Design and Construction without Deformation Joint of a 15,000 Square Meters Huge Concrete Non-beam Floor-slab Structure

Xian-hong XU

ABSTRACT

Combined with an engineering practice, this article analyzes the selection of concrete floor structural scheme, through qualitative or quantitative analysis and comparison among composite structure, non-beam structure and grid-beam structure in three aspects including schedule, cost and operating requirements. It introduces the no deformation joint design of the practice, which is a huge concrete non-beam floor structure of 15,000 square meters, by comprehensively applying post-pouring band, expansion reinforcing band, shrinkage-compensating concrete and non-bonding pre-stressed. According to the practice, the paper also summarizes the construction key-points in some aspects covering construction organization, concrete mix-proportion, construction process, shrinkage-compensating concrete and un-bonded pre-stressed works.

INTRODUCTION

There is temperature and shrinkage deformation in the hardening process of concrete, this phenomenon is apt to cause cracks of concrete structure. The serious cracks may reduce the integrity and durability of concrete structure. In order to solve this problem, traditional measure is setting deformation joint. But this measure is usually in contradiction with building’s utility demands, elevation effects and water-proof works. The ultra-long concrete structure which is no deformation joint was more and more applied to engineering practice in recent years, and many new construction technologies have been widely used too, such as shrinkage-compensating concrete and un-bonded pre-stressed etc.

Generally, the aims and demands of different project in schedule, cost and operating requirements are also different, so the selection of structure scheme is very important. At the same time, application of ultra-long concrete structure which no deformation joint and some new technologies put forward more higher requirements on construction activities. Author was lucky to take part in the practice of design and

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construction activity in a similar project, and now make a brief summary in this paper for reference to other similar projects.

BRIEF PRESENTATION OF THE ENGINEERING EXAMPLE

Mingtang Market located in the center of one city; its first floor and second floor are aggregate market, and its three to five floors are office places. Its total building area is 42,461 m²; the first floor of which is 15,001 m² and second floor is 15,518 m². The outline of its first floor and second floor like an irregular trapezoid, the length is 154 m, width is respective 141 m and 81 m (as shown in Fig. 1). Its column network dimension is 9 m × 9 m (partially 12 m × 12 m). The architectural design of which didn’t set deformation joint, so it’s a typical ultra-long and ultra-large area, no deformation joint building.

The project was demanded starting on July 6, its owner also strongly required the market open for business on next New Year's Day, so its days for construction is very urgent (It means that we must complete the construction task of 30,000 m² inside 179 days). And the construction place is extremely small, the project only covers an area of 18,500 m².

The project’s features above-mentioned put forward higher requirements on both structure design and construction activities.

![Diagrammatic sketch of the engineering practice](image)

**Figure 1.** Diagrammatic sketch of the engineering practice

Note: ① Light well, ② Post-pouring band, ③ Expansion reinforcing band.
1, 2, 3, …, 10 Construction sections.

SELECTION OF STRUCTURE SCHEME

According to the owner’s requirement, the primary goal is guaranteeing working period, secondly reducing cost and satisfying the use requirement as possible, so these three aspects are main contradictions of the selection of structure scheme. Because of the good geological conditions, the foundation selected single foundation under column which can accelerate construction speed. For the first and second floor-slab, which are ultra-long, large-span and no deformation joint, the pre-stress technology was used, and then selected the scheme of no-beam floor-slab structure after analysis and comparison among three alternative schemes.
THREE ALTERNATIVE SCHEMES

Scheme 1: Composite structure system, that composed of high effective pre-stressed concrete precast beam and thin-slab which as the bottom support and cast-in-place reinforced concrete.

Scheme 2: Non-beam structure system, it’s a slab-column frame structure, the top of column enlarged into column cap.

Scheme 3: Grid-beam structure system, the floor structure composed of small-distance grid-beam system and floor-slap.

COMPARISON AND ANALYSIS

Through methods of qualitative or quantitative, we analyzed and contrasted above-mentioned three alternative schemes in three aspects including time-limit, cost and operating requirements.

Analysis of Time-limit

Scheme 1: The precast element produces in factory, and the foundation and column can be constructed at the same time in construction site. After the hoisting works of precast beam and thin-slab is completed, we can immediately carry out the brickwork, installation works, etc. Contrasted with ordinary structure, the construction period can be accelerated as much as 20%, so this scheme can easily satisfy the requirements of the construction period.

Scheme 2: Before the pre-stress tension, concrete must have achieved 75% design strength, and the formwork can’t be removed before tension. Because of this, brickwork and installation works would be delayed, but in non-beam floor structure, formwork and steel-bar works are simple, so the construction period of common reinforced concrete can be shorten. By enhancing construction organization and management, we can still satisfy the requirements of the construction period.

Scheme 3: The formwork and steel-bar works of grid-beam structure are very complex, and there is also the work of pre-stress tension. So the construction period will be longest, and difficult to satisfy the requirements of the construction period.

