Long-span Unbonded Prestressed Cast-in-place Hollow Floor Structure Construction Technique

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Abstract. The education and teaching comprehensive building project of Wuhan Institute of Technology covers a construction area of 30,346 m^2. According to the functional requirements, the lecture hall is a large-span cast-in situ concrete structure with post-tensioning unbonded prestressed hollow floor technology. The filling material of the hollow floor is LPM (the main material is polystyrene foam). In the construction process, targeted measures have been formulated in the aspects of material selection and construction technology, especially effective measures have been adopted in the aspects of anti-floating of hollow plates, linear fixation of prestressed tendons, cyclic grading tensioning of prestressed tendons, anti-rust of prestressed tendons, etc. The above measures have achieved good results through tensile testing and physical inspection of the main structure after the removal of the template. Effectively ensure the construction quality. Using this technology, the floor weight and beam structure size are greatly reduced, and good economic benefits are obtained, which is in line with the requirements of building industry policy.

Keywords: Unbonded prestressing; Hollow floor; LPM

1 Introduction

The construction project for the Education and Teaching Complex Building at Wuhan University of Engineering utilizes prestressed hollow floor technology for the podium auditorium's 1 to 1/6 axis and 2/L to P axis floor areas[1-4]. The hollow floor employs a structural technology known as "A hollow floor with a combination of filling rods and filling boxes" (Patent Number: ZL201010560553.4). The material used for filling the hollow floor is "A foaming material-filled box with a reinforced layer and grouting holes" (Patent Number: ZL201010554837.2). The total thickness of the floor is 500mm. In this project, to minimize the structural dead weight, filling boxes with

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reinforcing and isolation layers are used. These filling boxes are made of self-extinguishing flame-retardant polystyrene foam with a density of not less than 15kg/m^3. The filling box thickness is 350mm, and the reinforced concrete thickness is 150mm, with a strength grade of C40 P6.

This project utilizes unbonded prestressing tendons and adopts the post-tensioning method. Each set of prestressing tendons consists of 6 strands of 15.2mm diameter low relaxation steel strands spaced at 1150mm. The standard strength of the prestressing tendons is 1860*MP*a, and the design tensioning control stress is 1395*MP*a [5-9]. One end of the prestressing tendons is anchored, and the other end is tensioned, which may be located on one side of the floor slab. Upon completion, all tensioned ends of the prestressing tendons are embedded within the concrete and not exposed externally. After tensioning, the tendon ends, anchors, and wedges are coated with epoxy resin or anti-rust paint for corrosion protection. After successful inspection and acceptance, the ends are sealed with fine aggregate concrete or micro-expanding cement mortar [10].

2 Main Materials for Bond-Free Prestressed Hollow Core Slabs

2.1 Hollow Floor Slab

The KXB2 type fill box is a 1000×1000×350 thick polystyrene foam plastic fill box with reinforcement and isolation layers. The box body of the polystyrene foam plastic is self-extinguishing and flame-retardant, and it complies with the requirements of the 《Technical Specification for Hollow Floor Slabs of Cast-in-Place Concrete Structures》 (JGJ-T268-2012). As shown in Figure 1. Polystyrene foam (Expanded Polystyrene, abbreviated as EPS) is a lightweight high-molecular polymer. By adding a foaming agent to polystyrene resin, gas is generated, forming a rigid closed-cell foam plastic. The density of EPS is determined by the expansion ratio of polystyrene particles. The main material of LPM, polystyrene foam, has a density of 15kg/m^3, which falls into the category of medium density (12~18kg/m^3) polystyrene foam. This density of polystyrene foam not only provides greater rigidity but also offers good insulation, sound insulation, and flame-retardant properties (using flame-retardant materials).

