

CONSTRUCTION TECHNOLOGY FOR TALL INCLINED LARGE-DIAMETER CONCRETE CIRCULAR COLUMNS

JiaBing Xiang^{1,2}, YueQiang Cao^{1,2}, YueBin Zhang³, Yue Xu^{1,2}, XiaoXia Zhao^{1,2*}

¹China Construction Fourth Engineering Bureau Co., Ltd., Guangzhou 510000, Guangdong, China.

²China Construction Fourth Bureau Construction Investment Co., Ltd., Shanghai 200000, China.

³Satellite New Materials R&D Co., Ltd., Jiaxing 314000, Zhejiang, China.

*Corresponding Author: XiaoXia Zhao

Abstract: To meet the demands of architectural form and spatial layout, tall inclined large-diameter concrete circular columns are widely used in construction projects. Taking a project in Jiaxing as a case study, there are 26 inclined circular columns on the lower three floors and 14 on the upper three floors, with a maximum height of 13.9m and an inclination angle of 76°. To address the difficulties in inclination control, safety verification of formwork support scaffolds, and compaction control during concrete placement, a collaborative support system combining traditional disk-lock steel tubular scaffolds and steel wire ropes is adopted to ensure construction safety. The forming quality is guaranteed through real-time surveying and monitoring, concrete pouring techniques, and other measures.

Keywords: Inclined circular column; Formwork support scaffold; Construction technology

1 INTRODUCTION

With the development of the social economy and people's pursuit of high-level working and living environments, an increasing number of non-residential buildings are innovatively designed as special-shaped structures, such as circular and inclined forms. These designs break through traditional constraints, transform the urban landscape, and lead a new trend in the evolution of architectural aesthetics. In contrast to the previously prevalent box-like buildings with regular concrete frame structures, people now show a stronger preference for complex and distinctive special-shaped buildings, which enhance the quality of life [1-3].

Owing to their symmetrical and aesthetically pleasing appearance, circular structures have been applied in several landmark buildings, such as the first building of Chongqing Power International, the Hopewell Centre in Hong Kong Region (1980), and Suzhou News Building [4-7]. Although the cantilevered structures of circular buildings meet people's needs, special-shaped components such as curved beams and inclined columns significantly increase the construction difficulty [8-9].

This paper relies on the project of a local enterprise office building in Jiaxing. It analyzes the construction process of large-inclination concrete inclined circular columns within the project, and establishes a calculation model for the formwork support using specialized software. The study provides a formwork scheme with a high safety factor and a safety verification method for the construction of concrete inclined circular columns, offering a valuable reference for the construction of similar inclined columns.

2 PROJECT OVERVIEW

The project covers a total land area of 71089m² and a total building area of 171638.23m². The main structure is a composite of frame structure and steel structure, with six floors above ground and one basement floor. The architectural form of the project is circular and gradually expands floor by floor. To meet the requirements of the overall shape, 26 inclined circular columns are arranged on the lower three floors and 14 on the upper three floors around the periphery of the main building starting from the roof slab of the basement. The maximum height is 13.9m, the inclination angle is 76°, and the diameter of the inclined circular columns ranges from 1000mm to 1400mm. Therefore, the inclined circular columns in this project present three major challenges: tall height, large diameter, and steep inclination, see Figures 1-2.

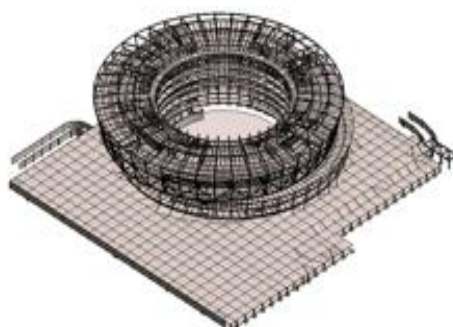


Figure 1 3D Model of the Project**Figure 2** 3D Model of the Inclined Circular Columns

