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CASE REPORT

Design and construction of "Bamboo Cubic" facade with laminated bamboo lumber

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Abstract: This paper presents the design and construction of the facade renovation project ("Bamboo Cubic" project) of Huangqiao Square in Shaowu City, Fujian Province, China. In this project, the structural form and cross-sectional dimensions were determined using a combination of manual and finite element analysis to meet relevant regulations. Once the structural form was confirmed, primary structural components such as the foundation, the column base, and the connection between frame elements were designed to comply with design requirements. Innovative connections were used to install a unique curved design, which required curved LBL members to be prefabricated with precision. The total height of the LBL bamboo frame part is 16.86 m. This project clearly showed that engineered bamboo can be used both as a structural primary member as well as for aesthetic purpose. Use of steel and LBL frames in the "Bamboo Cubic" facade project highlighted the prospect of future hybrid construction.

Keywords: Laminated bamboo lumber; "Bamboo Cubic" facade project; curved beam; connection; design; construction.

1 Introduction

Bamboo belongs to grass family [1], and the growth cycle of bamboo is exceptionally short taking only 3-5 years to mature [2]. Bamboo stirps that are typically used for various types of construction, comes from the hollow and thin-walled bamboo poles [3], which contain numerous nodes and internodes [4]. Bamboo nodes enhance the longitudinal connection of bamboo and improve the hardness and stability of slender bamboo [5]. However, since the bamboo nodes are wider than the internodes [6], the fibers near the nodes are irregular making the geometric size and performance of bamboo vary significantly [7].

To overcome the natural defects of original bamboo, various engineered bamboo products have been developed to be used in construction. Laminated bamboo lumber (LBL) is one of the superior engineered bamboo products [8] which is gaining popularity for its consistency in strength and aesthetic appearance. LBL production process is as follows: original bamboo is cut into bamboo strips (also

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known as ‘LBL units’) with specific width and thickness, which are dried and carbonized prior to being bonded using adhesive. At the final stage, the glued LBL is pressed at a specified pressure for dimensional stability and durability [2]; the process of LBL production is shown in **Fig. 1**. LBL not only retains the advantages of original bamboo such as beautiful color and excellent decorative quality but also overcomes the shortcomings of original bamboo [9-10]. LBL has reliable and superior mechanical properties and can be processed into various shapes and sizes according to requirements [11-12].

The basic mechanical properties of LBL have been investigated widely by researchers from across the globe [13-14]. Mahdavi et al. [15] reported that the strength and stiffness of LBL were comparable to wood, and, in some cases, superior to traditional building materials such as steel and concrete. Xuan et al. [16] studied the effect of bamboo nodes on the flexural performance of LBL units. Experimental results showed that bamboo nodes had some negative effect on the flexural performance, which was still much superior to that of common wood. Yang et al. [9] studied the compressive properties of LBL by taking the angle between fiber and loading direction as a parameter. It was observed that the compressive strength decreased with the increase of the off-axis angle. Li et al. [17] studied the embedding strength of LBL at different angles and the results showed that when the off-axis angle was 60°, the initial stiffness and embedding strength of the specimen was the smallest. Anokye et al. [18] found that the bending failure of LBL mostly occurred at the connection node, and with the increase of the node interval, the bending resistance of LBL improved considerably. Chen et al. [19] reported that the tensile strength of LBL was almost twice as high as its compressive strength, and the constitutive models for LBL under tension and compression along the fiber direction were proposed.

