

Simulation application of ALC external wall panel on rigid column frame brace system

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Abstract. Taking a building under construction as an example, based on ABAQUS software, studies the failure mode, hysteretic curve, displacement ductility and energy consumption capacity of ALC external wall panel under three working conditions of assembled stiffened column frame brace system, assembled frame system and cast-in-place frame system. The simulation results show that: 1. Under the action of low cycle load, the assembled stiffened column frame support system has no damage, the maximum stress value is 6.98 MPa, which is located at the position of steel plate at the column bottom; 2. Under the condition of ALC hanging wall plate, the structure ductility is better; 3. Part of the energy consumption is borne by the light material hanging wall plate, and the stiffened column frame support system has higher energy consumption capacity. The assembled ALC external wall panel based on the rigid column frame support system has better mechanical performance, can significantly improve the energy consumption capacity of the overall structure, and has high construction feasibility, economy and engineering application value.

1 Introduction

The composite beam and column structure with assembled stiffening columns is a new type of assembled structure system independently developed by China Construction Seventh Engineering Bureau Co., Ltd. Scholars at home and abroad have carried out some research on it, such as *Jiao Anliang*^[1], *Zhang Ailin*^[2], *Li Guoqiang*^[3] and *Lujiasen*^[4] et al.

But till now, there is no research on the simulation application of ALC external wall and external wall panel based on the rigid column frame support system in China. For this reason, this paper puts forward the research on the numerical simulation application of the assembled ALC external wall and external wall panel based on the rigid column frame support system, which provides some reference for the later design, production and construction.

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2 Project overview

The project is a comprehensive building of China Construction Technology Henan Co., Ltd. with an annual output of 1 million m² prefabricated component construction project. It is located in the southwest corner of the intersection of Yunan street and Yuzhong Road, Quliang Town, Xinmi City. The bottom floor of the building is 67.2 m long, 35.1 m wide, 16.8 m high and 4 floors above the ground. The structure is a composite beam frame structure with fabricated rigid columns, with seismic fortification intensity of 7 degrees.

The maximum span of the complex building is 7.2 m, the height of the first floor is 5.1 m, and the height of the second to fourth floors is 3.9 m. the external wall adopts the horizontal strip board system ALC external hanging wall board. In this paper, the size of ALC external wall panel is 6000 mm × 2500 mm × 150 mm, the section of stiffening column is 400 mm × 400 mm, and the section of frame beam is 200 mm × 400 mm. All beams and columns are made of C30 concrete, and the outer side of the rigid column is covered with 50mm thick fine aggregate concrete. See Figure 1 and Figure 2 for details.



Fig. 1. Overall effect diagram.

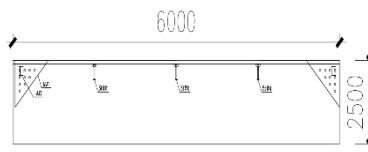


Fig. 2. External wall panel.

3 Establishment of finite element model

Three models of cast-in-place structure, assembled frame structure and assembled stiff column structure are established. Based on the three models, the influence of external wall panel on the overall frame is analyzed. See Table 1 for model information.

Table 1. Model information.

Model number	With or without External wall panel	Structural form
A	with	Rigid column frame bracing system
B	with	Assembled frame system
C	without	Frame structure system

3.1 Unit type and material properties

Based on ABAQUS, C3D8R element is selected for concrete and steel column element types. T3D2 element is selected for reinforcement element types. In the grid division, the concrete and steel column elements are distributed with 0.1 spacing, and the reinforcement elements are distributed with 0.01 spacing. All contacts in this paper are selected according to tie contact.

3.2 Boundary conditions and loads

The boundary conditions U_1 , U_2 , U_3 , R_1 , R_2 , R_3 are set to 0 at the bottom of the stiff column. The whole model is subject to gravity load. In order to make the model calculation results faster, displacement loading is adopted for the model. The loading system is controlled by $0.25\Delta_y$, $0.5\Delta_y$, $0.75\Delta_y$, Δ_y , $2\Delta_y$, $3\Delta_y$, $4\Delta_y$, $5\Delta_y$, $6\Delta_y$, $7\Delta_y$.

4 Analysis of simulation results

The failure mode, hysteretic curve, ductility and energy consumption capacity , are compared and analyzed, under the condition of model A ,B and C.

4.1 Failure mode

Model A is not damaged, stress value is 6.98 MPa, which appears at the position of steel plate, at the bottom of the column. Model B is damaged, the maximum stress value is 2.25 MPa, which appears in the concrete column. Under the action of horizontal seismic force, the maximum stress value exceeds the tensile strength of C30 concrete, and the concrete column is damaged. Under the condition of model C, the joint position of beam column is damaged. See Figure 3 for details.

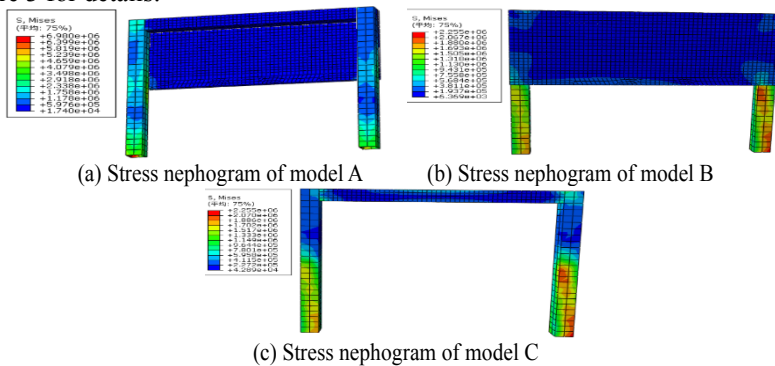


Fig. 3. Stress nephogram.

