Literature review of seismic performance of double-layer steel plate-concrete composite shear wall with stiffeners

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Abstract. Shear wall, as the main anti-sway component in high-rise buildings, plays an important role in resisting horizontal earthquakes. Shear wall has high ductility and high bearing capacity with the participation of steel plate, which can meet the requirements of high-rise building structures on structural members. Shear wall with steel plate is divided into two types according to the construction method, one is shear wall with single steel plate, and the other is shear wall with two layers of steel plates. In recent years, double steel plate shear walls with stiffeners have attracted much attention due to their good ductility and ease of construction. By summarizing the current research situation of steel plate concrete shear walls, suggestions are made for future research.

1. Introduction

People's requirements for building functions are increasing, the height of buildings is also increasing, the self-weight of the structure is also increasing, and the earthquake effect is increasing. Increasing the lateral stiffness of the building and ensuring sufficient ductility are the primary issues that need to be addressed in structural design. Shear wall, as the main anti-sway component of high-rise and super high-rise buildings, plays an important role in resisting horizontal earthquake action of building structure. Traditional reinforced concrete shear walls can no longer meet the requirements of current buildings in terms of bearing capacity, deformation capacity, and ductility. Use of shear walls with steel plates helps increase the area of the building. The presence of steel plates restricts the concrete, and the presence of concrete can prevent buckling and failure of the steel plates, and they are jointly stressed to improve the carrying capacity. The participation of the steel plate makes the combined shear wall have the characteristics of good ductility and strong energy consumption. Concrete has the function of heat insulation and sound insulation [1]. The combined shear wall has very good development prospects.

2. Development status of combined shear wall

In the 1970s, pure steel plate combined shear wall, which has the characteristics of strong energy consumption and good ductility compared to traditional shear walls. However, it has the disadvantages of large steel consumption and poor stability. Therefore, concrete-free steel plate shear walls are rarely used in engineering practice. At present, shear walls with steel plates are mainly divided into shear walls with one layer of steel plates and shear walls with two layers of steel plates.
2.1. Single steel plate concrete combined shear wall

The concrete is cast in the middle of the steel plate, and the steel plate is on both sides of the concrete. The concrete on both sides is given lateral restraint and wrapping protection for the built-in steel plate to prevent premature plate flexion and long-term exposure to air and chemical corrosion.

Some scholars [2] carried out low-cycle reciprocating pseudo-static tests on high-strength concrete shear wall specimens. Investigate the failure mode, hysteretic characteristics and energy dissipation capacity of specimens. The results show that the presence of steel plates can effectively improve the bending bearing capacity; Test results prove that the participation of steel plates makes the specimens have better ductility and improves the bearing capacity of the shear wall specimen; the larger the axial force, the worse the ductility of the specimens.

Some scholars [3] completed experimental research on four shear walls under hysteretic loading. This combined shear wall has better ductility; The presence of concrete can effectively limit plate flexion and significantly improve the energy consumption of shear wall specimens. When the concrete is thick enough, the steel plate instability can be completely eliminated, and the energy consumption of the shear wall specimen can be improved.

In 2012, some scholars [4] completed experimental research on four shear walls under reciprocating horizontal loads. Study the influence of stiffeners and concrete slabs on the mechanical properties of shear walls. The study found that the short stiffeners at the four corners of the steel plate can suppress the steel plate flexion, and dramatically enhanced the energy consumption and ductility of shear wall specimens. Properly reducing the distance between the angle steel and the concrete slab can also improve the mechanical performance of the specimen.

2.2. Double-layer steel plate combined shear wall

This kind of shear wall with double steel plates is composed of double-layer steel plates on both sides, filled with concrete, and combined by means of a shear connection or a stiffener. The outer steel plate can effectively limit the deformation of the core concrete, and the core concrete can also prevent the steel plate from instability. Internal concrete and outer steel plate resist the shear-force [5]. Steel plates, studs and stiffeners can be prefabricated in advance.

Zekai [6] carried out pseudo-static test on four shear walls with high-strength concrete inside steel plates. When the shear-span ratio of the shear wall is increased to 2.5, bending failure occurs and the ductility is good; Make the wall better seismic performance, stiffeners can be set; When setting restraint rods, the ductility performance of the test piece can be improved by appropriately reducing the restraint rod distance.

