Non-linear Finite Element Analysis of Shear Capacity for Multiple Ecological Composite Wall

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Abstract. Multiple ecological composite wall is one of the most commonly used lateral resistance components in the ecological composite wall structure. In order to make a study of the shear capacity of the multiple ecological composite wall, based on previous research results, the finite element model of the multiple ecological composite wall is established to analyze the main influencing factors of the shear bearing capacity of the wall. The results of finite element analysis show that the main factors affecting the shear capacity are shear span ratio, ribbed bar, height of strength section, reinforcement area of end columns and concrete strength of end columns.

1. Introduction

Ecological composite wall structure is a new seismic structural system with the advantages of ecology, environmental protection and energy saving. Multiple ecological composite walls (consisting of column connection with two or more ecological composite slab) is one of the most commonly used lateral resistance components in this structure (Fig. 1). Because there is a big difference between multiple ecological composite wall and standard ecological composite wall. In this paper, the shear capacity of multiple ecological composite wall is studied, the finite element model of multiple ecological composite wall is established, and the main factors affecting the shear capacity of the wall are analyzed.
2. Finite element model of the Multiple Ecological Composite Wall

The three-dimensional finite element model of the multiple ecological composite wall is established by ANSYS. Both concrete and block elements adopt eight-node solid element SOLID65. Based on the uniaxial compression test of vegetable fiber raw soil block, the constitutive relation with pertinence and accuracy is obtained, and the finite element model [4-5] is established. Fig. 2 shows the constitutive model of vegetable fiber soil-based block. Fig. 3 shows the finite element model of the specimen.

![Figure 2: The constitutive model of plant fiber soil-based block.](image)

![Figure 3: Finite element model of specimen.](image)

The three-dimensional nonlinear finite element simulation of the specimen under monotonic loading is conducted and the dates are compared with the experimental results. Obviously, the cracks distribution (Figure 4) of the wall under maximum load is basically identical with the final destruction of the wall. In addition, the horizontal load - displacement curve on the wall in the test is depicted and compared with the finite element calculation in figure 5 and Table 1. The results show that simplified finite element model is reasonable.

![Figure 4: Crack pattern](image)

![Figure 5: Comparison between test and calculation results.](image)

| Specimen | Maximum Load (kN) | Maximum Displacement (mm) |
|----------|-------------------|----------------------------|
|          | Experimental Result | FEA Result | Error (%) | Experimental Result | FEA Result | Error (%) |
| ECW-6    | 97.7 | 107.4 | 9.9 | 25.3 | 23.1 | 8.7 |

3. Influencing factors analysis on shear capacity of multiple ecological composite wall

Experimental research indicate that there are many factors influencing the oblique section shear capacity of ecological composite wall. They can be summarized as follows:

3.1 Shear span ratio

While bearing bending moment and shear force, the wall will undergo ultimate failure. The ratio of bending moment to shear force has a significant effect on the stress and failure mode of components. The general shear span ratio is used to describe the relative ratio of bending moment to shear force. Table 2 shows that under the same stability conditions, the shear capacity of the wall decreases with the increase of the shear span ratio, especially when the shear span ratio is less than 0.6, the trend does not change much. When the shear span ratio is small, shear failure will eventually occur.
Table 2  finite element analysis of walls with different shear span ratio

| Specimens | size/m          | shear span ratio | Number of rib column | FEA calculation (kN) |
|-----------|-----------------|------------------|-----------------------|----------------------|
| S 1       | 3.70×1.45×1.00  | 0.39             | 9                     | 121.36               |
| S 2       | 3.35×1.45×1.00  | 0.43             | 8                     | 117.07               |
| S 3       | 2.90×1.45×1.00  | 0.50             | 7                     | 105.30               |
| S 4       | 2.55×1.45×1.00  | 0.57             | 6                     | 84.89                |
| S 5       | 2.20×1.45×1.00  | 0.66             | 5                     | 74.23                |
| S 6       | 1.75×1.45×1.00  | 0.83             | 4                     | 64.32                |
| S 7       | 1.40×1.45×1.00  | 1.04             | 3                     | 56.58                |