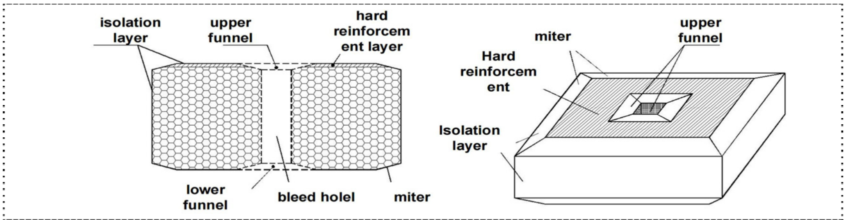


Fig. 1. Fill Box Sample

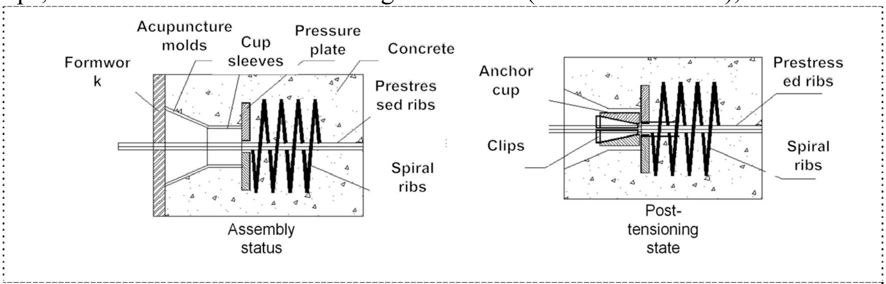
Prestressed reinforcementLPM filling material is a foam product molded from polystyrene beads. However, the specifications do not mention a specific service life for polystyrene materials. In general, under conditions without exposure to sunlight and water immersion, polystyrene hardly degrades, so it can be considered to have an extremely long natural lifespan under these conditions. LPM filling material is concealed within the cast-in-place floor, encased in concrete, and as such, it will not directly cause environmental pollution. It will last for the normal service life of the entire building structure.

2.2 Prestressed reinforcement

The "Technical Code for Unbonded Prestressed Concrete Structures" (JGJ409-2016) in Table 4.2.1 specifies the main mechanical parameters of commonly used prestressing tendons. These tendons have a nominal diameter of 15.2mm, an ultimate strength of 1860MPa, and a 1x7 steel strand structure with stable production quality. According to Article 4.1 of the "Code for Design of Prestressed Concrete Structures" (JGJ/279-2012), the unbonded prestressed structural system is suitable for roof applications. Therefore, this project selects prestressing steel strands of this type and employs the unbonded prestressing complete technology process, which involves applying lubricating and anti-corrosion grease to the strands and encasing them with plastic sheathing using specialized equipment.

2.3 Prestressing anchorage system

The prestressing anchorage system employs Type I anchorage equipment. The unbonded tensioning end features a single-hole wedge-type anchorage, consisting of a single-hole anchorage, anchor plate, hole mold, and threaded reinforcement. The anchoring end uses a extrusion anchor, comprising extrusion anchorage equipment, bearing plate, and threaded reinforcement. For specific details, please refer to Figure 2 for the prestressed tendon tensioning end and Figure 3 for the anchoring end node. The anchorage equipment and metal corrugated pipe comply with relevant regulations such as 《Steel Strand for Prestressed Concrete》 (GB/T5224-2014), 《Anchorage, Grips, and Connectors for Prestressing Tendons》 (GB/T14370-2015), and others.