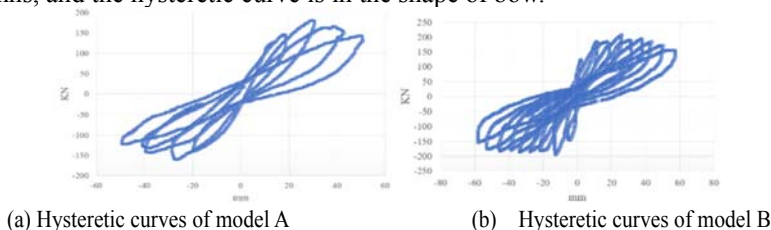
4.2 Hysteresis curve

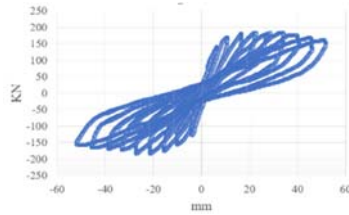
The hysteresis curves of the three models in Figure 4 are compared and analyzed.

1) In the initial stage of displacement loading, the hysteretic curve of model A is shuttle shaped. With the increase of displacement loading, the hysteresis curve appears a slight "pinching" phenomenon. It is assumed that there is no small slip between the steel and the concrete, or the phenomenon of "pinching" of the structure should be increased.

2) The hysteretic curve of model B at the initial stage of loading is also shuttle shaped, but with the increase of loading displacement, the phenomenon of "pinching" is intensified due to the small displacement constraint of reinforced concrete column.

3) Since no external wall panel is added to model C, all loads are borne by frame beams and columns, and the hysteretic curve is in the shape of bow.





(c) Hysteretic curves of model C

Fig. 4. Hysteretic curves.

4.3 Displacement ductility

The ratio of displacement to yield displacement, where the ultimate displacement is Δ_u and the yield displacement is μ . Table 2 shows the displacement ductility comparison of three models.

Table 2. Comparison of displacement ductility coefficient.

Model	Δ_u/mm	Δ_y/mm	μ
Model A	115.41	16.75	6.89
Model B	101.41	18.54	5.47
Model C	82.10	25.26	3.25

The ductility coefficients of model A and model B are higher than those of model C, which indicates that the efficiency of the structure is better under the condition of the existence of external wall panels.

The energy consumption of model A and model B exceeded that of model C. In the later stage of loading, the energy consumption of model A is significantly higher than that of the other two structural systems, which indicates that ALC rigid column frame system has higher energy consumption capacity.

5 Design suggestions

Because the external wall panel is larger than the size specified in the **Prefabricated Concrete External Wall Panel (16J110-2)**, so which requires special design, such as to add hidden beams and columns with a section of 150mm × 150mm on the three sides respectively, and to shorten the stirrup spacing to 100 mm, and to place double-layer steel mesh with 200mm spacing. As shown in Figure 5 for details.

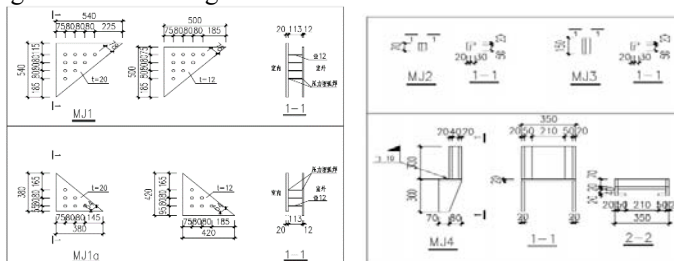


Fig. 5. The detailed design of node.

The hanging point shall be in accordance with the hanging point specified in the **Technical Specification for Precast Frame Structure assembled by stiff-columns and Hybrid-beams(JGJ /T400-2017)**, since the size of components in this project is too large, the connection between ALC external hanging wall panel and hanging parts shall be designed

separately. As a result, the embedded parts embedded in the external wall panel are composed of two triangular steel plates, and the middle part is welded with steel bars to form a whole, the stirrup at the corner of triangular steel plate is densified to 50 mm, which are all beneficial for stress diffusion.

6 Conclusions

Under the action of low cycle load, model A has no damage, the maximum stress value is 6.98 MPa, which is located at the position of steel plate at the column bottom. Model B appears the damage situation, when the maximum stress value is 2.25 MPa, which appears in the concrete column. Under the action of horizontal seismic force, when the maximum stress value exceeds the tensile strength of C30 cast-in-place concrete, the concrete column of model C will be damaged and the joint position of beam column will be damaged.

The ductility coefficient of model A is 25.9% higher than that of model B. The ductility coefficients of model A and model B are higher than those of model C. In a word, under the condition of ALC hanging wall plate (model A), the structure ductility is better.

At the initial stage of cyclic load, the energy consumption of the three models is almost the same. In the middle period of loading, the energy consumption of model A began to increase compared with the other two models, and the energy consumption of model A and model B with external wall panels exceeded that of model C. At the later stage of loading, the energy consumption of model A is significantly higher than that of the other two structural systems. Model A has higher energy consumption capacity. The assembled ALC wall panel based on the rigid column frame support system has better mechanical performance, can significantly improve the energy consumption capacity of the overall structure, and has high construction feasibility, economy and engineering application value.

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