the improvement of science and the development of assembled building technology in overseas countries, the development of assembled concrete structure has been paid attention to in our country. Rapid progress has been made in scientific research and practical projecting. Under this background, more and more research into assembled concrete structure connection technology has been carried out in our research group, including the connection technology between shear wall and frame column, the connection technology between shear wall and frame beam, the connection technology between coupling beam and shear wall, etc. [1-4]. From the research results at home and abroad, we can infer that the connection technology of assembled concrete structure components still focuses mainly on steel connection. In this method, the steel load-transferred path has hardly changed and the calculation of the whole structure is the same as the cast-in-place structure. However, the construction technology is relatively complicated, which leads to many constraints.

The use of steel transfer parts to connect concrete components can simplify the construction technology efficiently and also the connection mode flexibly and changeably. By using the steel transfer parts to connect prefabricated components, issues, such as load-transferred path transformation and uncoordinated deformation may occur. But, at the present scientific and technological level, these problems could be solved. Even based on such a connection method, the
structural system which has better seismic performance may be found improve the industrialization of assembled buildings in future and promote the development of assembled buildings. Accordingly, our research group put forward a variety of connection schemes based on the idea of connecting steel transfer parts. Some of the following schemes will be introduced to expatiate the function of steel transfer parts in assembled buildings.

2. The assembled concrete connection schemes based on the ideal of connecting steel transfer parts

2.1. The connection scheme between precast shear wall and coupling beam

In the current assembled concrete structure, the cast-in-place method is mainly adopted as the connection method between shear wall and coupling beam. By using this method, the concrete pouring quality is difficult to be effectively guaranteed because the amount of concrete is relatively low. Methods, such as steel connected by sleeve and then poured concrete is not available to connect shear wall and coupling beam. To solve these problems, our research group proposed a connection scheme by using the U type steel bar connector to connect precast shear wall and coupling beam, which is based on the idea of connecting steel transfer parts. This scheme mainly includes the precast coupling beam with connector, the precast shear wall with connector, the U type steel bar and the steel hoop, which is shown in figure 1(a), figure 1(b), figure 1(c) and figure 1(e), respectively. At the same time, the connector is composed of embedded steel, steel plate and U type plate with connecting hole, which is shown in figure 1(d).

![Figure 1. Components of assembled shear wall and coupling beam connected by U type steel bar.](image)

The implementation process of this scheme mainly includes as follows: first, the precast shear wall is fixed in the reserved position and the steel hoop round the connector of shear wall. Second, the precast beam is hoisted in the reserved position, the U type steel bar is inserted into the reserved hole of two connectors to ensure close contact. Then, the steel hoop skids off and round on the outside of U type steel bar, as shown in figure 2(a). Last, the U type framework is supported on the outside of connection location, the grouting material is poured into the framework. After grouping solidified material, the U type framework is dismantled to finish the connection between the coupling beam and the shear wall, as shown in figure 2(b).

In this scheme, the tension stress is caused by the bending moment between coupling beam and precast shear wall, which is transferred by the U type steel bar. The shear force is transferred by grouting material and steel hoop, the pressure is transferred by the U type steel bar and grouting material. In theory, through this method, the bending moment and shear force between precast...
components can be transferred effectively to satisfy the design requirement of “strong connection”. The connection reliability can be ensured in a suitable way for the coupling beam with any size or reinforcement. The connection process has the advantages of easy operation, small seam and no need for welding.

![U type steel bar](image1)
![Steel hoop](image2)

(a) The 3D graph of connection process  (b) The 3D graph of connection completion

**Figure 2.** Assembly process of frame shear structure and coupling beam connected by U type steel bar connector.

### 2.2. The connection scheme of precast shear wall structure

In the assembled concrete structure, a shear wall needs to be dismantled into 2 or more shear walls if the length is large. Then, the shear walls will have a horizontal connection in the construction site after dismantling. In the current practical project, the shear wall connection in the horizontal direction occurs mainly by inserting longitudinal steel into outstretched horizontal steel. The stirrup set around longitudinal steel to form the embedded column [5, 6]. Based on this, our research group proposed a connection scheme by using the mortise joint to connect shear walls in the horizontal direction, which is based on the idea of connecting steel transfer parts. This scheme mainly includes the lock catch connector and shear wall with C type card slot steel plate connector, which is shown in figure 3(a) and figure 3(b). The C type cart slot steel plate is shown in figure 3(c), which is inserted through the steel plate and welded in the perforated steel plate. There are two grooves in the C type card slot front. The holes on the steel plate are meant to weaken stiffness, which can save steel. The horizontal steel of shear walls goes through the perforated steel plate and welded with perforated steel plate after bending 90 degree.

The implementation process of this scheme mainly includes as follows: First, one precast shear wall is hoisted and fixed in the reserved position. Second, another shear wall is hoisted on the side of first shear wall to ensure that the C type card slot is fitted closely. Then, the lock catch connector is locked in the grooves of the C type card slot, as shown in figure 3(d). Last, the steel framework is supported between two shear walls. The grouting material is poured into the framework to finish the horizontal connection between two shear walls.

