Research Advances on Fabricated Shear Wall System

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Abstract. With the rapid development of the construction industry, building energy consumption has been increasing, has become a problem that cannot be ignored. It is imperative to develop energy-saving buildings. A new type of prefabricated shear wall is assembled and partially assembled by prefabricated parts, and some concrete is spliced together. The new structure has good integrity, seismic resistance and excellent energy saving and environmental protection performance. It reduces building energy consumption to a great extent. Therefore, the design method, manufacturing process, site assembly process and key technical problems of the system are discussed. For the construction industry gradually entered the energy conservation, environmental protection, safety and durability of sustainable development laid the foundation.

1. Introduction

With the rapid development of the construction industry, the energy consumption in the world is also increasing, and the energy demand in the world is increasing by 2% annually. A long-term forecast of world energy consumption shows that in 2050 the world's total energy consumption will be 4 times which of 1975. Practice has proved that using modern building construction method is the basic approach to achieve low consumption, low pollution and achieve the goal of resource conservation. Vigorously promote energy-efficient, high strength, light, environmental protection, low consumption of new energy-saving structure system, green building is the direction of development. Several commonly used assembled shear wall systems are introduced in this paper, which can be used for continuous prefabrication, construction site assembly and cast-in-place concrete in the factory. It can promote the construction of our industry to energy conservation, environmental protection and low energy consumption in a favorable direction.

2. General situation of research on precast shear wall structure at home and abroad

Construction of the prefabricated structure refers to the various parts of the building split into different segments. It completes the design and manufacture of components in the prefabricated parts plant and then transports them to the construction site. There is a small amount of splicing installation and wet work at the construction site 0. The precast shear wall structure can be divided into precast large panel structure, unbonded Post-tensioned prestressed precast shear wall structure, Composite slab prefabricated shear wall structure and so on in accordance with the connection form.
2.1 Precast Large Panel Structure

The Precast Large Panel Structure (as shown in Figure 1) is made up of prefabricated assembled wallboard, floor slab, stair and so on through horizontal joint, vertical joint, beam joint and floor joint. Compared with the structure of cast-in-situ slab structure, it has a large number of splice joints resulting in the local stress concentration, the discontinuous structural deformation, the poor integrity and too much rely on the connection performance in the splice joint.

In 1969, the Swiss Koncz[1] introduced four kinds of plate structure and pointed out that the panel system has a good economy, which meet the needs of large-scale mass production and the needs of small single project.

In the aspect of the integrity of the large plate structure, a large number of experiments and simulation studies have been carried out by foreign scholars. Pall [3] pointed out that the damage degree of the large plate structure is the smallest, and cracks only appear between the plate and the plate through the comparison of the slab structure and brick concrete buildings and frame construction after the severe earthquake from the former Soviet Union, Romania, Cuba, Japan and other countries, which further illustrated the safety and stability of the large plate structure.

On this basis, Pall[3] found that the arrangement of friction joints in the vertical joint can reduce the residual deformation, damage of the slab structure, the deformation of the structure under seismic loading and increase the ultimate load of the vertical joint. Pekau and Hum[4] took into account the influence of horizontal joints and explained that the arrangement of frictional joints at the vertical joints can improve the seismic capacity of structures.

Harry G[5] carried out a central compression test of 18 large structural horizontal joints widely used in North America and obtained the force displacement curve, the ultimate bearing capacity and the failure mode during the joint failure, and proposed that increasing the reinforcement and the length of the joint could improve the seismic performance of the large plate structure.

Harry and R.Foerster[6] carried out shear wall tests on five kinds of large shear walls with different connection forms and pointed out the ultimate bearing capacity and failure modes of five different joint forms under monotonic shear loading.

In the 70s, the China began to introduce the precast large plate structure from the Soviet Union, and built a large number of prefabricated large houses in Beijing, Tianjin, Kunming and other places according to the domestic characteristics. Compared with the cast-in-place structure, the large plate structure is more conducive to large-scale production, improving construction efficiency and reducing labor costs.

WanMolin[7] tested the connection from the strength and stiffness of the joints of the large panel structure. It includes concrete pure shear strength and adhesive shear strength of joint material, influence of shear span ratio on shear strength of section, the relationship between axial pressure and shear resistance, shear strength and deformation properties of vertical joints and so on. Subsequently, according to the structural characteristics of the horizontal joints, vertical joints and joint beams of the precast large plate structure, WanMolin[8] proposed the formulas for calculating vertical and horizontal joints, which provides the basis for the design of the overall stability between the plate and the plate. At last, according to British Ronai - Boeing apartment collapse and combined with the features of structure design of our country, Wan Molin[9][10] analyzed the structure and the causes of...
the collapse, and proposed three measures to prevent the progressive collapse, including the structural arrangement, calculation method and structural requirement.

2.2 Unbonded Post-tensioned Prestressed Precast Shear Wall Structure

In the 1990s, the United States and Japan jointly launched a PRESSS project (Precast Seismic Structure Systems), the project put forward a new type of vertical assembly connection: unbonded post-tensioned prestressed precast shear wall structure. The structure uses the unbonded prestressed reinforcing bars passing through the reserved holes to connect the vertical walls and the horizontal connections are connected by prestressed reinforcing bars with precast concrete coupling beams.