3.2 Rib steel bar
The test results show that the reinforcement in the rib beam plays an important role in the shear capacity of the wall. Horizontal steel bars in rib beams bear transverse loads in the form of direct tension. When the wall is damaged, the horizontal steel bar yields or breaks. At the same time, horizontal steel bar hinders the development of cracks and improves the ductility of masonry. The results show that horizontal reinforcement not only plays an important role in shear resistance, but also indirectly improves the shear capacity of ecological composite walls by limiting the development of inclined cracks.

3.3 Axial compression ratio
Figure 6 shows that when the axial compression ratio is greater than 0.4, the ultimate load of the ecological composite wall decreases with the increase of the axial compression ratio. It is noteworthy that this kind of compressive failure belongs to brittle failure and should be avoided in engineering design. Generally speaking, if the vertical compressive stress does not exceed 60% of the time (the actual situation is generally the case), the wall failure is mainly shear failure, which belongs to a good failure mode.

![Figure 6. Axial pressure and block strength](image)
3.4 Block strength
It can be known from the Figure 6, the shear capacity of ecological composite wall can be enhanced by increasing the block strength when the strength ratio of concrete is 0.22-0.275, and cooperative working performance and concrete and masonry material properties can be fully utilized.

3.5 section height and reinforced area of end column
From Figure 7, it can be seen that the contribution of reinforcement to the shear capacity of ecological composite walls increases with the increase of reinforcement area of end columns. However, when it increases to a certain range, the shear capacity of the wall does not increase significantly. In addition, Figure 7 shows the relationship between the height of the end column section and the shear capacity, which indicates that the shear capacity increases with the increase of the height of the section within a certain range. This is due to the increase of inner restraint and contact length of inclined crack.

3.6 Concrete strength of end frame column
The experimental and finite element results show that when the wall reaches its maximum shear capacity, the column strain of the end frame column basically reaches its limit state. Therefore, if the ecological composite wall shear failure occurs, increasing the concrete strength can increase the constraints on the internal wall panels, on the other hand, it is conducive to the overall damage of the internal wall.

4.Conclusion
Through numerical simulation, the main influencing factors of shear capacity of ecological composite wall are analyzed. The results of finite element analysis show that with the increase of wall shear span ratio, the shear capacity of the wall decreases gradually; horizontal reinforcement not only plays an important role in shear resistance, but also indirectly improves the shear capacity of the ecological composite wall through restraint, while limiting the development of inclined cracks; when the axial compression ratio is greater than 0.4, the wall The ultimate load decreases with the increase of the axial compression ratio, and when the concrete strength ratio is greater than 0.4, the shear capacity of the ecological composite wall can be improved by increasing the block strength. When the section height increases in a certain range, the shear capacity increases; when the shear capacity of the wall reaches the maximum load, the column strain of the end frame column basically reaches the limit state.

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References

[1] YANU Zengke, HUANU Wei. Research on construction process of eco-composite wall structure. International Journal of Earth Sciences and Engineering, 2015(6):1209-1214.

[2] HUANC Wei, CHE'N Junying. Study on failure modes of fundamental element of eco-logical composite wall. Industrial Construction, 2014, 44(3):68-73.

[3] HUANC Wei, LI Bin, ZHANU Wei. Seismic spouse analysis on the eco-composite analysis wall structure infilled with different material. Journal of Xi’an University of Architecture & Technology (Natural Science Edition), 2016, 46(4):179-183.

[4] Xie Yong-Qun, Yang Wen-Bin, et.al. Dimensional stability of ultra-low-density plant fiber materials during drying process[J]. Journal of Beijing Forestry University, 2008, 30:124~127.

[5] Alemdar Bayraktar. Experimental and finite element analysis on the steel fiber-reinforced concrete (SFRC) beams ultimate behavior[J]. Construction and Building Materials 23 (2009): 1064–1077