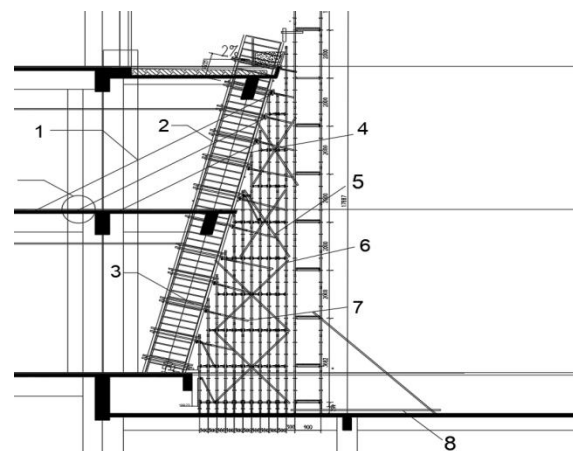
3 CONSTRUCTION TECHNOLOGY FOR INCLINED CIRCULAR COLUMNS

3.1 Inclination Control

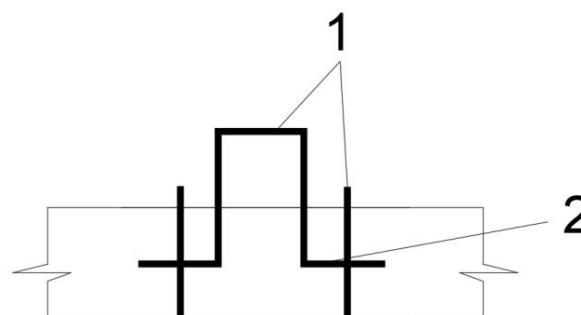
Given the large inclination angle of 76° , a method combining layered casting (each layer $\leq 3\text{m}$) and full-cycle tracking monitoring is adopted. A total station and a plumb bob are used to synchronously collect data on the inclination angle and mid-span horizontal displacement, covering all stages: before casting, during casting, and after the concrete has stabilized. The angle deviation is strictly controlled within $\leq 0.5^\circ$, and the horizontal displacement within $\leq 5\text{mm}$.

3.2 Formwork Support System

A collaborative support system consisting of socket-type disk-lock steel scaffolds and guy ropes is adopted. A rigid support structure is built with socket-type disk-lock scaffolds, and the base of the inclined column is fixed by embedded anchor bolts. The inclination angle is dynamically adjusted by combining with the guy ropes. For large-span inclined columns, inter-story formwork supports are added to form a composite support system with the existing external scaffolding, thereby enhancing the anti-overturning capacity, see Figures 3-4.

**Figure 3** Formwork Support System

Note: 1-steel wire rope; 2-wooden furring strip; 3-column clamp; 4-steel strap; 5-diagonal brace and debris net; 6-inclined tie rod; 7-inclined support; 8-kick brace; 9-tie-off point

**Figure 4** Wire Rope Tie-Off Node

Note: 1-anchored rebar; 2-anchorage depth $> 32d$

Since the diameter of the inclined columns is fixed on each floor, this project adopts customized timber formwork for circular columns. To ensure the strength and rigidity of the inclined circular columns and avoid formwork bulging and blowout, 18mm thick custom-made timber formwork is used. During construction, the formwork panels are laid with staggered joints and restrained by steel straps (30mm wide, spaced at 250mm). The outside of the timber formwork is reinforced with 35×85mm wooden furring strips and Ø48 steel tubes, see Figures 5-6.



Figure 5 Circular Column Formwork

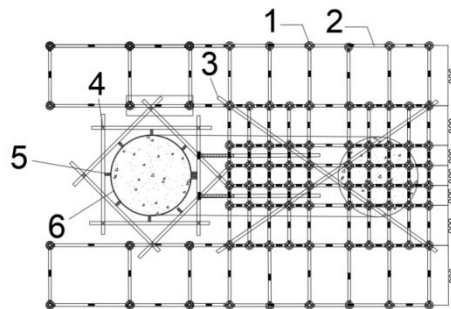


Figure 6 Formwork Plan of Inclined Column

1-disk-lock vertical standard; 2-disk-lock ledger; 3-diagonal brace; 4-coupler connection; 5-wooden furring strip; 6-steel strap + circular column formwork

3.3 Calculation and Analysis of the Support System

The calculation software used is MIDAS (a structural analysis and optimization design software specifically for civil engineering structures). The calculation and analysis are carried out for the first pouring stage, see Figures 7-8.

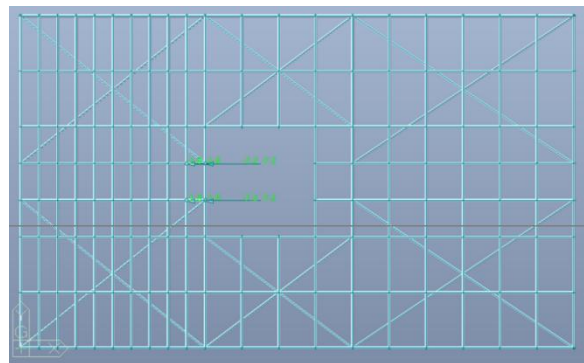


Figure 7 Plan of the Support System

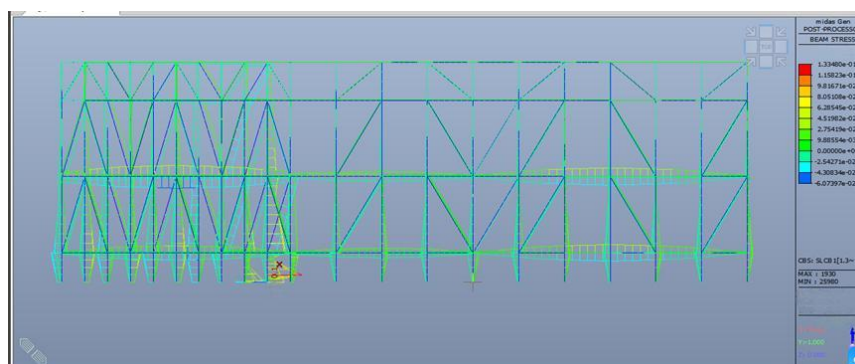


Figure 8 Stress Diagram

Calculation approach: The support system is divided into several units for separate checking. The slenderness ratio, plate width-to-thickness ratio, and internal forces of each unit are calculated, and then substituted into the formulas of the Chinese code GB 50017-2017.

