Bearing capacity analysis and field test of multi-layer formwork support system for high-rise buildings

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Abstract. The multi-layer reinforced concrete formwork support system is a comprehensive structural system considering the formwork, structural beam and steel plate and steel pipe support. The demolition and turnover of the formwork support are affected by the time-varying of the concrete structure and the randomness of the construction. In this paper, the multi-layer formwork support system of the 2# building project of a real estate development project is field tested, and the multi-layer formwork support system is obtained during the construction process. The time-course curve of the axial force of the rod and the concrete strength growth curve are analyzed. The force transmission mechanism and load transfer law of the multi-layer formwork support system are analyzed.

1. Introduction
The multi-layer formwork support system is widely used in the construction of high-rise buildings. The progress of formwork construction is one week or even faster. In order to meet the concrete strength requirements during demoulding, the construction unit is equipped with three sets of templates and support frames. However, if the configuration of the multi-layer formwork support system is unreasonable and improperly dismantled, the early curing of the concrete is not good, which often causes the support collapse accident and the cracking of the floor during the construction phase, which seriously affects the construction safety and the performance of the building. The study of multi-layer formwork support system is of great significance for selecting reasonable construction plan, avoiding engineering accidents and shortening construction period.

In this paper, the field test of a frame shear wall structure project under construction is carried out to obtain the force of the formwork support system during the construction process of the concrete structure. The force transmission mechanism and load transfer law of the multi-layer formwork support system are discussed to determine the reasonable formwork and support.

2. Project Overview
The project is located in Licheng District, Jinan City, on the ground floor, with 12 floors above ground. The height of the underground floor is 4.5m, the height of each floor is 3.9m, and the total height of the house is 44.70m. The structure is frame shear wall structure and concrete. Board foundation. The beam plan of the standard layer is shown in Fig 1.
In the support system, the straight-through wheel-type support frame is adopted. The specifications of the vertical rod and the horizontal rod are φ48mm×3.0mm (measured value, the same below), the distance between the poles is 900mm×900mm, 900mm×1200mm, and the horizontal step is 1500mm. The vertical and horizontal sweeping rods are arranged at the bottom of the pole at 200mm, the top is supported by the top support, the upper joist is made of φ48mm×3.0mm double steel pipe, the upper pipe of the steel pipe is 50mm×80mm, the spacing of the raft is 250mm, and the structural design of the scissors support is in accordance with relevant specifications. Provisions. The layout of the pole frame is shown in Fig 2.

3. Test program

3.1 Measured purpose
The multi-layer reinforced concrete formwork support system is a comprehensive structural system considering the formwork, structural beam plate and steel pipe support. Due to the influence of the
time variation of the concrete structure and the randomness of the construction, it is necessary to influence the calculation model of the formwork support system. Various factors are analyzed. These influencing factors include: the influence of concrete age, the stiffness of the formwork support, the thickness of the slab, the stiffness of the concrete structure foundation, the boundary conditions of the slab during construction, the column spacing, the support erection and the concrete pouring scheme, and the temperature. In order to understand the load transfer law of the multi-layer template support system and the interaction between the support system and the main structure, this paper conducts a comprehensive measurement and analysis of a multi-layer template support system by using various measurement methods.

3.2 Measured content and method
Formwork support system vertical shaft force: Place the pressure sensor at the bottom of the support pole and place a steel backing plate between the pressure sensor and the pole to ensure that the center line of the pole and pressure sensor is in a vertical line.

Change of concrete strength: When the concrete is poured for the first time, 6 sets of the same condition test block are indwelled, and the same condition is used for maintenance, and a set of the same condition test block is pressed every 5 days to draw the concrete strength growth curve.

Monitoring atmospheric temperature: Set an electronic thermometer at the construction site and record the measured temperature on the construction site every day.

3.3 Measuring point arrangement
According to the test requirements, two measuring points are set at the main beam position, and two measuring points are set in the short side direction in the middle of the board span. The measuring point arrangement is shown in Fig 3

3.4 Data collection
During the construction of cast-in-place reinforced concrete, the construction process is column steel bar binding → pillar formwork → erecting formwork scaffold support → tying beam and slab steel bar → pouring beam slab column concrete → curing concrete → removing the bottom plate template support. The above steps are repeated until the structure is completed. The performance and stress state of the structure during the construction process change with time.

This test begins when the structure is carried out to the above-ground five-story beam-slab column steel bar. When the four-story beam-slab-column concrete is poured on the ground, data is collected
until the ground six-slab beam concrete is poured. The above construction process is a time node, and the axial force change of the pole during the whole construction process is measured. Encrypted measurements are performed on processes with long durations or large changes in structural force, and the rest are measured once a day.

4. Test result analysis
Due to the different positions, the variation law of the axial force of each measuring point is also different, and the peak value of the axial force changes greatly. Therefore, the 1-4 rod is selected for analysis, and the supporting axial force time history curve is shown in Fig 4. At the time of the sixth day, four layers of beam-slab concrete were poured, and on the 12th day, five-story beam-slab concrete was poured, and on the 19th day, six-story beam-slab concrete was poured.

![No. 1 vertical shaft force diagram](image1)

![No. 2 vertical shaft force diagram](image2)

![No. 3 vertical shaft force diagram](image3)
As can be seen from the above figure, there are two peaks in the steel pipe support from the beginning of the test to the end of the test. First, after the concrete pouring of the four-layer roof on the ground, the value of the vertical rod increases continuously, and the value reaches the first peak. As the concrete age increases, the axial force value generally shows a downward trend; Secondly, after the five-story roof is poured on the ground, the four-story roof on the ground is transmitted to the support of the four layers above the ground by the deformation of the upper support, so that the second peak appears. The force then gradually drops until the support is removed.

Before the concrete is poured and the strength is not completed, the axial force of the pole is independent of the position, but as the strength of the concrete increases, the structure itself begins to bear the load. At this time, the settlement of the structural mid-span is inevitably the largest, resulting in the pole near the mid-span. More force. The No. 1 pole is located at the junction of the main beam and the secondary beam, so the maximum axial force of the pole is the largest, and the No. 2 pole is located at the edge of the main beam, so the peak force of the pole is slightly smaller than that of the No. 1 pole.

The No. 3 pole and the No. 4 pole are the force diagrams of the mid-span and shear wall side poles respectively. The axial force of the shear wall side pole is smaller than the axial force of the board spanning the neutral pole. This is because the shear wall slab has a certain supporting effect, and as the concrete strength increases, the supporting effect becomes more and more obvious.

5. Summary
Through the measurement of the multi-layer template support system of the 2# building project of a certain district in Jinan, the main conclusions are as follows:

The axial force of the support pole may peak in both cases. First, after the upper floor is poured, the axial force of the supporting pole reaches the first peak, and the second peak is reached when the second layer is poured and the lower support of the measured floor has been removed.

The axial force of the beam under the beam is greater than the axial force of the lower column. It is mainly affected by the self-weight of the beam and the load from the floor. Therefore, the number of supports near the reinforced beam in the construction design is not only to meet the requirements of pouring. It is also necessary to make the support rods evenly stressed during the construction process.

When the third layer of beam and slab concrete is poured, the concrete strength of the first layer reaches 98% At this time, the axial force of the first layer of struts is hardly increased, so three sets of templates are sufficient during construction to meet the safety of formwork construction. Sexual requirements.

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