In this scheme, the horizontal shear force between two shear walls is transferred to the C type card slot margins of the lateral steel plate, then the shear force transition is completed by the lock catch connector. In the meanwhile, the grouting material between shear walls can also transfer partial shear force. So, this method can achieve the reliability of connection. The connection process also has the advantages of easy operation, high assembly rate, fast construction speed, small seam and no need for welding.
2.3. The shear wall and column, shear wall and beam connection scheme of precast frame-shear structure

The popular technologies of assembled concrete structures mostly confined to pure frame structure or pure shear wall structure. There is little research done to investigate the assembled concrete frame-shear wall structure. Until now, the concrete frame-shear wall structure has been usually constructed by means of the cast-in-place method [7]. The conventional practice in assembled frame structure is the beam and column precast, the joint casting. The corresponding problems are steel binding difficulty and the joint construction quality is hard to be guaranteed. So our research group proposed a connection scheme by using the keyways to connect the prefabricated components of assembled frame-shear wall structure, which is based on the idea of connecting steel transfer parts. The scheme mainly includes: The precast column with column-wall embedded parts, which is shown in figure 4(a), the cast-in-place foundation beam with beam-wall embedded parts, which is shown in figure 4(b), the precast frame beam with beam-wall embedded parts, which is shown in figure 4(c), the precast shear wall with column-wall embedded parts and beam-wall embedded parts, which is shown in figure 4(d). The I-section column-wall connect key, the groove type beam-wall connect key and the cross type beam-wall connect key are shown in figure 4(e), figure 4(f) and figure 4(g), respectively. The column-wall embedded part and the beam-wall embedded part are shown in figure 4(h) and figure 4(j), respectively.

The implementation process of this scheme is shown in Figure 5 and includes the following steps: First, the precast column is hoisted above the foundation beam to ensure that the steel stretched at the bottom of foundation beam is inserted into the sleeve at the bottom of the precast column. The grouting material is poured into the sleeve, as shown in figure 5(a). Second, the precast shear wall is hoisted above the foundation beam to ensure that the beam-wall embedded parts on the lower side of the shear wall, the beam-wall embedded parts on the upper side of the foundation beam and the column-wall embedded parts on the side of column are aligned. Third, the I-section column-wall connectors, the groove type beam-wall connectors and the cross type beam-wall connectors between the foundation beam, the precast column and the precast shear wall are fixed. The groove type beam-wall connectors are inserted into the holes of the beam-wall embedded part webs, the cross type beam-wall connectors are fixed on the outside of the beam-wall embedded parts. Then, the precast frame beam is hoisted above the precast beam to ensure that the longitudinal steel is inserted into the polyvinyl chloride pipe of core node area. The grouting material is poured into the polyvinyl chloride
pipe. Last, the I-section column-wall connectors and the groove type beam-wall connectors between the precast frame beam and the precast shear wall are fixed, as shown in figure 5(b).

![Diagram](image_url)

**Figure 4.** Components of assembly frame shear structure connected by key-groove method.

![Diagram](image_url)

**Figure 5.** Assembly process of frame shear structure connected by key-groove method.
In this scheme, the pulling force between the frame beam and the shear wall is transferred by the groove type beam-wall connectors locked in the beam-wall embedded part web holes. The shear force between the two is transferred by the grouting material at gaps and the webs of cross type beam-wall connectors. The pressure between the two is transferred by the grouting material, the webs of beam-wall embedded parts and the groove type beam-wall connectors. The reciprocal shear between the frame column and the shear wall is mainly transferred by the I-section column-wall connectors and the grouting material. In theory, the force between the prefabricated components can be transferred effectively and ensure the reliability of the connector. The connection process also has the advantages of easy operation, high assembly rate, fast construction speed, small seam and no need for welding. It can also reduce the field wet operation. Besides, the deformation of the frame-shear wall structure along the horizontal direction can be controlled through adjusting the size of the embedded part and the connector, which makes it obtain better seismic performance.

3. Conclusion
Through introducing the connection schemes of precast concrete structure components based on the idea of connecting steel transfer parts, it can be observed that:

(1) By setting the steel transfer parts, the force between the precast shear wall and the coupling beam, the force along the horizontal direction of the structure and the force between the prefabricated components of the frame-shear structure can be transferred to satisfy the design requirement of “strong connection” in the structure. So, the schemes proposed by our research group have certain feasibility.

(2) In the connection schemes based on the idea of connecting steel transfer parts, the internal force is transferred by steel transfer parts, which makes the reliability of connection easily ensured. The connection process has the advantages of easy operation, high assembly rate, fast construction speed, small seam and no need for welding. The adjustment of the size and shape of steel transfer parts can make the structures have better seismic performance. So, this kind of method has good engineering prospects.

(3) In the connection schemes based on the idea of connecting steel transfer parts, there are still some problems, such as load-transferred path transformation and un-coordination deformation. In addition, the schemes themselves also have many problems that need to be improved, which require plenty of finite element simulations and experimental studies. Our research group will also carry out relevant work to provide technical support for the development of precast concrete technology.

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