Research on Construction of Double Curved Deformation Straight-line Twisted Surface Ceramic Plate Curtain Wall Based on BIM Technology

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Abstract. In recent years, with the increasing awareness of energy conservation and environmental protection and the development of the construction industry, the requirements for exterior wall structural systems and construction materials have become increasingly high. Traditional ceramic panel curtain walls are mostly designed with flat surfaces, which makes it difficult to achieve hyperbolic deformation effects. Based on this, this article analyzes the hyperbolic deformation construction of twisted ceramic panel curtain walls based on BIM technology, and studies key construction technologies such as the characteristics of curved ceramic panel curtain walls, deepening of main keel deformation, three-dimensional adjustment of aluminum alloy pendants, and hyperbolic measurement and setting out. The hyperbolic deformation construction of ceramic panel curtain walls has been achieved, accumulating experience for other similar projects.

Keywords: BIM Technology, Hyperbolic curtain wall, Straight twisted surface, Panel warping optimization, Keel optimization.

1 Introduction

With the development of the building curtain wall industry, the types and functions of curtain walls are constantly enriched, and the construction industry has put forward higher requirements for them, not only considering practicality, but also considering the aesthetic appearance and design sense [1]. As a type of curtain wall, hyperbolic curtain wall has unique advantages in the construction industry. It can enhance the spatial and hierarchical sense of buildings, increase structural strength and stability, and enhance sustainability and energy-saving effects, improving ventilation, lighting, and energy consumption efficiency of buildings [2-3]. Although curved curtain walls have obvious advantages, there are also certain challenges, which are relatively difficult in

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the actual construction process. The production and installation of panels require high accuracy and professional technology to ensure the stability of the structure [4-5].

With the development of BIM technology, its application in architecture is becoming increasingly widespread, throughout the entire lifecycle of buildings, improving design efficiency and reducing construction costs [6-8]. In curtain wall construction, it can solve problems such as low positioning accuracy and construction collision of curved curtain walls, not only improving the construction quality of curtain walls, but also improving the aesthetics and forming quality of curtain walls [9].

Based on this, this article takes the projects of Guangzhou Art Museum, Intangible Cultural Heritage Exhibition Center, and Literature Museum as examples to explore the application of BIM technology in the construction of hyperbolic deformation straight grain twisted surface ceramic panel curtain walls.

1.1 Project Introduction

A cultural venue project in Guangzhou stands on the south bank of the Pearl River. Under the design concept of "cultural giant wheel, time arcade, goose pool freehand brushwork, and Yunshan artistic conception", a large number of ceramic materials with rich cultural heritage are used for the facade building materials. The surface of ceramic materials is coated with white glaze, which is gentle and slightly refracted in the river-side water, forming a sparkling skin texture. Through the treatment of opening slices, ice cracks form on the surface of ceramic materials, enriching the details and cultural connotations of the material.

The northern side of the project connects the venue buildings into a whole through a three-dimensional time arcade. At the same time, the Time Archway uses wavy ice cracked white glazed ceramic plate material, connecting history and modernity through hyperbolic gradient, and constructing a cultural expectation of the old city's new scenery.

The building curtain wall at the time arcade of this project is a wavy ceramic panel curtain wall system, with honeycomb aluminum panels designed on the indoor side. The overall effect is shown in Figure 1. The curtain wall adopts a hot-dip galvanized steel column support system, and the system is connected to the main structure using a three-dimensional adjustable connection method. The panel is a 60mm thick wavy white glazed ice cracked ceramic plate, with a length specification of 500mm (width) x 2000mm (length). The entire arcade spans 230m, achieving a height gradient and hyperbolic deformation of 13m to 22.5m along the horizontal direction. The maximum warpage value of this system's ceramic board is 35mm, and the ceramic board cannot achieve cold bending and deformation adaptation like glass, making it difficult to construct the facade effect.

In the construction project of hyperbolic curtain walls, due to the complex shape, optimization is difficult [10-11]; In order to achieve a hyperbolic effect, a large number of ceramic plates are required, it is difficult for ceramic plates to avoid warping, which directly affects the quality of construction [12]. However, there are certain challenges to the analysis of panel warping; Due to the curved construction, there are certain difficulties in positioning and installing the panel. To ensure installation accuracy, the

installed pendants can be fine tuned [13]. This article conducts relevant research based on BIM technology, as shown below.

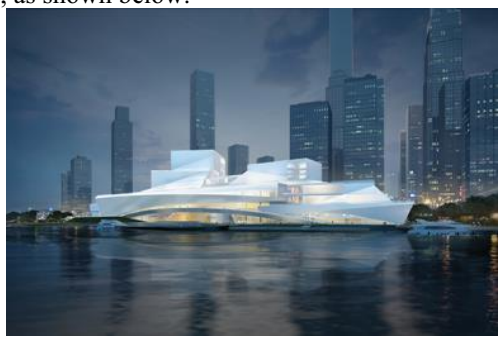

Fig. 1. Overall effect of cultural venues.

