Superposition Technology of Complex Giant Reinforced Concrete Beams

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Abstract. Superposition technology construction is widely used in Large-span structures, super high-rise structures and large drop concrete structures. Based on the construction process of reinforced concrete for deep foundation pit engineering in Changsha Ice and Snow World, superposition technology and support design of large section concrete structures are discussed. ABAQUS finite element analysis was used to obtain the pouring process. It provides the technical foundation for the future design and construction of complex giant reinforced concrete structures.

1. Introduction

In recent years, there are more and more buildings with complex structures, such as large span, super high rise, deep foundation pit and large drop in the field of housing construction[1]. The functional requirements of large-span and large-span structures are inevitably accompanied by the appearance of multi-section forms and large-section scale main structure beams. The construction quality of the main structure is bound to be higher. The problem of difficult construction process and high construction quality is more acute.

For the large-scale giant beam main structure, especially the giant beam with the lower support system with a high height (more than 18m), the problem of the giant beam is prominent because it is difficult to support the cast-in-place giant beam and the engineering volume is large[2]. The superposition casting method is to cast the whole beam in different layers[3]. Superposition technology is used to bear part of the construction load and structural dead weight in the later stage to reduce the burden of the lower support system. The superposition of prestressed reinforced concrete beams can give full play to the characteristics of steel and concrete, which has the advantages of convenient construction, saving support and good mechanical performance. As the main beam structure form, it is widely used in the construction process of the main structure beam with large section and large span engineering[4].

Based on Changsha Ice and Snow World, this paper mainly introduces the superposition construction technology and key technologies of large multi-section prestressed reinforced concrete, which provides reference for other similar projects.

2. Construction technology of superstructure prestressed reinforced concrete composite beams

2.1. Construction scheme analysis
The project sits on top of a deep mine. The depth is about 100m, the slope is steep, and the slope angle is about 80°~90°. The platform beam is similar to an ellipse of 440m×350m and adopts the form of prestressed concrete beam and slab structure. The main girder has a basic span of 48 meters. The maximum box section is 5000 mm×2500 mm×500 mm×500 mm, most of the primary and secondary beams are H type, and the height is between 2m and 5m.

The construction difficulties of large-section structural beams are as follows:

a) The structure beam volume is large, the section is large, the resource organization is difficult. There are about 13 cross section types of major and secondary beams with huge cross section, with a total of 382 structural beams. The one-time casting of concrete will lead to the concrete vibration curing difficulty and affect the quality of concrete.

b) Complex construction environment. The concrete pouring of the 16-meter platform cannot be carried out directly in the 100-meter deep pit with sky pump, and the construction space of the facade is limited.

According to the characteristics of the project and the conditions of the construction site, the primary and secondary beams are all cast by stacking method. In the pouring process, a large distributing machine is used to replace the pump, and the vertical distance of concrete pumped upward is up to 60m[4]. In the process of stacking construction, the poured lower concrete can be used as the support system to bear part of the weight of the superstructure and reduce the burden of the lower support system. The stack construction technology can reduce the one-time concrete pouring amount and effectively ensure the stability of the lower support system. At the same time, the turnover of people, materials and machines can be effectively carried out according to the site conditions, so as to solve the problems of large beam section, limited construction site and difficult construction support to a certain extent.

2.2. Numerical simulation analysis

Due to the large section height of the primary and secondary beams, considering the site conditions and construction safety, the concrete cannot be cast in one time. According to the height division principle of "main beam is divided into three layers and secondary beam is divided into two layers", the stacking construction technology is adopted for the pouring.

In this paper, the construction process of composite beam with large section i-type simply supported beam is simulated by nonlinear finite element method. The finite element simulation parameters are shown in table 1 below. Separate method was adopted to establish each component, and steel cushion blocks of 1500mm×1000mm×500mm were respectively arranged at the support. The steel bar is Embedded into the concrete by the Embedded Region command. ABAQUS finite element software was used, and the finite element model was shown in figure 3.
Table 1. Finite element simulation parameter table

| Model parameters | Values                                               | Note |
|------------------|------------------------------------------------------|------|
| Concrete         | C40                                                  |      |
|                  | Cross section type                                  | H4000×1500×700×500 |
|                  | Protective thickness                                | 50mm |
|                  | Level 3 reinforced                                  | T3D2 |
| Reinforced       | Reinforced type                                      |      |
|                  | C16@100/150(4)                                      |      |
|                  | 16C32;30C32 9/21                                    |      |
|                  | G2C22@150                                           |      |

In ABAQUS, life and death units were used to simulate the two-stage manufacturing and secondary stress processes of composite structures. The simulation results of integral cast beam and composite beam are shown in figure 3 below. For the whole cast beam, the concrete stress is tensile stress and increases linearly. For composite beams, the compressive stress on the top of the composite surface increases first, and after reaching a certain value, it will no longer increase, but gradually decreases, forming "load prestress". Casting large section beam by superposition casting method can effectively prevent the occurrence of cracks in the later use stage and improve the bearing capacity of the beam.
2.3. Stack construction technology

The pouring scheme of stacking construction is as follows: After the first layer of concrete meets the strength requirements, the second layer of concrete is poured. The lower support system only bears the dead weight and construction load of the first layer concrete, and the construction load is shared by the deformation of the first layer concrete and support system. After program design and program numerical simulation analysis, the layered heights of each primary and secondary beam are shown in table2 below.

| Stratification height | Casting parts    | Time control                  | Schematic diagram |
|-----------------------|------------------|-------------------------------|-------------------|
| First layer: 2m       | Lower wing plate, web | ---                           | ![Schematic Diagram 1](image1) |
| mSecond floor: 1.5m   | Web              | After the first layer is poured for 28 days | ![Schematic Diagram 2](image2) |
| Third layer: 1.5m     | Upper flange, web | The second layer was poured for 28 days | ![Schematic Diagram 3](image3) |

When pouring the second layer of concrete, attention should be paid to it. The web concrete is cast in a stepped manner. In order to avoid the phenomenon of honeycomb and other non-compactness of the concrete at the beam end, the material is poured from the other end to the opposite direction. Close at 2 ~ 3m from the end, and the method continuously pours. It can avoid segregation caused by excessive flow of concrete in the process of vibration.

![Concrete strain curve along with the change of time](image4)
2.4. Construction effect
In this paper, the superposition construction technique is used to carry out the flowing water construction. After pouring, the concrete surface did not appear honeycomb surface, forming effect is good. The molding effect of concrete beam on site is shown in Figure 4.

![Figure 4. Construction Effects of Concrete Pouring](image)

3. Conclusion
In super large reinforced concrete structures, especially in large span and deep foundation pit projects, the construction of giant beam sections in such structures is not only difficult, but also difficult to implement quality control. This paper takes the ice and snow world project under the construction condition of 100-meter deep pit as an example. The construction technology of prestressed reinforced concrete composite beam is introduced. The paper innovatively solved the construction problems of the super-heavy beam and super-high support mold in the 100-meter deep pit of the ice and snow world. Superposition technology can effectively reduce the input of the lower temporary high support mold system, improve the field construction efficiency and reduce the cost of the project. It ensures the safety of box girder construction process and has certain social benefits, which can provide reference for similar projects.

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