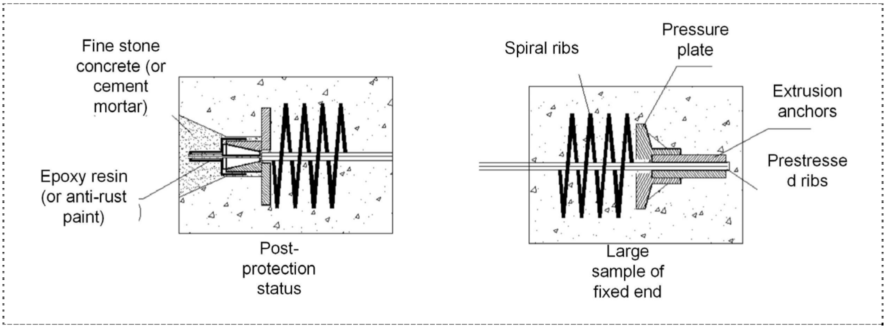


Fig. 2. Prestressed rib tension ends, anchor end nodes are large

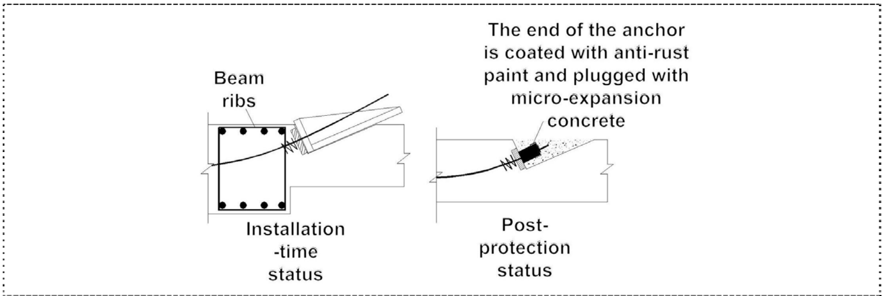


Fig. 3. Prestressed Reinforcement Plate Surface Tensioning Sample

3 Technological Advantages and Limitations

3.1 Technical Advantages

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The adoption of this plan can significantly reduce the weight of the structure, lower the structural height, reduce the dimensions of vertical components, improve structural performance, and also has advantages in speeding up construction progress, as well as insulation and soundproofing. The main advantages are as follows:

(1) Reduced structural weight: Compared to solid slabs, this hollow floor slab can reduce its own weight by approximately 35%, thereby reducing seismic forces correspondingly. Compared to traditional primary and secondary beam structures, its equivalent concrete thickness is roughly the same.

(2) Lowered structural height: Compared to beam-based structures, the hollow floor slab reduces the structural height by approximately 60%.

(3) The LPM main material, polystyrene foam, has a density of 15kg/m³, which falls into the category of medium-density (12~18kg/m³) polystyrene foam. This density of polystyrene foam has high stiffness and outstanding advantages in insulation, soundproofing, and flame resistance (using flame-retardant materials).

3.2 Limitations

While this technology offers the advantages mentioned above, it also has limitations. For significant public buildings, if structural modifications are required in the future, there is a higher probability of creating openings in the structure. Unbonded prestressing is not suitable for making structural openings, and even if openings are made, the construction process is intricate, significantly affecting the structural performance and posing safety risks during construction. Specialized construction teams are required for such work.

4 Construction Process

4.1 The prestressed hollow floor of this project's report hall is not divided into construction phases.

The scaffolding throughout the hall is set up with a longitudinal and transverse spacing of no more than 800mm×800mm and a step spacing of no more than 1800mm. After the construction of the lower framework columns and the staircase steel formwork of the floor is completed, concrete is poured first. After the side formwork is removed, the scaffolding is tied to the framework columns, with at least two tie points per column. After the floor formwork is properly installed and accepted on-site by the supervising engineer, the positioning lines for the hollow boxes and shear reinforcement are marked. After verifying their accuracy, the bottom reinforcement of the floor is tied, and the hollow boxes and prestressed steel bars are placed. Key Points for On-Site Steel Reinforcement Tying Control

The steel reinforcement design for this project uses HRB400 grade steel. For beams, columns, and floor reinforcement, specifications of Φ16 and above employ direct threaded connections, while specifications below Φ16 use tying and overlapping connections. The length of tying connections should comply with the design and the requirements of drawing 11G101. The main material for filling boxes is LPM, and these filling boxes are completely embedded in concrete. Even if the steel reinforcement is in close proximity to the filling material, it does not affect the durability of the steel or the mechanical properties of the hoop reinforcement. Therefore, when making ribbed beam hoops, the outer dimensions of the ribbed beam hoops are made equal to the width of the ribbed beam, ensuring that the hoops can effectively limit the horizontal movement of the filling material.