Load combinations for stress verification (fundamental combinations):

Load combination No.-Combination name: Coefficient (Load case) + Coefficient (Load case) + Coefficient (Load case).

1sLCB1: Self-weight (1.300) + Inclined column (1.300);

2sLCB2: Self-weight (1.000) + Inclined column (1.000).

Load combinations for deflection verification (characteristic combinations):

Load combination No.-Combination name: Coefficient (Load case) + Coefficient (Load case) + Coefficient (Load case).

3sLCB3: Self-weight (1.000) + Inclined column (1.000).

Calculation analysis of the steel wire rope (Figure 9):

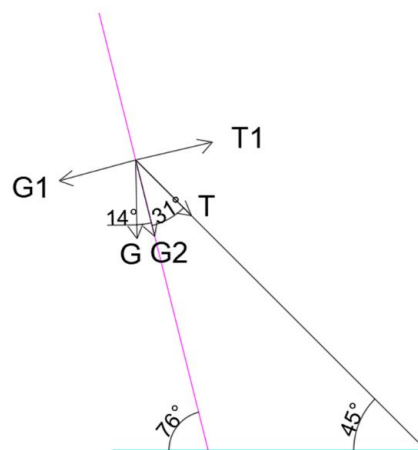


Figure 9 Simplified Diagram of Wire Rope Force Calculation

The calculation is performed with one guy rope set every 3m (the circular column is calculated based on the maximum diameter of 1400mm).

$G = 3 \times \text{circular cross-sectional area} \times \text{obtained load value}$, which is then substituted into $T = 0.46G$.

The safety factor for the guy rope is taken as: $K = 3.5$.

The breaking tensile stress of the wire rope is: $P = 3.5 \times T < \text{the breaking tensile stress of the wire rope}$.

3.4 Quality Control

The inclined column casting is carried out in two layers, with each layer not exceeding 3m in height and an interval of more than 20 minutes between layers. High-fluidity concrete is used to ensure compaction. The concrete formwork system is monitored throughout the process using plumb bobs and a total station. Combined with the finite element model to predict the load transfer path, the layer interval time and vibration parameters are optimized. Simultaneously, the concrete temperature is monitored in real time, and the hydration heat data are fed back instantly to keep the internal-external temperature difference within 25°C, thereby reducing the risk of cracking.

At the contact position between the bottom formwork and the ground, 10mm thick M10 cement mortar is used to fill the gap to prevent leakage during concrete casting, which could cause loss of concrete and moisture and affect the forming quality.

At the connection node between the column side formwork and the disk-lock scaffold support, the sequence from inside to outside is: column formwork-steel strap-wooden furring strip-double steel tubes-inclined support. The steel straps are spaced at 250mm. The wooden furring strips are of 35×85mm section, and the coupler-type steel tubes are double tubes of Ø48×3mm. The inclined support member is composed of Ø48 steel tubes and a U-head jack, and is connected to the disk-lock scaffold by couplers with at least 2 connection points.

For the guy rope tie-off, a U-shaped rebar of Ø20mm is pre-embedded and reinforced with two Ø10mm rebars. The inclined column and the pre-embedded tie-off point are connected by a guy rope. The wire rope and the pre-embedded tie-off point are fixed with rope clamps, with the number of clamps not less than 3. The length from the wire rope end to the first clamp must be greater than 120mm, and the distance between clamps must be greater than 6 times the wire rope diameter.

4 CONCLUSIONS

Based on the construction practice of the tall inclined large-diameter concrete circular columns in an office building project in Jiaxing, this paper addresses the construction challenges of 76° large-inclination and 13.9m high inclined circular columns. A complete set of construction technologies is established, integrating inclination measurement and control, a composite support system, finite element safety verification, and whole-process quality control. A collaborative support scheme combining disk-lock steel tubular scaffolds and steel wire rope guy ropes is adopted, together with

multiple reinforcement measures for customized circular column formwork. Specialized calculations for the forces on the scaffold and steel wire ropes are completed using MIDAS software. At the same time, quality measures such as layered casting, real-time displacement monitoring, bottom sealing of columns, and temperature-controlled crack prevention are implemented to precisely control the inclination deviation and horizontal displacement of the inclined columns, effectively solving problems like overturning, formwork bulging, leakage, and cracking of high inclined columns. This construction method is safe, reliable, and ensures controllable forming quality, providing a complete technical reference for the construction of similar large-size inclined circular special-shaped structures.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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