2 Construction technology

As shown in Figure 2, the ceramic plate is a rigid material. To achieve the hyperbolic torsion surface effect, BIM technology is used for parameterized modeling to analyze the warpage of the hyperbolic ceramic plate curtain wall panel and determine the warpage value of the panel; By using the method of 'replacing curved panels with straight ones' and based on panel warping data, deepen the processing and transfer of steel components to control the entry and exit of the panel, set up plug-in hooks to control the installation elevation of the ceramic panel, and subdivide the vertical panel installation to achieve a hyperbolic gradient effect.

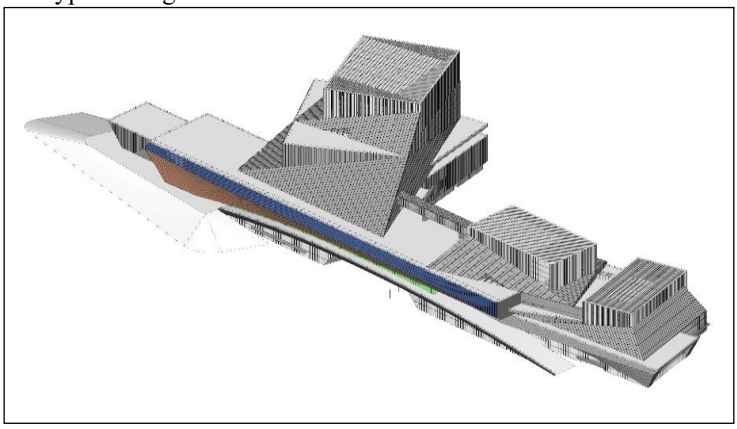

Fig. 2. Effect drawing of the hyperbolic deformation straight-grained twisted surface ceramic plate curtain wall.

2.1 Process flow

The construction and installation process of hyperbolic deformation straight grain twisted surface ceramic panel curtain wall is shown in Figure 3, mainly including pre deepening construction preparation based on BIM, system component installation, and process acceptance review, ultimately achieving good surface effect and functional performance of the curtain wall system.

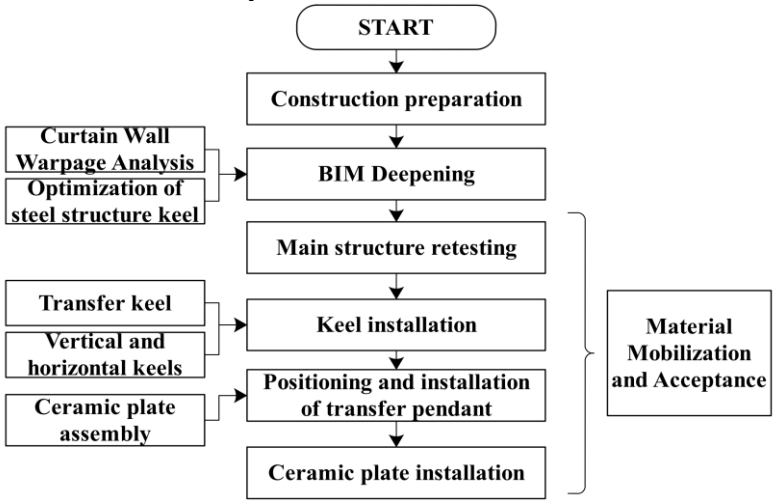

Fig. 3. Construction technology process of the hyperbolic deformation straight-grained twisted surface ceramic plate curtain wall.

2.2 Deepening Based on BIM Technology

The curtain wall in this construction is mainly composed of curved ceramic panels and steel structural keels. BIM software is used for parametric modeling and analysis, and Revit and Rhino are mainly used to establish a basic model. After generating the model, the Grasshopper plugin is used to render the exterior skin and optimize the surface [14]. Based on the characteristics of curved ceramic panels, the shape, size, and warping value of each ceramic panel surface are determined through optimization analysis of the skin grid and surface, to ensure that the ceramic panels can accurately adapt to the design requirements of curved curtain walls, as shown in Figure 4. Based on the characteristics of the steel structure keel in the curtain wall, a hyperbolic rhinoceros curtain wall skin model is established. The surface effect is formed by accurately setting out the positioning data of the steel structure main keel through the skin model. At the same time, the shape and layout are optimized based on topology optimization technology to reduce structural weight and construction costs.