4.2 Filling Box Placement and Anti-Floatation Measures

For this project, standard-sized filling boxes measure 1000x1000mm. At each corner of the filling box, an anti-buoyancy point is installed, and an additional one is placed at the center of the filling box. In cases where non-standard-sized filling boxes are used, adjustments are made to increase or decrease the number of anti-buoyancy points as necessary. However, it is ensured that within every square meter, there are no fewer than 2 anti-buoyancy control points, and the maximum spacing between adjacent anti-buoyancy points is kept within 800mm. To install the anti-buoyancy control points, holes are drilled in the bottom formwork. Considering ease of operation and timely removal of drilling debris, hole drilling is performed when the formwork for the rib positions is just laid out. The layout of anti-buoyancy points on the plane is as shown in Figure 4."

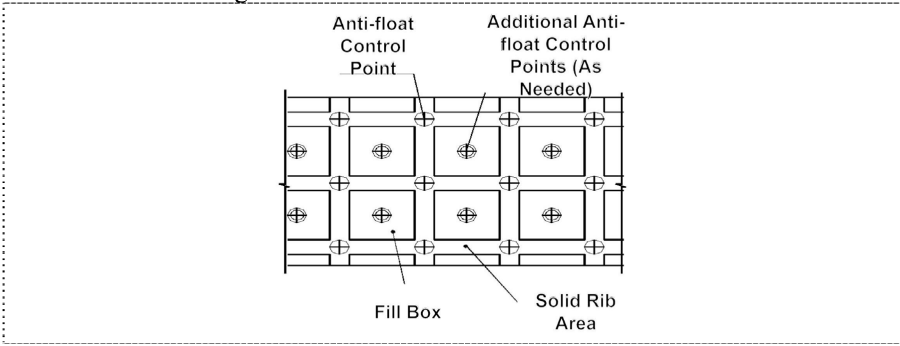

Fig. 4. Anti-Buoyancy Point Layout Plan

Prestressing, Anti-Corrosion, and End Sealing Treatment

(1) Conditions for Tensioning

Tensioning of prestressing bars can only be carried out once the concrete reaches the design-required tensioning strength. Tensioning can also be performed when the strength of concrete test cubes under the same conditions reaches 90%.

(2) Tensioning Equipment and Tools

YCN25 pre-tensioning hydraulic jacks are used for prestressing bars. An appropriate number of tensioning equipment is arranged based on the project quantity and progress. The tensioning equipment and instruments are managed and used by dedicated personnel, and they undergo regular maintenance and calibration. The control tensioning force value for individual prestressing bars is determined according to the design requirements, and its calculated elongation value is determined in advance. The jacks and hydraulic pumps used for tensioning are calibrated according to the design requirements.

5 Conclusion

In conclusion, the application of the non-bonded prestressed hollow floor technology in this project has yielded excellent results. Effective measures were taken during construction to address issues such as anti-floating of hollow slabs, fixation of prestressing tendons, staged tensioning of prestressing tendons, and rust prevention of prestressing tendons. These measures were validated through tensioning tests and thorough inspections of the main structural elements after formwork removal, ensuring a high level of construction quality. The non-bonded prestressed structure offers the advantage of ease of construction, and the hollow floor itself possesses notable characteristics such as low self-weight and excellent thermal and sound insulation properties. These advantages provide new solutions for addressing challenges in large-span structures, and hold significant potential for future development and widespread adoption. However, it is important to pay particular attention to the limitations of this technology when it comes to structural modifications and renovations in the later stages.

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