Research and Application of Fair-Faced Concrete Construction Technology for Three-Dimensional Curved Cantilever Structures: Postprint

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Date: 2017-11-06T00:00:00+00:00

Abstract

To address the challenge that traditional plywood formwork cannot be utilized to shape spatially irregular concrete structures, this paper proposes a construction technology for fair-faced concrete in three-dimensional curved cantilever structures. In this technology, the formwork system employs a composite steel panel and steel keel support assembly to resist deformation during construction. Irregular variations in the normal direction of the curved surface are accommodated through a precision steel panel cutting and splicing process. Computer-aided three-dimensional modeling is utilized for the detailed design, lofting, and fabrication of the steel keel framework, enabling the T-section steel keel assembly to accurately replicate non-uniform variations along its longitudinal axis. The inherent drainage holes within the framework are strategically exploited to provide additional reinforcement to the entire formwork support system, thereby ensuring smooth structural contour curves and meeting the stringent visual quality requirements for fair-faced concrete finishes.

Full Text

Research and Application of Construction Technology for Fair-Faced Concrete in 3D Curved Cantilever Structures

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Abstract

To address the problem that traditional plywood cannot shape spatial special-shaped concrete structures, this paper proposes a construction technology for fair-faced concrete in 3D curved cantilever structures. In this technology, the formwork employs a "steel panel" + "steel keel" support system to resist deformation during construction. Steel panel cutting and assembly techniques are used to address irregular changes in the surface normal direction. Computer 3D modeling is utilized for the detailed design, layout, and fabrication of the structural steel keel, enabling the T-shaped steel keel framework to accurately simulate irregular variations along the longitudinal direction. By fully utilizing the drainage holes of the structure itself to reinforce the entire formwork support system, this technology ensures smooth structural contour curves and meets the high-standard requirements for fair-faced concrete appearance.

Keywords: Special-shaped Structure; Formwork System; Fair-Faced Concrete; Construction Technology

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Introduction

In recent years, building shapes have become increasingly complex with highly free-form architectural expressions, posing significant challenges to construction. The Petal Art Framework project for the 2014 Qingdao International Horticultural Expo Theme Plaza (Figure 1 [Figure 1: see original paper]) is located in the northwestern section of the Qingdao Horticultural Expo site, covering an area of 40,000 m^2. The entire theme plaza consists of 20 petal-shaped structures, nine of which are reinforced concrete petal art frameworks. These are all spatial special-shaped cantilevered multi-curved structures with complex geometries, and the interior surfaces of the petal art frameworks are required to be fair-faced concrete.

Consequently, traditional plywood cannot achieve smooth transitions for special-shaped frameworks. It is essential to rationally select and design the formwork system, and strictly control formwork processing and installation to effectively manage the curvature accuracy of fair-faced concrete arcs and the misalignment of formwork joints, thereby ensuring concrete casting quality.

Addressing the characteristics and difficulties of this project, steel panel cutting and assembly techniques are employed to effectively solve the problem that traditional plywood cannot shape spatial special-shaped concrete structures, playing a crucial role in fair-faced concrete formation. Furthermore, to address irregular variations along the framework' s longitudinal direction, detailed design of the framework keel was conducted, and T-shaped steel keels were fabricated to simulate these variations.

1. Template System Selection and Design

1.1 Construction Process Flow The construction process follows this sequence: detailed drawing refinement → positioning and layout → main steel keel installation → secondary keel installation → panel installation → steel tube support.

1.2 Computer-Aided Detailed Design of Steel Keel Before steel keel installation, framework drawings are studied and the structure is divided into 50 cm segments in CAD. The geometric dimensions of formwork and tie rod lengths are determined based on formwork installation and concrete construction processes. After determining steel formwork dimensions, strength and deflection calculations are performed to establish panel thickness, backing rib selection and spacing, and tie rod positions and diameters. AUTOCAD software is then used to simulate positioning and installation, with layout drawings determined as shown in Figure 2 [Figure 2: see original paper]. Following detailed keel design, computer-controlled cutting is used to verify geometric dimensions of each component, as shown in Figure 3 [Figure 3: see original paper].

1.3 Positioning and Layout Due to the unique curved shape of the artistic framework and its location on sloped terrain with varying cross-section elevations, GPS positioning is adopted to improve layout accuracy. By locating the endpoints and arc vertices from the drawings, the main keel positions are determined to ensure the final structure matches the design.

2. Template System Installation

2.1 Main Steel Keel Installation After fabrication in the factory, main steel keels are delivered to site. Before installation, temporary supports are erected and keel bottoms are welded to embedded chemical anchors in the foundation, as shown in Figure 4 [Figure 4: see original paper]. As each keel has different dimensions, they are numbered according to the layout drawings after fabrication to avoid installation sequence errors that would cause deviation from the original design. Main steel keel positions are checked and adjusted, then secured to pre-installed chemical anchors to prevent displacement during construction. After installation, adjacent main steel keels are connected with steel bars or rectangular tubes to ensure overall stability.

2.2 Secondary Keel Installation Secondary keels use 20$\times 20mm\times$2mm thin-walled square steel tubes spaced at 100 mm to prevent deformation during concrete pouring, welded at both ends to main steel keels. The top of thin-walled square tubes is flush with the main keel top for tight contact with the steel panel, ensuring integrated force distribution, as shown in Figure 5 [Figure 5: see original paper].

2.3 Steel Panel Installation Formwork panels use 1.5 mm thick steel plates in 1.00 m × 2.00 m sheets, laid along the keel direction and spot-welded to secondary keels. Panel cutting is based on 50 cm cross-sections to calculate developed area. During spot-welding, proper spacing is maintained to avoid excessive welding heat causing panel deformation and casting defects, while excessive spacing may cause grout leakage. Steel panel joints are kept $ $1 mm, sealed with tape if necessary to prevent leakage during concrete pouring.

2.4 Back Side Template Installation After fabrication, back side templates are numbered for orderly management and proper placement. Due to varying elevations on the back side, template configuration should match these changes.

2.5 Internal Steel Tube Support Before support system erection, the scaffold foundation is leveled with backfill compaction meeting code requirements. The ground must have proper drainage to prevent water accumulation and excessive moisture content changes. The support system utilizes drainage holes reserved in the framework base. Steel tubes are placed at angles consistent with these holes, locked inside and outside the framework with steel tubes and right-angle couplers (quantity determined by calculation). Wooden blocks fill gaps between tubes and drainage holes to prevent vertical movement. Main steel keel supports must be tightly braced, with diagonal supports ensuring accurate force transmission, as shown in Figure 6 [Figure 6: see original paper].

3. Economic Benefit Analysis

The 3D curved cantilever fair-faced concrete construction technology effectively solves problems of visible joints and misalignment caused by complex geometries, achieving aesthetically pleasing results and noticeable quality improvement. Main steel keels, detailed through computer 3D modeling and positioning, ensure the concrete structure matches the design intent. This approach establishes a new concept for special-shaped multi-curved concrete construction, providing reference for future applications of this technique.

Compared with new materials like glass fiber reinforced plastic formwork, the steel formwork method has lower material costs. Compared with traditional earth-forming or timber formwork, it saves significant labor. The resulting concrete finish is superior, avoiding post-casting repair costs. Construction duration is shortened, saving labor and equipment rental expenses. The project was completed 40 days ahead of schedule with 400+ workdays saved. Cost savings: labor 400\$ $\times 260 = 104,000 yuan; equipmentrental 5,400 yuan/day \times$ \$40 days=210,000 yuan. Total savings: 314,000 yuan.

References

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Note: Figure translations are in progress. See original paper for figures.