Prefabricated Concrete Sandwich Wall with T-type under Cyclic Loading

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Abstract. In this research, a new sandwich wall system has been presented as structural elements which has unique structural configuration such as core column reinforced by spiral stirrup along the panel cross-section with spacing 650mm, foamed concrete as insulation layer, self-compacting concrete used in external layers which is significantly different from traditional sandwich wall. Seismic performance of sandwich walls with planar or 3D steel wire system is studied by low cycle repeated load test. According to the analysis of hysteresis performance and skeleton curves, this sandwich wall exhibits good seismic performance and crack resistance. Specimen with 3D steel wire shows better seismic behavior with higher strength and ductility.

1. Introduction

Concrete sandwich panel is usually composed of two concrete layers and an insulation core by light filler material. In the 1990s, sandwich walls were first used as non-structural compartment components in US office buildings. This kind of wallboard has the particular characteristics of light weight, fast construction, standardized size and environmental friendliness. In recent years, concrete sandwich panels have been recognized as a good alternative to reinforced concrete solid walls in seismic regions. Michele Palermo [1] conducted a shaking table test on the three-layer sandwich wall panel structure. The results showed that the strength and stiffness of the overall building system were much larger than that of panel unit under cyclic loading. Fabriio Gara [2] carried out experimental and numerical analysis on the seismic performance of sandwich wall panels, and the seismic performance meets the requirements. Guo Zheng-xing [3-4] studied the seismic behavior of a prefabricated reinforced concrete sandwich wall using a new connection method. Zhong Xun [5] introduced a seismic test on the semi-assembled concrete wall. The test results showed that the specimen has sufficient strength and good seismic performance. Xiong Feng [6] investigated the structural behavior of sandwich panels under cyclic loading. The smaller the diameter of the wire mesh of the sandwich wall, the better the seismic performance of the sandwich wall is proved. Liu Li-hua [7] used finite element software to analyze the mechanical behavior of prefabricated concrete sandwich panels in cold regions under cyclic loading.

The traditional sandwich wall panel also has obvious shortcomings, such as relatively low strength and rigidity, brittle fracture, and unserviceability for high-rise buildings. Fire resistance is also relatively insufficient, and toxic gas will even be released from some insulation materials filled in the sandwich panel under high temperatures. In order to overcome the shortcomings of conventional sandwich walls, new structures are employed in sandwich walls, such as 3D wire mesh systems and core posts every 650 mm. This makes the new sandwich wall have good seismic performance and crack resistance. The external layer is made of self-compact fine concrete, which is convenient for construction and can
enhance load-bearing capacity. The components of foamed concrete blocks and steel system are all prefabricated. The foamed concrete blocks can not only play the role of fireproof and heat insulation, but also function as side template in the process of panel prefabrication.

2. Experimental program

2.1. Description of Specimens

There are two specimens, one has planar steel mesh in concrete layer and the other has three-dimensional steel mesh system. The specimens are numbered as T1 and T2 and displayed in Figure 1-2. Detailed information is shown in Table 1. The actual concrete compressive strength after 28 days curing is 45.6MPa.

Table 1. Specimen information

| No. Specimen | Wall height | Concrete layer thickness | Insulation thickness | Steel wire mesh type | Steel wire diameter | Diameter of spiral stirrup | Diameter of column rebar |
|--------------|-------------|--------------------------|---------------------|---------------------|---------------------|----------------------------|----------------------------|
| T1           | 2400        | 25                       | 60                  | planar              | 3                   | 4                          | 8                          |
| T2           | 2400        | 40                       | 60                  | 3D                  | 2                   | 4                          | 8                          |

2.2. Test setup

There are reinforced concrete beams at the bottom and top of specimens. The bottom beam is fixed on the laboratory floor by anchor bolts. The function of top beam is to uniformly distribute the vertical load to the specimen. A constant axial force 350kN and 700kN is applied to the top of T1 and T2 respectively. The specimen is vertically connected with the reaction frame, and a hydraulic actuator as the horizontal loading device is used to perform low-cycle reversed loading. At the same time, in order to prevent the out-of-plane instability, a protective equipment is applied on both sides of specimen’s top. The vertical displacements and horizontal displacements of specimen are measured with LVDTs, and the values of applied load are measured with load cell sensor. All measurement data, including loads, displacements and strains, are recorded by the data acquisition system. The test device is shown in Figure 3.