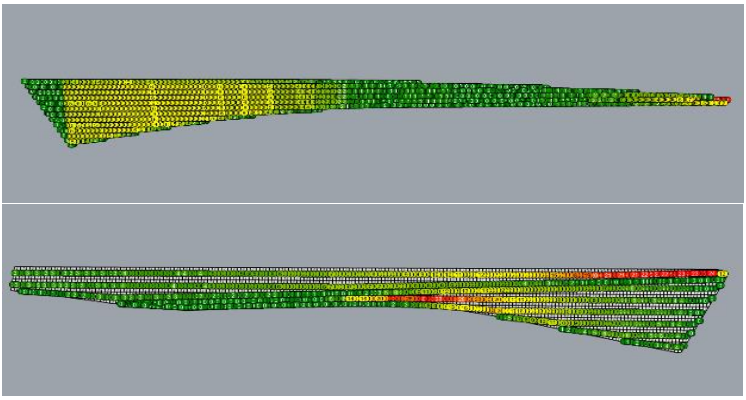

Fig. 4. Analysis of ceramic plate warpage.

2.3 Main structure retesting and verification

According to the coordinate points, elevation points, and axis positions given in the curtain wall construction drawing, use measuring tools such as level gauges and total stations to provide fixed points, columns, grids, and corners on the main structure, and conduct calibration and retesting.

The measurement and setting out of the curtain wall grid axis should be coordinated with the measurement and setting out of the main structure. The horizontal elevation should be measured layer by layer from the ground to avoid error accumulation. The error should exceed the specified allowable deviation, including the vertical deviation value, if it exceeds the adjustable error range of the curtain wall.

Simulate and analyze the measurement data of the main structure and the warping data of the 3D ceramic panel curtain wall through retesting, providing processing dimensions for the next step of the curved curtain wall transition keel processing.

2.4 Installation of Keels

The keel of the curtain wall can reflect the shape changes of the exterior facade of the curtain wall. BIM technology is used to quickly calculate and analyze the curvature and chord height in the keel curve. Combined with the main structure retest data, the processing dimensions and installation positions of the transition keel, vertical keel, and horizontal keel are analyzed, and the data is provided to the processing factory. Through factory prefabrication processing, the processing accuracy of the keel can be improved, ensuring the subsequent installation of curved curtain walls. For the transition keel, the size of the transition keel shall be inspected and accepted according to its processing drawings, installation positioning drawings, and numbering drawings. For transition keels with large size deviations, they shall be removed from the site; The connection method between the transition keel and the main structure can be determined based on the form of the main structure. If the main structure is a steel structure, the transition

keel can be welded and connected to the main structure; If the main structure is a concrete structure, embedded parts design needs to be carried out in advance, and the embedded parts should be embedded and constructed synchronously with the main structure.

For vertical keels, aluminum alloy keels and hot-dip galvanized steel keels can be selected. For example projects, the vertical keels are hot-dip galvanized steel keels; If both the vertical keel and the transition keel are processed with aluminum alloy profiles, they are connected with bolts; If hot-dip galvanized steel is used for processing, the transition keel and vertical keel are connected by welding. The example project keel is a hot-dip galvanized steel keel.

For the horizontal keel, it is connected to the vertical main keel using a crossbeam connecting cantilever, and the connecting cantilever is connected to the vertical keel using bolts; The horizontal keel of the curtain wall is fixed on the connecting cantilever. Adjust the connecting bolts of the support in three dimensions to ensure the levelness and entry/exit position of the column and crossbeam support installation. After the column is installed in place, measure the positioning line according to the previous process, and make an initial adjustment in the three-dimensional direction with an error of less than 1mm. After the basic installation is completed, mark the vertical keel according to the horizontal grid, corresponding to the height of the crossbeam, and then install the crossbeam adapter at the end. After the adapter is installed and corrected, start installing the crossbeam, place a level gauge on the horizontal keel, adjust the level and fix it on the vertical keel.

The length of the horizontal keel of a curved curtain wall is determined based on the vertical keel spacing, and generally speaking, the size of the horizontal keel is in a modular relationship with the width of the ceramic panel. For example, in the case study project, a ceramic panel with a width of 500mm is used, and three ceramic panels are combined into a group. Therefore, the horizontal keel length of the curved ceramic panel curtain wall is 1.5m.