So the best is scheme 1, scheme 2 is also better, and scheme 3 is worst.

Analysis of Cost

Both the cost of engineering entity and construction investment were considered in the analysis of cost.

1) Cost of engineering entity

According to the past engineering experience and estimation, the cost of pre-stressed works had no obvious change. Excepted pre-stressed works, the costs and comparison result of three schemes above-mentioned were shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1. COST OF ENTITY AND COMPARISON RESULT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme 1</td>
</tr>
<tr>
<td>Cost [CNY/m²]</td>
</tr>
<tr>
<td>Comparison result</td>
</tr>
</tbody>
</table>

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2) Construction investment

According to the owner’s time-limit, through preliminary construction deployment, we obtained the main construction investment of three schemes as follows:

Scheme 1: We must lease 4 places as factory for producing prefabricated units, purchase production equipment 4 sets, and allocate enough special heavy platform truck. At the construction site, we need tower crane (Model is FO23/B or FO23/C) 4 sets. In this scheme, the investment of formwork and its support system is least in three schemes.

Scheme 2: We need 4 sets general tower crane whose arm-length is 50m, steel pipe Φ53 2,000t, fastening which number is 340,000, formwork 40,000m², 50mm×100mm wood brace 750m³.

Scheme 3: We need also 4 sets tower crane the same as scheme 2, steel pipe Φ53 2,000t, fastening which number is 340,000, plastic formwork shell 30,000m², formwork 15,000m², 50mm×100mm wood brace 280m³.

Considering the project locates in the center of city and construction place is very narrow, it’s very difficult to lease some place, so the best is scheme 2, scheme 3 is better and scheme 1 is worst.

3) Whether satisfying the use requirement or not

Scheme 1: The height of beam is larger, stalls separation would be limited, can’t satisfy the owner’s demands that they can arbitrarily separate no suspended ceiling.

Scheme 2: The under-surface of floor-slab is plain, so it can absolutely satisfy the owner’s wishes.

Scheme 3: Grid-beam also influence the separation arbitrary.

So the best is scheme 2, scheme 1 and scheme 3 are both worse.

DETERMINATION OF SCHEME

Based on above analysis and synthesized various factors, the orders of three scheme in comprehensive effect were obtained as follows: scheme 3 is worst because it can’t satisfy the required-time, in another two schemes each has itself advantages. In consideration of the restricted conditions in construction site and its environs, the final determination is scheme 2.

Finally, the project was designed as slab-column frame structure, the two-way post-tensioning un-bonded pre-stressed concrete non-beam flat structure were adopted in its floor-slab, whose depth is 250mm(280mm in partial).

TECHNICAL MEASURES IN STRUCTURAL DESIGN

We used synthetically technologies of post-pouring band, expansion reinforcing band, shrinkage-compensating concrete and non-bonding pre-stressed, and achieved the no deformation joint design of the project, which is a huge concrete non-beam floor structure.

Shrinkage-compensating Concrete

The shrinkage-compensating concrete can control the concrete cracks effectively. The project used UEA shrinkage-compensating concrete, its strength grade is C35,
and UEA mixing amount is 10% (the post-pouring band and expansion reinforcing band are C40, and UEA 14%).

**Technology of Post-pouring Band**

Applying post-pouring band, the concrete structure be divided into some small sections, which can effectively decrease the temperature and shrinkage stress, thus control the cracks. As shown in Fig. 1, the project has one post-pouring band in each of vertical and horizontal directions, which is 6m in width. Concrete strength grade of the band is C40, its pouring time must be postponed for one month than its two sides.

**Expansion Reinforcing Band**

The micro-expansion of concrete in expansion band can compensate the shrinkage deformation of its two sides, and reduce the cracks. As shown in Fig. 1, the project has one expansion reinforcing band in horizontal direction and two in vertical direction, their width is 2m. The concrete grade is C40. The designer permitted the pouring of expansion band at the same time with its two sides except for the second expansion band in vertical direction, which must be postponed for 14 days.

**Technology of Non-bonding Pre-stressed**

The pre-stressing technique can improve the strength and stiffness of the components, and is one effective measure in controlling deformation and crack of concrete. The two-way non-bonded pre-stressed technology was used in this project, pre-stressing tendon was 1860MPa, φ15.24 low relaxation non-bonded pre-stressed steel strand. Before the pre-stress tension, concrete must have achieved 75% design strength.

**KEY POINTS OF CONSTRUCTION**

**Construction Technology Process**

Floor formwork installation→ordinary steel bar installation in bottom of slab→non-bonded pre-stressed steel strand installation→ordinary steel bar installation in top of slab→concrete pouring of slab→concrete curing→tension of pre-stressed→removing formwork.

