The influence of the number of rib columns on the Compressive strength of multi-rib composite wall

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Abstract. Based on the mechanical characteristics of Multi-ribbed composite wallboard, the computing model of different number rib column are established by ANSYS command flow segmented modeling methods. The model are progressively applied vertical load, horizontal and vertical interaction load, then the stress, strain and displacement of structure under the corresponding loads were calculated. Further analysis on the mechanical properties that affect of rib column number to multi-ribbed composite wallboard. Calculated the stress of multi-ribbed composite wallboard under different rib columns number, and analyze its working mechanism. Combined with displacement, stress and strain rule can be found: With the increase number of the rib column, displacement, stress and strain of structural model are gradually decreasing trend. And with the impact of rib columns number on the average size of ribs is gradually reduced. The displacement, stress and strain decreasing trend gradually slowing down. Combined with the actual construction environment and economic considerations can provide theoretical support for the rib column design of the real case structure.

1. Introduction

Since the 1980s, especially since the beginning of the 21st century, with the gradual development of China's reform and opening up and the gradual improvement of the national economic level, urban commercial housing construction has presented a blowout trend. After decades of radical and bold development of the construction industry, construction waste, construction noise and construction dust have gradually deteriorated into a social problem. Along with the historical process of comprehensively deepening the reform of the country, people's awareness of environmental protection and energy conservation has gradually increased. New low-carbon and more secure building structures and building materials emerge in an endless stream; therefore, the development concept and technical innovation speed of the construction industry are accelerating [1, 2]. In this context, modular, prefabricated, assembled, energy-saving, mass production of ribbed composite wall structure system will be widely applied in the development of country promote the industrialization of housing and the low carbon.

Multi-ribbed composite wallboard is made of reinforced concrete frame, bar and aerated concrete block, the new building components was rose and used to promote in recent years. Based on preliminary studies and achieved certain results, this article mainly analyses effect of rib column number to the compressive property properties of multi-ribbed composite wall.
2. Modeling process of multi-ribbed composite wall.
The multi-ribbed composite wall is composed of frame, frame grid and block, which the frame is cast-in-situ reinforced concrete structure, the frame grid is composed of precast reinforced concrete ribbed beam and column, and the block is made of industrial waste. The three parts coordinate and coordinate with each other when they stressed. In the process of bearing the load, the three parts restrain each other, resist the external force together, and coordinate the deformation so as to give full play to the advantages of different materials.

2.1 Unit selection
Concrete and block select Solid65 units without reinforcement. Solid 65 unit is a solid unit on the basis of Solid45 unit, and it is used to analyse materials of tensile strength far less than compressive strength, such as concrete and rock [3]. It can simulate the tensile and crushing properties of reinforcement bars and materials inside concrete. Each unit has eight nodes, and each node has three degrees freedom [4]. In this paper, the concrete crushing switch is turned off when the unit is used [5].

Considering the fact that the reinforcement section is a circular one, Beam188 element is selected to simulate the reinforcement in this paper, and Plane42 element is selected as the surface element for stretching.

2.2 Definition of material properties, reinforcement and section size of components
The material properties, the sectional dimensions and reinforcement of the components are shown in table 1 and table 2 respectively. In this paper, the yield strength of material is not defined when the model is established.

| Table 1. The material properties. |
|----------------------------------|
|                                | C40 concrete | HRB400 steel bar | Aerated concrete block |
| elasticity Modulus (N/mm²)      | 3.25×10⁴     | 2.0×10⁵          | 2×10³                  |
| Poisson's ratio                 | 0.2          | 0.3              | 0.2                    |
| compressive strength (N/mm²)    | 26.8         | 360              | 6.5                    |
| Tensile strength (N/mm²)        | 2.39         | 360              | 0.65                   |

| Table 2. Section size and reinforcement (note: length unit is mm). |
|---------------------------------------------------------------|
| Section size                                                 | Box beam (b×h) | Box column (b×h) | The rib beam (b×h) | Rib column (b×h) | Block (b×h) |
| 300×300                                                      | 300×300        | 300×150          | 300×150            | 150×150          |
| Longitudinal reinforcement                                    | 4Φ32           | 4Φ32             | 4Φ20              | 4Φ20             | --          |
| Stirrup                                                      | Φ16@150        | Φ16@150          | Φ16@150           | Φ16@150          | --          |

2.3 Establishment of mathematical model
The modeling methods of reinforced concrete can be roughly divided into: separated type, integrated type and combined type [6]. The separated modeling method is selected In this paper without considering the slip between the reinforcement and concrete, and the advantage of ANSYS command flow is fully utilized to establish the finite element calculation models of the multi-ribbed composite wall with different numbers ribbed columns respectively (the span of the models built is 6.3m, and the floor height is 4.2m). Then the mapping element division method is used to divide the grid (the size of the grid is 75mm×75mm) so that there are nodes with the same coordinate between the reinforcement and the concrete and between the concrete and the block [7]. further nodes with the same coordinates are combined in batches to form an overall computing model by coupling nodes [8,9].The final generated model is shown in Figure 1 (the four rib columns are represented by the spacing from left to right of 1125mm, 1125mm, 1350mm, 1125mm, 1125mm).
3. Calculation results and discussion

Due to the large number of models and loading times, the y-direction displacement cloud diagram, Mises stress cloud diagram and Mises strain cloud diagram under the vertical load is 5.0MPa of the model (represented by 4 ribbed columns) are only shown in Figure 2, 3 and 4 respectively. The y-direction displacement, Mises stress and Mises strain of each model under other load conditions are listed in numerical form in table 3, 4 and 5 respectively.