2.5 Positioning and Installation of Transfer Hangers

The transition pendant is connected to the horizontal keel through bolts, and the installation of curved ceramic panel curtain wall is mainly controlled by the transition keel to achieve its hyperbolic effect. However, since the transition keel spacing is determined by the vertical keel spacing, a crossbeam transition pendant system is set up to fine tune the curved curtain wall effect. The adjustment principle of the transfer pendant is shown in the following figure 5:

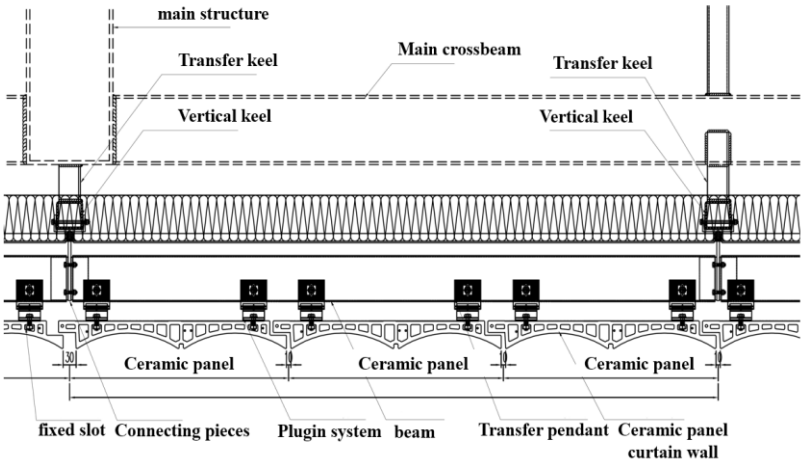

Fig. 5. Three-dimensional adjustment of aluminum alloy pendant.

2.6 Installation of Ceramic Plate and Plate

The ceramic panel can be assembled on the ground. Before the production of the ceramic panel, a BIM skin model is used to draw the processing diagram of the ceramic panel, determine the hole position of the ceramic panel, and the factory will conduct hole opening on the back plate of the ceramic panel. At the same time, the factory will install the U-shaped fixed aluminum groove of the ceramic panel. After the assembly of the ceramic panel is completed, the acceptance and impact resistance tests of the ceramic panel will be conducted.

The assembled ceramic plates are transported to the corresponding compartments by a crane, and the hanging parts are fixed in the crossbeam. The front and rear warping values of the ceramic plates are adjusted through the hanging parts, and they are fixed and locked after reaching the design data; The installation of ceramic plates follows the principle of bottom-up and left-to-right installation. After installation in a row, use a ruler to recheck the gap spacing and overall warping value of each ceramic plate. For individual ceramic plates with large inlet and outlet values, readjust the spacing to ensure good overall coherence and natural warping; After the installation of the lower ceramic plate, a special flexible gasket should be installed at the end of the lower ceramic plate before the installation of the upper ceramic plate to prevent collisions during the installation process and damage to the ceramic plate caused by settlement and deformation of the later building. The overall installation diagram is shown in Figure 6.

Fig. 6. Effect drawing of hyperbolic pottery plate hoisting.

2.7 Installation of Supporting Systems

To ensure the integrity of the curtain wall system, it is necessary to install supporting systems such as ceramic panel curtain wall waterproof backboard and insulation rock wool. For waterproof aluminum plates, first install the adapter steel parts: set out the corresponding skeleton position, fix the aluminum plate steel keel on the steel structure, and then check whether the position of the aluminum plate steel keel is accurate and firm, and check the centerline and surface elevation. In order to ensure the installation accuracy of the waterproof aluminum plate, it is advisable to use a theodolite to connect the crossbeam and vertical frame members. Properly handle deformation joints, settlement joints, and variable cross-section areas to meet usage requirements.

For insulation rock wool, fixed nails are arranged on the back of the installed waterproof aluminum board according to the insulation rock wool, and the insulation material is cut according to the corresponding grid. The insulation material is fully laid on the aluminum back board, and the cut is sealed with aluminum foil tape to prevent loose packaging. The cutting error is ± 3mm. Connect the fixed nails on the aluminum plate with connectors, firmly bond them, and position them according to the drawing requirements. If there are no requirements, stick them at a rate of 4 pieces per square meter.

3 Conclusions

The construction process of the hyperbolic deformation straight grain twisted surface ceramic plate curtain wall in this project focuses on the BIM analysis of the ceramic plate warping during the construction preparation stage, and the design of special adapters based on the warping value to adjust the inlet and outlet relationship to achieve a staggered curved surface effect, thereby achieving the overall twisting effect; During

the construction process, prefabricated processing and refined installation are used to improve construction efficiency and quality.

With the widespread promotion of ceramic panel curtain wall materials, the application of curved and hyperbolic ceramic panel curtain wall systems has increased synchronously. This article discusses the construction technology of hyperbolic deformation straight grain twisted surface ceramic panel curtain wall, which can effectively solve the installation problem of hyperbolic ceramic panel curtain wall. It is suitable for the installation and construction of ceramic panel curtain walls with hyperbolic building effects and a grid width of ceramic panel panels not exceeding 500mm. It has a reference value for promoting the construction of related system curtain walls.

However, the results of this study also have certain limitations, which are only applicable to the installation and construction of ceramic panel curtain walls with a grid width of no more than 500mm. At the same time, it is necessary to have an accurate building BIM model.

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