Experimental Study on Seismic Performance of Multiple Ecological Composite Wall

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Abstract. The multiple ecological composite wall is the main force-bearing component of ecological composite wall structure. Its construction and mechanical properties are quite different from those of standard composite wall. In this paper, the low cycle cyclic loading test of multiple ecological wall is carried out, and the failure mode and process of composite ecological wall are discussed. On this basis, the seismic performance such as bearing capacity, deformation, ductility and energy dissipation are analyzed respectively. The Experimental results show that the multiple ecological wall has better seismic performance than the standard wall.

1. Introduction

Multiple ecological composite wall is the main force-bearing member in ecological composite wall structure, which is a new seismic structural system with the advantages of environmental protection, ecology, energy conservation and so on [1-3]. The multiple ecological composite walls are usually composed of columns and two or more ecological composite slabs (Figure 1). Therefore, the mechanical performance of multiple ecological wall is quite different from that of standard wall. In this paper, the seismic performance is studied by the low-cycle cyclic loading test of a multiple ecological composite wall. The bearing capacity, deformation, ductility and energy dissipation of the wall are analyzed.
2. Test Specimens and Setup

| specimens | height-width ratio | Maximum vertical load/kN | Design axial compression ratio | section of Outer frame and Rib frame/\(\text{mm}\) | Steel of Outer frame | Steel of Rib frame |
|------------|-------------------|--------------------------|--------------------------------|---------------------------------|---------------------|--------------------|
|            |                   |                          |                                | beam | column | Rib beam | Rib column | beam | column | Stirrups | beam | column | Stirrups |
| ECW-1      | 1:1               | 110                      | 0.23                           | 1.4×1.44×0.1 | 100     | 100     | 50       | 50    | 4ф6   | 4ф6     | 4ф4   | 4ф4    | ф4@100 |
| ECW-6      | 1:2               | 220                      | 0.23                           | 2.7×1.44×0.1 | 100     | 100     | 50       | 50    | 4ф6   | 4ф6     | 4ф4   | 4ф4    | ф2@100 |

In order to study the coupled ecological composite wall seismic behavior, the test of a 1/2-scale model specimen under low-cycle repetitive loadings is carried out[4]. The design of members is shown in Table 1. Firstly, the horizontal force is controlled by horizontal load; the horizontal loads of the specimens are 20 kN, 40 kN, 50 kN, 60 kN, 70 kN, 80 kN and 90 kN, respectively. Each stage is a cycle, and then the cyclic loads are controlled by displacement to add force for each stage three times. Finally, the wall is destroyed by single push.

3. Test results and Analysis

3.1 Failure process.

From the experimental phenomena it can seen that the failure process of the multiple ecological composite wall can be divided into three stages, namely, elastic stage, elastic-plastic stage and failure stage (figure 2).

3.1.1 Elastic stage. Before the horizontal load reaches 40% of the ultimate load, the multiple ecological composite wall has elastic characteristics and its hysteretic curve is linear. After unloading, there is almost no residual deformation and a small number of micro-cracks can be seen in the filling block. In this loading step, the composite wall can be regarded as an equivalent elastic composite plate. When the horizontal load is about 40% of the ultimate load, diffuse micro-cracks appear around the diagonal line of the filling block in the middle of the wall. The obvious inflection point can be seen on the P-\(\Delta\)curve, and the horizontal load at this time is defined as the cracking load of the wall.

3.1.2 Elastic-Plastic stage. When the horizontal load increases to 70% of the ultimate load, the cracks in the filling block increase, and inclined cracks appear in the rib beams and columns. The stiffness of the wall is obviously reduced, the residual deformation is obvious, and the area of hysteretic curve is obviously increased. When the horizontal load reaches 80% of the ultimate load, obvious inclined cracks appear in the rib beams and columns of the walls. At the same time, the strain of reinforcing bar in the ribbed beam rises rapidly and gradually yields. The bearing capacity of the wall increases gradually, but the stiffness decreases sharply and the plastic deformation is obvious. The horizontal load at this time can be called the yield load of the wall.