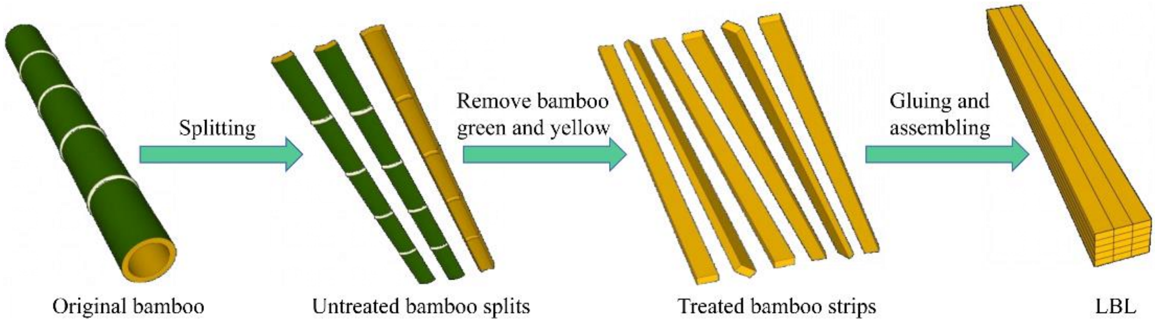


Fig. 1 Manufacturing process of LBL [9]

Fig. 2 shows the cross-sections of three kinds of LBL products. In recognition to its superior mechanical properties, LBL has been used as the primary structural material [20] in many buildings. One such LBL office building with the building area of more than 1000 m^2 designed in 2020 has been reported recently by Su et al [21]. The main structure used many LBL members highlighting the potential of LBL in structural applications.

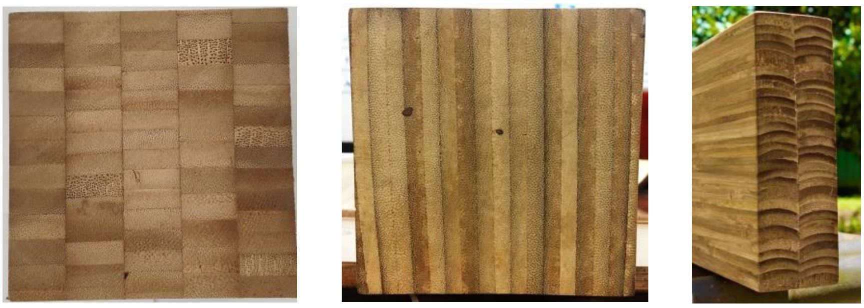


Fig. 2 Cross-sections of three kinds of LBL products

With increasing scientific recognition for LBL as a reliable structural material, the construction industry is keen to develop new LBL structures to promote its use in modern society. The "Bamboo Cubic" project of Huangqiao Square in Fujian Province has pushed the application of LBL to a new height. The name "Bamboo Cubic" refers to the extensive use of bamboo in the structure. The curved LBL members were used to create a beautiful landscape in the three-dimensional space. This design combines the local bamboo culture and geographical features to promote bamboo as an alternative low carbon material for future civilization.

2 Engineering introduction and design

2.1 Engineering introduction

The survey, design, construction, and safety processes of this project were carried out by suitably qualified professionals. An optimum balance was achieved between the architectural aesthetics and the main structural form to ensure a durable structure at a feasible cost.

This project mainly comprised of four parts including 3 steel frames and one bamboo (LBL) frame as shown in **Fig. 3**. The overall shape of the bare frame structure was revised several times to find the most optimal shape and orientation. This process also involved design calculations using finite element (FE) analysis software to determine all member shapes and sizes. It is worth noting that the FE calculation results were cross-checked using some specific manual calculations based on fundamental design equations suggested in relevant design codes [24-26].

A large number of LBL sections were used in this project, and the basic mechanical properties of the LBL were tested prior to designing the structure. Key test results are shown in **Table 1**.

