Study on Detailing Design of Precast Concrete Frame Structure

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Abstract. Taking a certain precast concrete frame structure as an example, this paper introduces the general procedures and key points in detailing design of emulative cast-in-place prefabricated structure from the aspects of structural scheme, precast element layout, shop drawing design and BIM 3D modelling. This paper gives a practical solution for the detailing design of precast concrete frame structure under structural design codes in China.

1. Introduction

For precast concrete structures, it is time and energy consuming to correct the design errors during construction stage. The detailing design, therefore, is compulsory and profound for time limit and cost reasons. The traditional detailing design based on CAD software is insufficient and error-prone, and even worse, is of high cost. BIM technology is better at detailing design, finding and solving problems in advance and increasing the construction efficiency. The development of BIM technology and commercial software makes it possible to apply BIM software in large scale and increase detailing design efficiency. The application of BIM technology in precast concrete structure, although under exploration currently, is of great practical value [1]-[3].

By the introduction of the detailing design of a five-story concrete frame office building, this paper summarizes general procedures and key points in detailing design as a reference for similar projects. Figure 1 shows the assembled 3D model and overall picture of precast elements in this project.

2. Key technology of detailing design

2.1. Structural scheme

In the preliminary design stage, architects and structural engineers shall work collaboratively for a structural scheme suitable for industrialized construction. Some adjustment, even compromise, is necessary [4]. For example, the dimensions of column grids and precast element sections should be uniform, and precast elements with irregular section shall be avoided for maximum use of molds. Emulative design principle [5], which means the structure has similar performance as cast-in-place concrete structure, is adopted in structural design for this five story project, and the beam column joint, together with the upper layer of composite beam and slab is cast-in-place. The structural analysis methods and procedures are the same as traditional cast-in-place structures. Some measures are taken in...
detailing design to guarantee emulative performance. The detailing design is conducted on the commercial BIM software Revit 2016.

Figure 1. 3D model and general view of precast member

2.2. Precast element scheme
Standardize the products and minimize element types to increase the turnover efficiency of molds and reduce cost. The precast element scheme must take into consideration the crane capacity, dimension of pedestal and limitation of transportation comprehensively. The prefabricated concrete elements include all the composite beams, columns, composite slabs, cladding panels, staircases and sun shield plates. In this project, the column is precast at each story and the beam is prefabricated at each span. Concrete at the joint region and the upper layer of beam and slab are cast-in-place. According to the architectural scheme, the cladding panel is separated by story height and each element is no more than 2m in width (figure 2).

Figure 2. Cladding panel

2.3. Key points in detailing design of precast elements
The main beam is composite, and the height of cast-in-place concrete layer is 150mm for middle beam and that of boundary beam is 300mm due to the protruding bar of cladding panel (figure 2). Key slot is designed at beam end to increase the vertical shear capacity. For precast main beam, the stirrup is enclosed in dense hoop reinforcement area and open end in other area. For secondary beam, the stirrup is all open end (figure 3). To adjust construction error, the horizontal distance between the boundary of the main beam and the secondary beam is 15mm horizontally, on each side. The main beam is 10mm over the boundary of precast column in horizontal direction, and the bottom of composite beam lies on the top surface of the precast column.
The composite slab is separated by each beam, and some of them are separated once again for stiffness consideration. The thickness of slab is 150mm, with 70mm precast layer and 80mm cast-in-place concrete. Stretching rebar at the end of precast slab is abridged to simplify the mold and increase construction efficiency. The truss bar evenly distributed in the slab is used to reinforce the element under lifting and transportation conditions (figure 4).

The position conflict of protruding rebar at joint region is unacceptable. The avoidance of position conflict must follow strict rules. Uniform section and rebar diameter is desirable, and the longitudinal rebar of precast column shall be concentrated at the four corners to spare space for beam rebar. The relative position between beam and column involves two types, one is axis aligned and the other is boundary aligned, and the position of stretching rebar at beam end should be adjusted accordingly (figure 5). The precast column is optimized to one kind, with the same section and reinforcement. The stretching rebar of precast beam is reduced to three kinds by optimization, and full use of boundary mold for precast beam was fulfilled. The reinforcement avoidance in perpendicular direction is fulfilled by modifying the beam height or curve the rebar in the precast beam in advance.

According to Chineses seismic design code [6], the ratio of reinforcement at the bottom and top of beam end, should be no less than 0.5 for seismic design grade 1 and 0.3 for seismic design grade 2 and 3. For the convenience of joint construction and reinforcement avoidance, the rebar stretching the beam end should be as few as possible. Rebar with large diameter is adopted for main beam. The secondary beam is void of stretching rebar, but structural steel instead, and fits into the groove in the main beam. Such a detailing fulfills the assumption of hinge joint between main beam and secondary beam (figure 6).
The staircase elements include stair tread, slab and partition wall. Generally, due to vertical clearance and functional demand, the height of the first story is different from the other stories. A cast-in-place stair flight is designed on the base to standardize the precast staircase elements.

2.4. Serial number management

The general information of precast elements includes: material, dimension, reinforcement and location. The name of a precast element should be concise, expressing its key features. Elements with various detailing should be named differently, for the convenience of merging, detailing design and account.

To prevent construction errors, a single serial number should be given to an element if any of its detail, such as dimension, reinforcement or embedded part, is different from the others. Special attention should be paid to built-in fittings that are used for lifting, installation and transportation, such as reserved hole, distribution box and wire box in cladding panel and interior partition wall. In addition, some special requirements, for instance, lightning protection steel in precast column, must not be neglected.

A certain type of precast element should be named separately and all the detailed information shall be manifested on a separate drawing. The detailed information include all the views, sections, position, material, cutting dimension of steel rebar, etc., to visualize all the detailing.

2.5. Model check

At the end of the detailing design stage, the integrated 3D BIM model shall be established, and the family for each element shall be loaded to check the detailed information, including dimension, location, embedded part, etc. Common errors include reinforcement collision, absence or malposition of
embedded part. Due to the principles and general rules adopted at previous steps of detailing design, the adjustment in this procedure is local and has little effect on the scheme.

3. Conclusion and Suggestion

This paper summarizes the general procedures and key points of detailing design for emulative cast-in-place concrete frame structure, and provides a practical solution for similar projects. The application of BIM technology and software in structural detailing design can solve construction problems and correct design errors in advance, which is beneficial to efficient construction.

Further study is still urgent in some aspects. For instance, better performance can be expected with the cooperation of the architect and MEP engineers. What’s more, standard family stock and element information database should be established, to increase detailing design efficiency. Further study to simplify the beam column joint detailing is required for reinforcement avoidance and to increase mold efficiency.

References

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