Although scholars have done a lot of research and improvement on this connection, the limitation is still very conservative[11]. The current research focuses on the seismic energy dissipation performance and seismic design method of unbonded prestressed shear walls. Kurama[11] adopts nonlinear static analysis and time history dynamic analysis method to research the mechanical behavior of two unbonded post-tensioned frames with six stories. The result indicated under seismic loading, the energy dissipation capacity, bearing capacity and stiffness of unbonded prestressed frames are similar to those of cast-in-place structures.

Smith[12] introduces a seismic design method conformed to ACI 318 (2008) and ACI ITG-5.2 (2008) for concrete walls based on ACI ITG-5.1 (2008) as a new type of reinforced concrete shear wall. As shown in Figure 2, it studies the following parameters: (1) the relative volume of low carbon steel and PT steel; (2) the ratio of height to width of the wall; (3) the form of concrete constraint; (4) whether the wall is open or not. The calculation model and the calculation formula of force and deformation are put forward in this paper. It is proved that the connection mode has good seismic performance.

![Figure 2. Smith experimental model.](image)

Sun Weiwei[13] proposed a model of post tensioned unbonded prestressed assembly coupled shear wall system in order to study the anti lateral force performance of beam combination, analysis model is established with the axis angle of a beam moment, and to verify the analysis using finite element software. The result shows that the residual deformation of the coupling beam is smaller after unloading, and the design suggestion is put forward to improve the ductility of the coupling beam.

LvXilin et al.[14] summarized the lateral resistance performance of prefabricated shear walls with unbonded post tensioning, and introduced the modeling method of lateral force model. Based on OpenSees software, two mechanical models of different force transfer modes are proposed and simulated by quasi-static method. The results show that the type of shear walls can bear large deformation with little residual deformation and high self recovery.

2.3 Composite Slab Prefabricated Shear Wall Structure

The composite plate prefabricated shear wall structure is a splicing structure, comprising a laminated wallboard, a laminated floorslab and so on, which are spliced into an integral structure through a cast-in-place component. The laminated wallboard and laminated floorslab can be prefabricated in advance in the prefabricated parts factory. After the field installation completed, the concrete laminated layer is poured, equipped with supporting equipment, so that the adjacent components are connected into a whole. Among them, the construction of more complex, more complex parts of force, can be fully used cast-in-place method[15].
Pfeifer[16] carried out single shear test on 31 pieces of concrete sandwich walls. It is proved that the form of wall rib in fabricated composite laminates can effectively improve the shear resistance. Bush[17] tests the shear properties of two composite precast concrete sandwich panels (PCSP). The static test results show that the method of strengthening joints can effectively improve the stiffness and flexural capacity, and the stiffness loss is smaller during the 55000 loading period of fatigue test.

Reaveley[18] a prefabricated wallboard with loose-plate connector is installed at the vertical joint of the plate, and the experimental study under the simulated seismic load is conducted. Studies have shown that this connection is poor in ductility and therefore unsuitable for use in high seismic areas, and suggests minor modifications to the connections to increase the ductility of the connections.

Benayoune[19] summarizes the results of experiment and simulation on precast reinforced composite sandwich panels. A full-scale test was carried out and its vertical bearing capacity was determined. The deformation, displacement and crack development under the action of load are recorded. This paper briefly reviews the previous researches on the bearing capacity of reinforced concrete solid walls. By comparing the results obtained from the test and finite element analysis, based on the current design formulas. It is confirmed that these empirical formulas are also applicable to the calculation of sandwich panels and the empirical formula is put forward in combination with the experimental.

2.4. The other prefabricated shear structures

As shown in Figure 3, Precast reinforced concrete hollow-core shear wall structure is composed of a prefabricated hollow shear wall. A new type of shear wall structure is fabricated by splicing the concrete between the plate to plate and placing concrete in the round hole[20].

![Figure 3. Typical circular hole design section.](image)

According to the assembly structure at home and abroad, Beijing Architectural Design Institute Co. Ltd designed a type of prefabricated shear wall structure named profiled steel concrete composite structure, which uses a horizontal and vertical joint through embedded or post steel and a new type of prefabricated structure connected by welding or bolt connection. CaiLiuhe et al.[21] studied the seismic performance of the horizontal joint of the structural system under axial force and horizontal reciprocating force (shown in Figure 4). The model was verified by ABAQUS software. The results show that the new horizontal connection has good energy dissipation capacity sutures.

![Figure 4. Schematic diagram of shear key connection of H steel in the middle of wall.](image)
Professor Yao Qianfeng[22] of Xi'an University Of Architecture And Technology has proposed a multi-ribbed composite wall, which is made of prefabricated multi-ribbed composite wallboard and concealed frame. As shown in Figure 5, The multi-ribbed composite wall is the main bearing member, wall connecting column and beam forming the outer frame, aerated silicate blocks filled in the frame of industrial wastein order to form a constraint on the wall.

![Figure 5. Schematic diagram of multi ribbed composite wall.](image)

3. Conclusion
The fabricated shear wall system is a kind of building with low energy, energy saving and environmental protection. It fully reflects the integration of industrial technology, from component production, construction to the use of the overall structure. This system can realize the construction of low consumption, low pollution, saving resources and achieve the goal of environmental protection. Also, it can promote the construction industry to the sustainable direction of energy saving, durability and security development and further improve the measures and methods of energy-saving building. The fabricated shear wall system can achieve the effects of building energy saving and structure reliability and realizes the building energy saving in the real sense.

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