Table 1. Mechanical properties of LBL [22]

	Compression parallel to grain	Compression perpendicular to grain	Tensile parallel to grain	Tensile perpendicular to grain	Shear parallel to grain	Bending
Strength/MPa	71.6	16.5	84.5	4.15	13.9	92.6
Elastic modulus/MPa	9680	1867	7013	-	8658	7999

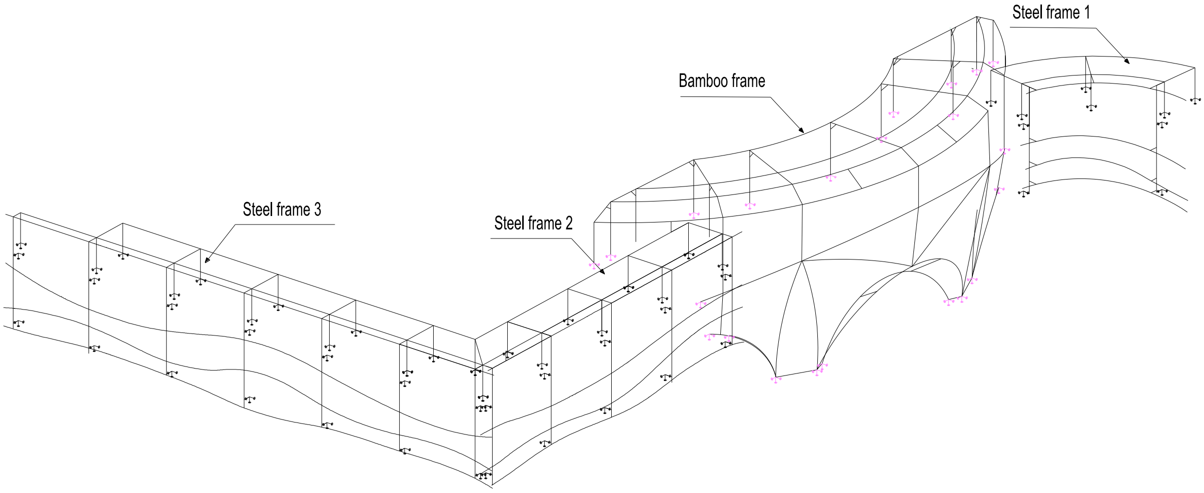


Fig. 3 Schematic of the bare frame structure

2.2 Engineering design

2.2.1 Design steps

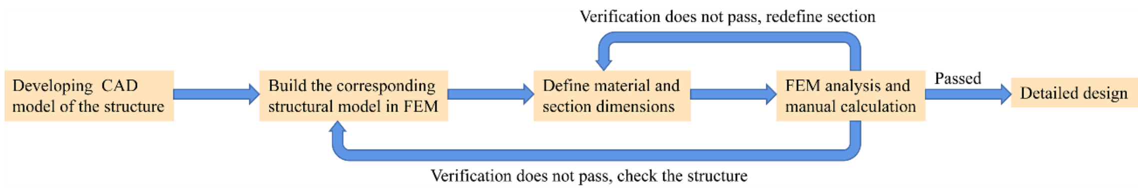


Fig. 4 Flow chart of the design process

Basic steps of the design were as follows: 1. the preliminary section size of each member was determined based on initial estimates; 2. Internal forces and deformations for all members were determined and checked against the corresponding requirements; 3. the section sizes were carefully revised if the requirements were not met; 4. Based on the amended section size, the structural form was revised to meet the requirements of internal force and deformation; 5. foundation, column base and connections of the structure were designed according to the results obtained from the final frame geometry. The whole design process used a combination of manual calculation and FE analysis to cross-check key design parameters. The design process is shown using a flowchart in **Fig. 4**.

2.2.2 Load value

The seismic fortification intensity was considered as 6 degrees, in which the basic seismic acceleration is takes as 0.05 g. The design earthquake group was the first group, whilst the building site category was considered as class II and the ground roughness was class C [24-25]. The roof live load was taken as 0.5 kN/m^2, whereas the basic wind pressure was taken as 0.45 kN/m^2 (once in 100 years) [25]. It is noteworthy that the basic snow pressure was negligible and taken as 0.00 kN/m^2 (once in 100 years) [25].