The specimens are loaded with a displacement-controlled system to simulate the cyclic reversed loading scenario. Before the displacement reaches 10 mm, there is one load cycle for each displacement amplitude and the increment of displacement is 1mm. While after the displacement reaches 10 mm, there is three load cycles for each displacement amplitude and the increment of displacement is 5mm for T1 and 2mm for T2 until the specimens completely fail or the residual strength reduces to 85% of the maximum load.
3. Failure mode
Specimen T1 exhibits elastic performance in the initial loading phase. When the displacement cycle reaches 4 mm, the first horizontal crack appears at the corner bottom of T1 and the crack closes after the load has been unloaded to zero. With the development of lateral displacement, more cracks appear at the bottom of specimens, and some horizontal cracks develop obliquely toward the upper zone of the wall. When the displacement is loaded to 10 mm, the first visible horizontal crack appears at the flange of specimen. In the subsequent displacement cycle, large-sized cracks appeared on the flange surface of specimen and grow in both horizontal and diagonal directions. When the displacement load increases up to 14 mm, several fully developed cracks through the height of wall panel appear. The concrete partially falls off at the vertical crack of web at the displacement of 18 mm, and the crack width increases significantly. The specimen reaches the maximum strength at load cycle of 25 mm and the test is stopped. At the ultimate state it can be observed that there is a wide vertical crack and there is obvious concrete falling off at the corners of specimen. The steel mesh in the region of concrete crush is basically pulled off. The residual strength of specimen drops to 80% of peak value. According to the ultimate state of specimen T1, a shear-controlled failure could be verified. The failure mode of T1 is shown in Figure 4.

Most of the T2 cracks appear at the edge of the rib and develop along the horizontal direction. The T2 has similar failure process with T1, however for T2 the displacement in each loading stage is larger than that of T1. The destructive feature of T2 is that there are no obvious cracks in the foot and top of specimen and the horizontal crack and oblique crack distribution are concentrated at the 1/3 height of specimen surface. In the final state the concrete at the bottom of specimen is significantly crushed and the wire in the exposed zone is observed to fracture. Therefore, the failure mode of specimen T2 is controlled by a combination of bending and shear failure with relatively ductile performance. The damage of T2 is shown in Figure 5. The main results of experiments have been listed in Table 2.

| Number | Cracking load | Ultimate load | Lateral deflection |
|--------|---------------|---------------|-------------------|
| T1     | 102.0kN       | 327.0kN       | 20.2mm            |
| T2     | 183.7kN       | 616.3kN       | 26.7mm            |

3.1. Hysteresis curves
The hysteresis curves of specimens have been presented in Fig. 6-7, for T1 the strength decreases rapidly after the peak load and sudden failure of specimen accompanying with corner concrete crash. Compared with the specimen T1, the T2 has higher strength. After reaching the peak load, the hysteresis loop still covers more area during the process of stiffness degradation, which indicates that the specimen has better deformation ability and seismic behavior.
3.2. Skeleton curves

The comparison of skeleton curves is shown in Figure 8. It can be seen that the slope of T2 skeleton curve in the elastic phase is greater than T1 which indicates that the stiffness of T2 is greater than T1. The peak strength of T1 and T2 is almost the same under positive horizontal load, however, the peak lateral displacement of Y2 is 26.7 mm, while Y1 is 20.2 mm. After specimen reaches maximum load-bearing capacity, the strength of T1 has significantly reduction, and the residual strength of T2 could keep a relatively high value. The comparison of the skeleton curves shows that the seismic performance of T2 is better than that of T1 because of the existence of 3D steel mesh system which can effectively reinforces the concrete layer and improves rigidity and crack resistance of panel.
4. Conclusions
In this paper, the seismic performance of a new type of assembled wire mesh sandwich panel is experimentally studied. The innovation of this wall system includes core column with spiral stirrups with 650 mm spacing, 3D wire mesh system in concrete layer. The experimental results indicate that the seismic performance of T-shaped full-scale specimen under reversed cyclic loading is governed by a combined failure of compression and shear action. All the specimens have no out-of-plane failure, which proves that the existence of the reinforced core column has a certain effect on improving stiffness and stability of wall panel. The seismic performance of specimen with 3D steel wire mesh is superior to the specimen with planar steel wire mesh in terms of hysteresis curves, skeleton curves, crack distribution and ductility.

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