**Construction Organization**

1) For organizing flow construction and speeding up construction progress, based on the positions of post-pouring band and expansion reinforcing band, we divided the floor-slab into 10 sections (see Fig.1), and adopted the construction order of from 1 to 10.

2) For ensuring the quantity and quality of concrete supplying, we set up two sets automatic batching mixing system (JDY1000 Forced mixer) in construction site, they can produce concrete 200m$^3$ every day. And we planned to use two sets of concrete pump (HBT-60) for pumping construction of concrete.
Design of Construction Mixture Proportions

The proportion of UEA must be determined through restrained expansion rate test, and conform to the design and related standard. We adopted the double adding technology of high-effect water reducer and fly ash, which can reduce the amount of cement, improve concrete working performance, and achieve targets of fitting PCC (pumped concrete construction) and decreasing cracks. After mix-design and tests, the laboratory mix proportion is shown in Table 2.

<table>
<thead>
<tr>
<th>Strength grade</th>
<th>Dosage of each composition material [kg/m³]</th>
<th>Water</th>
<th>Cement</th>
<th>Sand</th>
<th>Gravel</th>
<th>Fly ash</th>
<th>UEA</th>
<th>Water reducer</th>
</tr>
</thead>
<tbody>
<tr>
<td>C35</td>
<td></td>
<td>175</td>
<td>335</td>
<td>712</td>
<td>1,063</td>
<td>56</td>
<td>57</td>
<td>2.53</td>
</tr>
<tr>
<td>C40</td>
<td></td>
<td>160</td>
<td>357</td>
<td>695</td>
<td>1,117</td>
<td>45</td>
<td>65</td>
<td>2.65</td>
</tr>
</tbody>
</table>

CONCRETE CONSTRUCTION CONTROL

Mix-proportion Adjustment

The construction activities were during the rainy season, so the concrete laboratory mix proportion must be converted into construction mix proportion according to the actual water ratio.

Mixing and Transport

Regular checking the working performance of machinery and equipment, to guarantee the material be mixed evenly. The mixing time should not be less than 90s. Using the soggy sackcloth to cover the pump-pipe for cooling when the air temperature is above 30 degree centigrade.

Concrete Pouring and Curing

For eliminating the original crack of concrete, the processes of secondary vibration before initial setting and secondary troweling before final setting has been adopted.

The curing is a critical activity for ensuring concrete strength, and more important insuring shrinkage-compensating concrete have enough volume expansion ratio. In practice, covering plastic film in time as soon as the secondary troweling is completed, arranging special person to water-cured concrete, and the curing time should not be less than 14 days.

Treatment of Construction Joint

The treatment of construction joint must strictly accord with design and code requirement. Before the concrete pouring of construction joint site, the joint surface must be chiseled, swashed, and smeared a layer of cement slurry or cement mortar which is the same composition with concrete. The concrete must be vibrated carefully in order to ensure the compatibility. By these measures above-mentioned make the new pouring concrete closely combined with the existing one.
Formwork Removing

Because the structural span is large, according to the code requirement, the bottom formwork can’t be removed before concrete strength reaches 100% and meanwhile the pre-stressed tension have been completed. In construction, we judged it by testing concrete samples cured under the same condition with building structure, which was made at the same time of pouring.

Un-bonded Pre-stress

1) Making the secondary deepening design, working out the special construction technology program, drawing the segmented installation drawing and the details of tension end, and determining the construction technology parameters, etc.

2) For ensuring the position and elevation of pre-stressed tendon, we used Φ14 steel bar holder as shown in Fig. 2.

![Steel bar holder sketch.](image)

3) The pre-stressed tendon can’t be stretched before concrete strength reaches 75%, we judged also by the same conditional samples.

4) Adopting the “double-control” pre-stressing technology of controlling the tension force as oriented and adjusting the elongation value at the same time.

5) Dividing four tension sectors in accordance with the position of post-pouring band, and adopting the symmetrical tension order from center towards two sides in each sector.

CONCLUSIONS

1) As being certified in this project, it is feasible that adopting the non-beam floor-slab without deformation joint by using un-bonded pre-stressed technology in ultra-long and large-span structure.

2) The successful accomplishment of a project needs reasonable design, elaborate construction organization and management.

3) The non-beam floor-slab can accelerate construction pace, shorten the construction period. At the same time, it can also reduce thickness of the structure and increase indoor headroom.

4) The un-bonded pre-stressed technology can increase structural stiffness and decrease the deformation, effectively control concrete cracks. Meanwhile, its construction is simple because of no needing setting-up hole and grouting.

5) The post-pouring band and expansion reinforcing band are effective measures for releasing the temperature and shrinkage stress, also for controlling the cracks.

6) The shrinkage-compensating concrete can decrease the deformation and control the concrete cracks effectively.
ACKNOWLEDGEMENT

This work was supported by the Scientific and Technological Research Project of Hubei Provincial Department of Education, China (Project Number is B2016276).

REFERENCES