Research Progress on Internal Shear Connection of Double Steel Plate-concrete Composite Shear Wall

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Abstract. A comprehensive analysis of three types internal shear connection of double steel plate-concrete composite shear walls is carried out. There are internally welded shear connectors, tension restraints shear connectors, and cavity-type. The analysis shows that these three types of shear connection forms have significant effects on the improvement of the seismic performance of shear walls, and can give full use of the properties of steel and concrete. Compared with the traditional shear wall, the steel plate concrete shear wall has been greatly improved and has a high level of industrialization. Aiming at these three types of shear connection forms, their deficiencies and future development directions were clarified.

1. Introduction

With the advancement of urbanization and rapid economic development in China, super high-rise buildings have developed rapidly. Up to now, more than 20 high-rise and super high-rise buildings have been completed or are under construction in China, and the heights of Shanghai Center Building, Shanghai Financial Center, Shenzhen Ping An Finance Building, and Tianjin 117 Building are all over 600mm. As the height of high-rise buildings becomes higher and higher, the vertical pressure that the shear walls must bear is also increasing, and the difficulty of construction is also uprising. In the double-steel-concrete shear wall, which is filled with concrete and steel plates on both sides, the concrete and steel plates constrain each other, which greatly improves the ductility of the wall, and the steel plates on both sides simultaneously serve as formwork, speeding up the construction speed.

In order to further enhance the ductility of the shear wall, and prevent the excessive self-weight caused by the excessively thick shear wall, the study found that strengthening the internal shear connection form can effectively enhance the seismic performance of the wall. Therefore, optimizing the internal shear connection structure of the shear wall has become the key to the current research of shear wall. At this stage, the shear connection types inside the double steel plate-concrete composite shear wall can be divided into three types of connection types: internal welded shear connection, connection with tension restraint and cavity type. This article analyzes these three forms and summarizes the current research status. Based on the advantages and disadvantages summarized in this article, a preliminary design proposal for the internal shear connection of double steel plate-concrete composite shear wall is proposed.
2. Research Status of Double Steel Plate-Concrete Shear Walls with Internal Welded Shear Connectors

The main structural forms of the internal welded shear connection between the outer steel plate and the infill concrete of the double steel plate-concrete composite shear wall are shown in Figure 1, which are bolted connection and spliced plate connection. This type of steel plate shear wall makes up for the shortcomings of pure steel plate shear walls and built-in steel plate shear walls. Hossain [1] studied the seismic performance of the double-sided profiled steel plate filled concrete composite shear wall with studs is studied. Nie Jianguo [2] based on this, the seismic performance of the double steel plate-concrete composite shear wall with welded studs of steel plates and configured with steel bars and columns on the wall were studied. Li Jian [3] conducted a pseudo-static test on a double steel plate-concrete composite shear wall in the form of an internal shear bolt connector combination. Subsequently, Nie Jianguo [4] carried out low-cycle reciprocating test research on double-steel-concrete composite shear walls with batten plates tied or no batten plates tied.

According to research at domestic and abroad, the double steel plate-concrete composite shear wall with internally welded shear connection effectively improves the bearing capacity, lateral stiffness, ductility and energy consumption of the shear wall, which has a significant effect on the improvement of seismic performance. The double steel plate and the concrete are restrained by the combination of the connecting members. The degree of buckling of the steel plate is limited by the internally welded connecting members, which further ensures the good seismic performance of this type of wall.

However, the test results show that this type of wall still has shortcomings. 1) The internal welding shear connectors which including the problem of complex construction are mostly welded. The steel plate at the weld seam is more prone to local buckling, which results in greater internal force at the reweld seam, and finally the phenomenon of cracking of the weld seam is more likely to occur; 2) The constraint provided by the welded shear connector on the concrete is accompanied by concrete damage increasing the degree is more likely to fail.