3.1.3 Failure stage: At this stage, the load continues to increase. When the horizontal load reaches the ultimate load, the dispersed inclined cracks run through the whole wall diagonally. With more and more fragmentation and spalling of fillers, a small amount of micro-pressure appears in the compression zone of end-frame columns, and a small amount of steel bars yield in the tension zone of end-frame columns. Then the test enters into the cyclic process with displacement as the main factor. The crushing and peeling of packing blocks are more serious. When the displacement equals the ultimate displacement, large shear and sliding deformations occur on the wall, almost all the filling blocks are peeled off, and the wall degenerates into a pure frame, consisting only of concrete frame grilles and concealed frames. There is no obvious damage to ribbed columns and concealed frames, and there are many shear-plastic hinges on ribbed beams.

3.2 Hysteretic curves

The hysteretic curve (As seen in figure 3) shows that the wall is fine as a whole in elastic stage. The hysteretic curve is mainly a line and the stiffness does not vary. Accompanied by the increase of load,
the test member become plastic, the hysteretic loops is in shuttle-shape and the area of hysteretic loops expands too. The residual deformation appears and the stiffness retrogresses sharply. With the increase of the load, the cracks become smeared and the hysteretic curve becomes in the shape of bow as well as the expansion of the area of hysteretic loops. Load-displacement curve shrink and close due to the opening and closing of the oblique section as well as the influence of the shear-deformation (slipping in the wall and bottom beam). When the stress reaches the submit loading, the degree of the displacement increase with several times, and the area of hysteretic loops become plump and alter to the shape of anti-S shape. The tendency of shrinking is obvious, which reflect the influence of shearing and sliding. After the member is subjected to ultimate loading, the bearing capacity of the wall decline quickly and become constant at certain degree. The displacements rise remarkably and show the walls favorable ductility. Accordingly, the phenomena of sliding is already outstanding when the wall is subjected to large magnitude of cyclic loading since the block and the concrete fall and the steel bar yield, the stiffness retrogress evidently. The shrinking and centering in the middle of hysteretic loops is remarkable and the hysteretic loops are in the anti-s shape[5-6].

3.3 Seismic performance

As seen in Table 2, the seismic performance parameters of multiple ecological composite wall can be Listed as follows:

| specimens | Axial compression stress | cracking | yielding | ultimate | damage | ductility limit | rotation |
|-----------|--------------------------|----------|----------|----------|--------|----------------|----------|
| ECW-1     | 0.78                     | 21       | 1.3      | 64.8     | 7.6    | 81.6           | 19.5     | 70.7       | 32.5     | 4.28   | 1/44    |
| ECW-6     | 0.79                     | 30.4     | 2.2      | 79.2     | 10.2   | 97.7           | 30.0     | 80.4       | 49.5     | 4.82   | 1/29    |

3.3.1 Bearing capacity. As seen in Table2, the cracking load, yield load and ultimate load of the multiple ecological composite wall are higher than those of the standard ecological composite wall, which is due to the cooperative work between the two single walls and the overall effect of the external frame.

3.3.2 Deflective property. The stiffness of multi-limb ecological composite wall is obviously greater than that of standard wall, so the horizontal lateral displacement of multiple ecological composite wall is less than twice that of the standard wall.

3.3.3 Ductility. From the table2, the ductility coefficient (the ratio of ultimate displacement to yield displacement) of the ecological composite wall is slightly larger than that of the standard wall, which is 4.82, indicating that the ductility of the multiple ecological composite wall is better than that of the standard wall.
3.3.4 Energy dissipation. Similarly, the data in Table 2 show that with the increase of horizontal load, the equivalent viscous damping coefficient of the wall increases gradually, and the increase rate also increases gradually, which shows that the wall has good energy dissipation performance.

3.3.5 Collapse-resistant capacity. When the load increases to the failure load, almost all the blocks withdraw from work. At this time, all the vertical loads of the wall are borne by the frame composed of rib beams, columns and frames. When the wall is damaged, the displacement and limit rotation of the top of the wall reach 40 mm and 1/29, respectively. It shows that the wall has good anti-collapse ability.

4 Summary
Multiple ecological composite wall is the main forced member in ecological composite wall structure. In this paper, the seismic behavior of multiple ecological composite wall is studied by the low-cycle cyclic loading test of the wall. Through the analysis of experimental phenomena, it is found that the failure process of the wall can be divided into elastic stage, elastic-plastic stage and failure stage. The bearing capacity in each stage (cracking load, yield load and ultimate load) of the multiple ecological composite wall is higher than that of the standard wall. Because of the cooperative work between the two single walls and the overall effect of the external frame, the flexural performance and ductility of the ecological composite wall are better than those of the wall standard. At the same time, the results also show that the multi-ecological composite wall has good energy dissipation performance and anti-collapse ability.

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