2.2.3 Bamboo frame model

The complete bamboo frame not only had various primary load carrying members but also had many grilles. To make the FE model efficient, the primary members were explicitly considered in the bamboo frame model whereas the bamboo grilles were considered as an external permanent load applied to the corresponding primary member. Due to the curved shape of the bamboo frame, the length of the grille at the front position of the bamboo frame was different. If the load conversion of each grille had been carried out, the process would have been extremely complicated and inefficient. Therefore, to be on the safe side, all the front parts of the grilles were considered as the longest grille of each part and then were converted into external permanent load. The top surface of the bamboo frame was covered with 17 mm Polyethylene (PE) sunshine board, which was regarded as a roof. In FE analysis, the weight of the sunshine board, together with the permanent load of 0.5 kN/m^2 acting on it, were simplified as a uniform dead load to the corresponding member. In addition, the live load of 0.5 kN/m^2 acting on the member was also converted into the uniform live load to the corresponding member.

In modeling the bamboo frame, the connections between the bamboo frame and the main structure or foundation were regarded as rigid connections, which were defined as fixed support. The connections between the bamboo members used steel connectors and anchor bolts. Since the shear force of the anchor bolt in such connection and the local extrusion of the bamboo member formed a moment, the joint had a certain ability to resist the bending moment. However, this bending resistance did not meet the requirements of rigid joints and hence they were regarded as semi-rigid joints. The bending moment was released at the joint by the end release method, and part of the fixed value was set to 0.5, which was defined as a semi-rigid joint. The total height of the frame is 16.86 m. The final model of the bamboo frame is shown in **Fig. 5**.

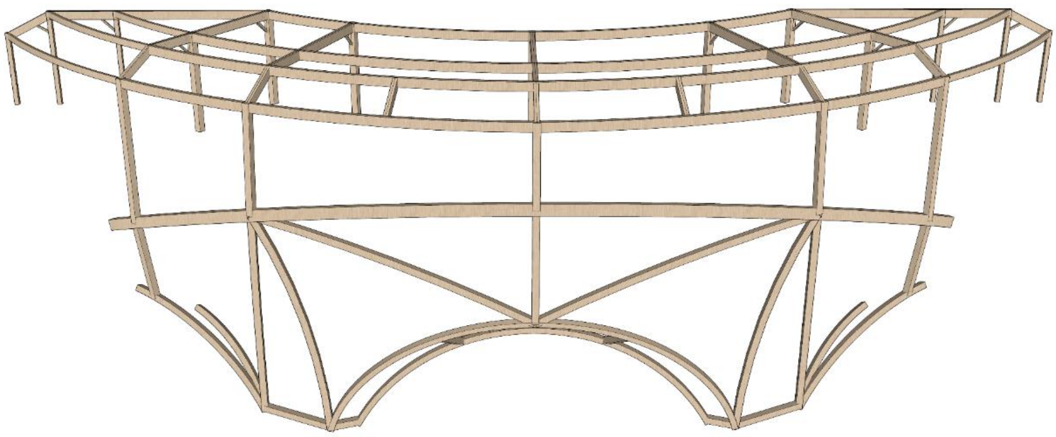


Fig. 5 Bamboo frame model showing primary beams and columns

2.2.4 Steel frame model

In the whole project, the steel frame part can be divided into three parts, as shown **Fig. 3**. The front and side steel frames were inter-connected, whereas the corner steel frame was an independent frame itself. Therefore, the analysis of the steel frame in FE analysis was divided into two parts.

The bamboo grilles on the steel frame were also considered as external constant loads. At the same time, due to the existence of curved beams, the lengths of the bamboo grilles on the steel frame part were also different. Therefore, the same simplified method, as the bamboo frame part, was also adopted for steel frame modelling. The longest grilles were considered in all parts of the frame model and were converted into constant external loads. The grille in the steel frame had a certain cantilever length, so it was necessary to model and check the grille with the longest cantilever length after transforming the grille weight into a constant load; this check ensured that the deformation and stress of the grid met the requirements under various working conditions. The steel frame at the corner was vertically reinforced by channel steel sections due to the long span of the curved beam. The simplified assumptions of PE sunshine board laid on the top surface of the steel frame was the same as that of the bamboo frame.