Figure 2. The y-direction displacement cloud diagram of four rib column models.
Figure 3. Mises stress cloud diagram of 4 rib column models.

Figure 4. Mises stain cloud diagram of 4 rib column models.

Table 3. Maximum y-direction displacement of each model and load condition.

| Load value/MPa | 1 rib columns | 2 rib columns | 3 rib columns | 4 rib columns |
|----------------|---------------|---------------|---------------|---------------|
| 0.5            | 0.6197120     | 0.5337160     | 0.4558560     | 0.4164200     |
| 1.0            | 1.3703900     | 1.1859000     | 1.0157600     | 0.9282970     |
| 1.5            | 2.1210700     | 1.8380800     | 1.5756700     | 1.4401700     |
| 2.0            | 2.8717500     | 2.4902700     | 2.1355800     | 1.9520500     |
| 2.5            | 3.6224300     | 3.1424500     | 2.6954800     | 2.4639300     |
| 3.0            | 4.3731100     | 3.7946400     | 3.2553900     | 2.9758000     |
| 3.5            | 5.1237900     | 4.4468200     | 3.8153000     | 3.4876800     |
| 4.0            | 5.8744700     | 5.0990100     | 4.3752000     | 3.9995600     |
| 4.5            | 6.6251500     | 5.7511900     | 4.9351100     | 4.5114300     |
| 5.0            | 7.3758300     | 6.4033800     | 5.4950200     | 5.0233100     |
Table 4. Maximum value of Mises stress under each model and load condition.

| Load value/MPa | 1 rib columns | 2 rib columns | 3 rib columns | 4 rib columns |
|----------------|---------------|---------------|---------------|---------------|
| 0.5            | 23.7359000    | 20.9374000    | 18.4423000    | 17.5660000    |
| 1.0            | 49.6140000    | 43.4140000    | 37.9856000    | 35.8925000    |
| 1.5            | 75.4922000    | 66.0169000    | 57.5289000    | 54.2191000    |
| 2.0            | 101.3700000   | 88.6198000    | 77.0723000    | 72.5456000    |
| 2.5            | 127.2480000   | 111.2230000   | 96.6156000    | 90.8721000    |
| 3.0            | 153.1270000   | 133.8260000   | 116.1590000   | 109.1990000   |
| 3.5            | 179.0050000   | 156.4280000   | 135.7020000   | 127.5250000   |
| 4.0            | 204.8830000   | 179.0310000   | 155.2460000   | 145.8520000   |
| 4.5            | 230.7610000   | 201.6340000   | 174.7890000   | 164.1780000   |
| 5.0            | 256.6390000   | 224.2370000   | 194.3320000   | 182.5050000   |

Table 5. Maximum value of Mises strain under each model and load condition.

| Load value/MPa | 1 rib columns | 2 rib columns | 3 rib columns | 4 rib columns |
|----------------|---------------|---------------|---------------|---------------|
| 0.5            | 0.0001960     | 0.0001510     | 0.0001240     | 0.0001110     |
| 1.0            | 0.0003960     | 0.0003150     | 0.0002640     | 0.0002250     |
| 1.5            | 0.0005950     | 0.0004810     | 0.0004030     | 0.0003440     |
| 2.0            | 0.0007950     | 0.0006480     | 0.0005420     | 0.0004630     |
| 2.5            | 0.0009950     | 0.0008140     | 0.0006820     | 0.0005820     |
| 3.0            | 0.0011950     | 0.0009810     | 0.0008210     | 0.0007010     |
| 3.5            | 0.0013950     | 0.0011470     | 0.0009610     | 0.0008200     |
| 4.0            | 0.0015950     | 0.0013130     | 0.0011000     | 0.0009390     |
| 4.5            | 0.0017950     | 0.0014800     | 0.0012390     | 0.0010580     |
| 5.0            | 0.0019950     | 0.0016460     | 0.0013790     | 0.0011760     |

It can be seen from the calculation data of each model that the y-direction displacement value, Mises stress value and Mises strain value of the whole structure gradually decrease with the increase of the number of rib columns under the same load condition. Moreover, it can be seen from the load-Mises stress diagram and Load-Mises strain diagram that with the increase of the number of rib columns, the influence of the number of rib columns on the average size of the frame gradually decreases, and the reduction of the Mises stress value and the Mises strain value of the structure becomes smaller and smaller. When the load is the same, the Mises stress value and Mises strain value of the structure are almost the same in the case of three rib columns and four rib columns. At this time,
it is not necessary to increase the number of rib columns in terms of building cost and design requirements of structural compressive bearing capacity.

4. Conclusion
The cloud diagram and calculation data show that the overall stiffness and strength of the structure increase gradually with the increase of the number of rib columns, and the internal stress value of the structure decreases gradually, that is, the increase of the number of rib columns can improve the compressive bearing capacity of the multi-rib composite wall. Through further research on the data found that the increased number of rib columns is not linearly related to the reduced value of structural stress and strain. The larger the number of rib columns, the smaller the influence of the number of rib columns on the average size of the frame, which leads to the gradual decrease of influence on the stress and strain of the structure. When the number of rib columns reaches a certain number, the increase of the number of rib columns will have little effect on improving the compressive bearing capacity of the structure. Since the maximum displacement value in the Y direction appears in the middle of the structure, the odd number of rib column layout can better reduce the vertical displacement of the structure and improve the stiffness of the structure. It is suggested that the odd number of rib column layout should be adopted in the structural design process.

In addition, the stress concentration phenomenon at the contact part between the rib column and the rib beam should also be considered in the structural design of the multi-rib composite wall.

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