Jianguo [7] proposes a form of shear wall with square steel tube concrete columns at both ends, and conducted experimental research on this composite shear wall form. The results show that: the longitudinal weld steel pipe burst, crushed is crushed concrete walls and bottom of the steel sheet localized buckling, bending and shear crack development oblique middle wall concrete obvious; The hysteresis curves obtained from the tests are relatively full, And have high energy consumption capacity.

3. Proposal of double steel plate concrete shear wall with stiffeners

Most of existing double steel plate-concrete shear wall forms adopt the form of welding bolts on the inner side of the steel plate [8]. This method has a large welding workload, and the studs will break at the later stage of loading, reducing the ductility of the shear wall. The restrained tie rod combined steel plate shear wall adopted by Hongliang [9] can save material by restraining concrete. This form has good mechanical properties. However, the appearance of openings in the steel sheet not only reduces the mechanical properties of the steel sheet, but also is inconvenient for construction. Therefore, the proposed outer plate steel shear wall with stiffener not only effectively improves the energy dissipation capacity of the wall, but also facilitates construction outer plate steel shear wall with stiffener is mainly divided into the following two forms.
3.1. Box type stiffened double steel plate concrete shear wall

Vertical and horizontal steel partitions are set inside the double-layer steel plates to form multiple box-shaped spaces. Concrete is then filled in each box-shaped unit to form a composite wall (Figure 1). Emori [10, 11] Emori has completed experimental research on three sets of 1/4-scale box-type stiffener composite shear walls. The theoretical formula is proposed and the finite element simulation is performed. The results show that the presence of concrete can obviously avoid premature steel plate instability. And the box-type stiffener can restrain the concrete, thereby improving the seismic performance of the specimens.

![Figure 1. Details of box type stiffened double steel plate-concrete composite shear walls.](image_url)

3.2. Outer plate steel concrete shear wall with vertical stiffener

The stiffeners are arranged vertically inside the steel plate, concrete and vertical stiffeners resist shear-force, which increases the bearing capacity and energy consumption capacity (Figure 2). Link [12] conducted experimental research on an outer plate steel concrete shear wall with vertical stiffener. The results show that under the shear pressure of the test specimen, the internal concrete cracks appear at the beginning of loading, cracks in concrete during subsequent loading, the steel plate is yielded, and the final specimen is destroyed. According to the aspect ratio of the shear wall, the failure of the test specimen is divided into ductile failure and brittle failure; When ductile failure occurs, the steel plate at the bottom yields first and then the concrete is crushed; When brittle failure occurs, the concrete is crushed before the steel plate yields.

Shengyong Li [13] conducted pseudo-static tests on 11 multi-cavity double-layer steel plate-high strength concrete shear walls. Under the condition of large axial pressure ratio, the combined shear wall of this structural form still has good ductility, and no large-scale bulging occurred in the test steel plate; Based on this finite element model, a parametric analysis was performed to analyze the effects of axial compression ratio, concrete compressive strength, steel plate yield strength, steel content ratio, shear span ratio and other parameters on the stiffness, bearing capacity and ultimate displacement angle of the shear wall. The anchoring measures and connection structure of the combined shear wall are discussed, and several design suggestions are given.
4. Conclusion

At home and abroad, the research on outer plate steel concrete shear wall with vertical stiffener is mostly based on experiments, supplemented by numerical analysis. However, there are few theoretical researches, and there are still insufficient in the calculation of load transfer mechanism and bearing capacity. There are no relevant norms to guide practice, which hinders the promotion and development of steel shear walls.

Based on the deficiencies in the existing literature, several suggestions are made:

First, test research on full-scale specimens should be carried out, which can be closer to practical applications. Most of the existing tests are scale-down tests, and the size effect structure has a great impact. Once problems occur in actual engineering, the consequences are very serious.

Secondly, the selection of the optimal size of the component is further studied. There is no reasonable regulation on steel plate thickness, concrete strength, stiffener form, etc. to ensure that each part of the material can fully exert its performance.

Third, optimize the finite element model to make the analysis calculations and test results closer to each other, in order to perform the finite element analysis more accurately.

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