The steel frame was connected to the main structure by anchor bolts, and thus the translation and rotation were limited. Therefore, the connection between the steel frame and the main structure was regarded as fixed support. The connection joints between steel members were bolt-welded joints, which were also rigid joints. Therefore, the joints in the steel frame were defined as rigid joints in FE analysis. When the grille was modeled and checked, the connection between the grille and the steel beam was regarded as a fixed support, and the connection between the bamboo elements was regarded as a hinged joint. The final model of the two-part steel frame is shown in **Fig. 6**.

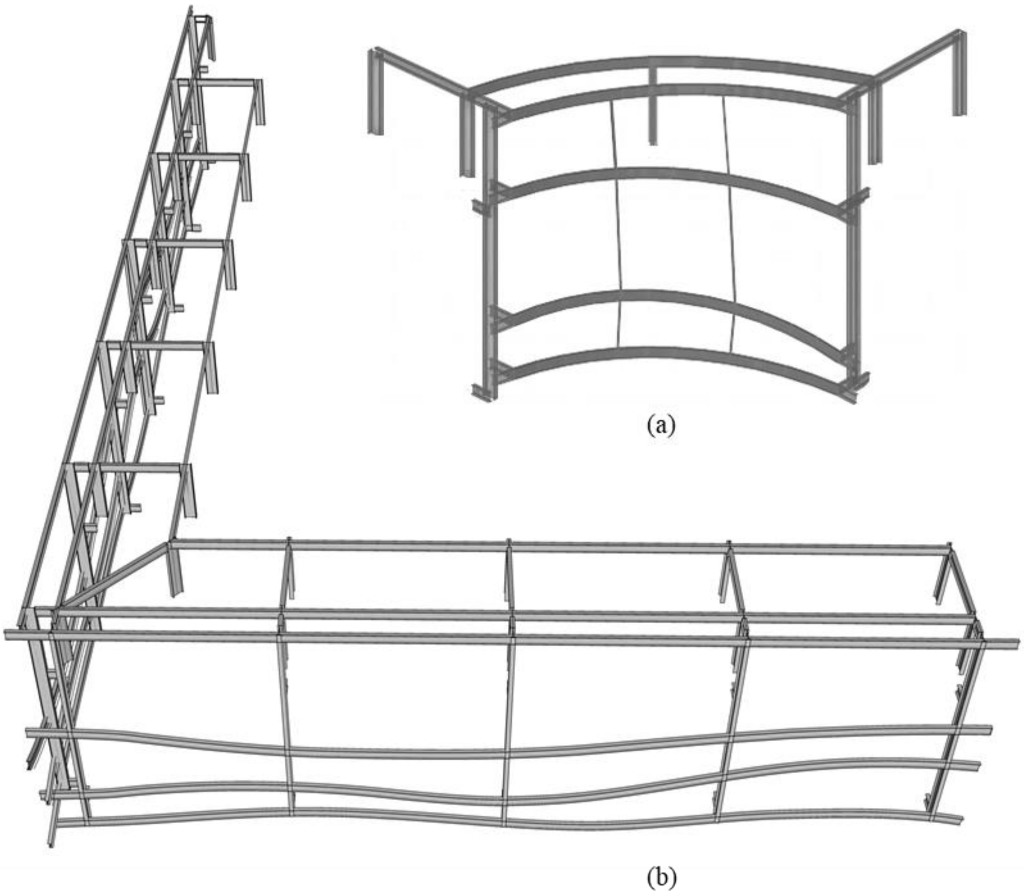


Fig. 6 Steel frame: (a) Corner steel frame model; (b) Front and side steel frame model.