3. Research Status of Double Steel Plate-Concrete Shear Walls with Tension Restraint Connectors

The wall needs to adopt a large number of methods such as welding shearing connectors, which include complex construction problems. Therefore, a double steel plate-concrete composite shear wall with tension restraint is proposed. The main form is shown in Figure 2. The steel plate does not need to be welded with an anti-shear connection, but restrains the concrete in the middle by restraining tie rods, thereby improving the bearing capacity and ductility of the wall. Clubley [5] first adopted the form of changing the internal structure to a double-layer steel plate filled concrete composite wall connected with tension bolts, and studied the hysteretic performance of this type of wall. The final result was that, compared with the shear wall with internal welding studs, the bearing capacity of the force wall is higher. Later, Liu Hongliang [6] carried out an experimental study on the seismic performance of the tension bolt connection to a shear wall with restrained tie rods. The test results show that the shear performance of the shear wall using the plum blossom arrangement is better. Ma Kaize [7] studied the double steel plate-concrete composite shear wall with restrained tie rods for high axial compression ratio and high strength concrete.
Through domestic and foreign research, we can know that the steel plates on both sides of the shear wall are connected by restraining tie rods, which avoids the welding difficulties of using internal welding shear connectors, and also avoids the problem of insufficient restraint with connection of studs and slabs to the concrete in the middle; restraint rods make the steel plates on both sides more tightly connected to the concrete, effectively increasing the synergistic restraint effect between the restraining members, steel plates and concrete. Further preventing the steel plates from buckling outward, and allowing the steel plates to fully exert their mechanical properties.

Disadvantages: 1) the concrete is restrained by the tensile restraint members, but the concrete restraint on the ventral side is not enough to fully exert the performance of the restraint concrete; 2) the restraints provided by the restraint rods are weakened by the surface steel plate openings.

Figure 2. Tension restraint connection

4. Research Status of Cavity-type Double Steel Plate-Concrete Shear Walls

Because the tensile restraint will open holes in the wall surface and weaken the wall's force, it is proposed that the ventral side of the section is divided into multiple chambers by a steel partition to improve the shear performance of the wall. The main form is shown in the Figure 3. Emori [8] studied the seismic performance of a box-type double steel plate shear wall, as shown in Figure 4. By dividing the double-layer steel plate into a plurality of small cells through a transverse partition and a longitudinal partition, therefore, the local buckling of the steel plate is well limited. And the final experimental phenomenon shows that the ductility of this kind of shear wall is favorable. Zhang Xiaomeng [9] further simplified the internal structure. The shear wall was welded with C steel to form a "steel tube bundle" to constrain the concrete to form a cavity steel plate-concrete shear wall. Zhang Wenyuan [10] studied the influence of the number of internal cavities on the seismic performance of shear walls, such as the 3-cavity, 4-cavity, and 5-cavity multi-cavity double-steel-concrete composite shear walls. Wu Xiaodong [11] studied the seismic performance of double steel plate-concrete shear walls with CFST boundary columns.

Based on the above research status at home and abroad: the partition divides the internal concrete into multiple chambers, so that boundary columns and the concrete inside each chamber are constrained by steel plates. At the same time, the buckling phenomenon of the steel plates on both sides is well limitation, so the ductility and seismic performance of the shear wall have been greatly improved.

There are still some shortcomings in the cavity-type shear wall: In actual construction, since the partition in the cavity-type double-steel-concrete shear wall penetrates up and down, the internal partition cannot be completely welded at the connection position between the upper and lower floors.

Figure 3. Bulkhead connection
5. Conclusion
The double steel plate-concrete composite shear wall has the advantages of good ductility, convenient construction and simple structure. It has a broad application prospect in high-rise and super-high-rise buildings. In order to further improve the seismic performance of shear walls, researchers at domestic and abroad have conducted in-depth research on the shear forms inside the wall. The restraint of steel plates on the internal concrete is strengthened, and the performance of each component is fully applied, which also makes it possible to apply such shear walls in high-rises and super high-rises. From a construction perspective, however, there are still many problems with this new type of shear wall, the welding and construction problems in some parts have not yet been resolved. From a design point of view, quantitative analysis results have not yet been given for double steel plate-concrete using various shear connections. Therefore, there is necessary of in-depth research on various forms of shear connection. As the application of various aspects of the double steel plate-concrete shear wall becomes more and more extensive, the research on the improvement of its seismic performance will become more thorough and perfect.

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