Research and Finite Element Analysis of Prefabricated Concrete Box Structure System

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Abstract. This paper proposes a new type of assembled concrete box structure system, and proposes the relevant shear wall structure and floor structure. The finite element analysis of prefabricated wall is carried out to analyze its mechanical performance and mechanical characteristics, which can provide theoretical basis for further experimental research.

1. Introduction

The box structure system refers to the box made in the factory as a unit, and different boxes are hoisted on site to form a box structure. Experts at home and abroad have done a lot of research on the box structure. Habitat 67 [1] was built in Montreal, Canada. Prefabricated accessory units, stairs, elevator wells, air platforms, passages, etc. are all constructed of exposed concrete box structure. The box on the lower layer supports the box on the upper layer. The supporting points between the upper and lower boxes are made of steel plates and rubber pads, and anchored together with steel bars, forming an energy consumption structure to absorb seismic loads. In 1972, heikawa Jizhang designed the BOC cabin building in Japan [2]. The building has 140 cabin modules in total, which are connected by prefabricated module units, with the dimensions of 2.3m × 3.8m × 2.1m and suspended on the reinforced concrete core tube with internal elevator and pipeline. In 2009, Wolverhampton student apartment [3] was built in the UK, which is the highest integrated modular building in the world, including three buildings with 8-25 floors. There is also a 12 storey student apartment [4] in Bristol, UK. The module unit is a special-shaped module. Wu Bin, Professor of Harbin University of technology [5], etc. put forward the "single row and half grouting sleeve horizontal joint connection method", and tested the seismic performance of the prefabricated shear wall box structure using this connection method through the pseudo dynamic test method, and studied a series of indicators such as its strength, rigidity, failure mode, etc. According to the development situation of domestic fabricated structures, this paper proposes a new fabricated structural system-reinforced concrete box structure diagram system. Through the relevant finite element analysis, the failure mode and stress characteristics are obtained, which provides theoretical guidance for further experimental analysis.

2. Construction form of fabricated box structure system

2.1. Structural system construction form

The reinforced concrete box housing system is made into two trough-shaped wall panels by dividing the wall into two halves. The basic assembling unit of the "box" system is formed by assembling the four side channel wall panel into a tetrahedron and temporarily enclosing the box with connecting angle steel and support. When the box is hoisted as a whole, the wall panels which are divided into
two parts shall be close to each other, and then the concrete shall be poured to make the walls integrate into one and form a shear wall, in which the prefabricated groove plate can be used as both the load-bearing component and the formwork. The overall structural system is shown in the figure below.

2.2. Wall design

The wall is made up of two pieces of prefabricated concrete walls of slot type, which are prefabricated in the factory and cast-in-place concrete in the end area of the wall at the construction site to form a whole. As shown in the figure below, a 360mm cavity is arranged for every 600mm of the wall. After the two grooved plates are assembled, the cavity that appears in the middle can be filled with one empty two, filled with one empty, or fully filled according to the floor height and force, so as to increase the stress performance of the wall. The external surface of the prefabricated wall panel is smooth to achieve a good architectural appearance, and the internal surface is rough, increasing the contact surface between the cast-in-place concrete and the wall. The length of the wall is set to a fixed modulus according to the size of the house, and each room is used as a wall unit. The wall surface is flat, only need to scrape the putty to spray or decorate, reduce the 20mm plastering, reduce the consumption of materials, and eliminate the wet work and labor costs of on-site plastering.

2.3. Precast floor

The floor slab is a two-way multi-ribbed slab with a rib height of 150mm, a rib width of 60mm, and a rib spacing of 600mm. Aerated concrete or foam concrete blocks are used as filling materials between
the ribs to reduce self-weight and enhance sound insulation and anti-shake functions. Each bay is used as the floor unit, and the reinforcement is reserved around the slab. The upper reinforcement of the rib is welded with the upper reinforcement of the adjacent slab, and the rest of the reinforcement is anchored into the concealed beam to achieve the purpose of multi-span continuous slab, which has large floor stiffness and avoids the lamination of the laminated slab. The bottom surface of the floor slab shall be flat without plastering, and 20mm cement mortar shall be saved. The floor structure is shown in the following figure.

Figure 3. Typical floor plan.

2.4. Node connection form
Through the fixed size end columns and concealed beam left between the wall and the wall, and between the wall and the floor, the concrete is poured in to form an effective connection between the wall and the wall, and between the wall and the floor, finally forming a whole, completing the establishment of a complete set of box structure system.

3. Finite element analysis of prefabricated box structure shear wall

3.1. Material definition
In this paper, the shear wall of fabricated box structure is analyzed. In order to fully understand the force transfer mechanism and stress distribution law of the wall, six wall models composed of two groove walls are established by ABAQUS software. The different parameters of the wall models are studied. The low cycle reciprocating test process is simulated and analyzed, taking into account geometric nonlinearity and material nonlinearity. The finite element model and mesh generation are shown in Figure 4. The wall reinforcement and concrete are meshed by using the sweeping grid division technology. The concrete unit type is C3D8R. The reinforcement adopts the T3D2 truss unit. The friction contact between the prefabricated wall and the cast-in-place concrete wall is established. According to the definition of code for design of concrete structures (GB50010-2002), C40 is selected as the constitutive model of concrete materials, and the elastic modulus is 32500mpa. HRB400 is selected as the reinforcement, and its constitutive model is defined by the clough reinforcement model of subroutine (Fang Zihu): in the mechanical variable, the elastic modulus is 206000mpa, and the yield strength is 400MPa.
3.2. Finite element analysis and hysteresis curve analysis

Through the comparison of hysteretic curves, it can be seen that when the concrete is filled, the peak bearing capacity of the load increases obviously, and the change of rib width and wall thickness has little effect on the overall mechanical performance.
It can be seen from the concrete stress cloud diagram that the corners at both ends of the wall gradually deform as the displacement increases, and the concrete stress gradually reaches the limit strain. The area reaching the limit strain increases with the increase of displacement. Finally the wall under the side of the wall is damaged due to the compression. It can be seen from the reinforcement stress cloud diagram that with the increase of displacement, the reinforcement stress gradually increases. When the displacement is maximum, most of the reinforcement stress and strain in the middle of the wall reach the limit stress, and the reinforcement of the wall yield to failure. The above analysis results can provide some basis for the following wall related experiments and theoretical research.

4. Conclusion
1. This paper proposes a new box structure system. The precast walls and floor slabs are firmly connected through the connection of cast-in-place nodes to form a box structure system.
2. A new prefabricated concrete wall composed of a new type of double-groove precast concrete wall panels is proposed.
3. Through the finite element analysis of the mechanical performance of the wall, the ultimate bearing capacity of the wall and the related failure mechanism were obtained, which laid the foundation for further research.

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