3 Calculation of internal stresses

3.1 Calculation for bamboo members

Due to the lack of corresponding bamboo structure standards, the stress and stability of bamboo members were checked with reference to the Chinese wood structure design standard GB 50005-2017

[23]. Bending, compressive, tensile and shear stresses under various load combinations were checked according to GB 50005-2017 [23]. In particular, as for the bamboo grille, it was necessary to analyze and calculate several groups of grilles with the longest cantilever length or the largest grille height. A group of grilles with the largest force and deformation was also selected for relevant strength and deformation checks.

Referring to the provisions in GB 50005-2017 [23], it is necessary to adjust the strength design value and elastic modulus under different service conditions and design service life. In this project an open-air environment was considered for the bamboo structures with a design service life of 100 years. According to the relevant provisions of GB 50005-2017 [23], the bending strength design value of bamboo grille was multiplied by an interaction coefficient of 1.15 when checking the bending strength.

3.2 Calculation for steel members

Steel members were subjected to appropriate strength testing in accordance with the relevant provisions of the steel structure design standard GB 50017-2017[27]. The steel members were all I shaped sections, and the steel grade was Q235B. In addition to the corresponding strength calculation, the overall stability of the flexural members and the compressive members were checked as part of the design process.

3.3 Checking results

The section forms of bamboo members and bamboo grilles were rectangular sections, and the steel members were H-section and C-section. The curved beams were vertically strengthened with channel steel at the corner frame. To conform with standard requirements, the section sizes were carefully checked and redesigned when required.

FE analysis results were checked by manual calculation to determine section sizes that met the strength and serviceability requirements specified in the relevant standard. Three section sizes of the bamboo frame were (height×width): 500 mm×300 mm，400 mm×200 mm，300 mm×300 mm. Two section sizes of the bamboo grille were (height×width): 120 mm×80 mm，80 mm×50 mm. Three section sizes of the steel frame were: H 400 mm×200 mm×8 mm×13 mm，H 300 mm×150 mm×6.5 mm×9 mm，C 100 mm×48 mm×5.3 mm.

4 Detail design

After the section sizes were all determined, the bamboo frame and steel frame were designed in detail. The main material of the bamboo frame was LBL, and the main material of the steel frame was Q235B H-section steel. Once the frame design was complete, the LBL grilles used in the facade were designed accordingly.

4.1 Design of the bamboo frame

The main body of bamboo frame is shown in **Fig. 5**; the lower end of the bamboo frame was supported to the ground, and the upper end of the LBL column was connected to the top of the concrete main structure. It is worth noting that most of the main members were curved members making the design process quite challenging.

4.1.1 Design of the foundation

The bamboo frame was built at the front entrance and exit of the concrete main structure. To ensure its aesthetics, practicability, and safety, the bamboo frame had to be rested on to the ground and the connection required special considerations. Before excavating the foundation pit, the corresponding underground pipeline drawings and geological and hydrological data were checked carefully. An appropriate depth for the foundation was selected based on existing underground pipelines.

Fig. 5 shows that the bamboo frame was design in a way to have only four supports to the ground; this was the most feasibly option considering cost effectiveness, aesthetics and uninterrupted access and exit to the building. Reinforced concrete (RC) foundations were designed for each of those ground supports for the bamboo frame. The size, shape, and reinforcement arrangement of independent RC foundations were calculated and designed based on the load transmitted from the superstructure; all load combinations were carefully considered using FE analysis. Due to the lack of corresponding bamboo structure design standards, the provisions of wood structure design standards were used where required [23]. The bamboo frame was kept at 300 mm above the ground using extruded RC foundations.

4.1.2 Design of the column base

The LBL column was connected to the roof beam of the main structure (the roof beam had been strengthened in advance). At the column base, a concrete column pier was poured 300 mm above the ground, which formed the platform for the steel plate to be fixed with M24 anchor bolts. The LBL column base and the concrete column foundation were connected by welding steel connectors and steel plates. The steel connectors and the LBL column were fixed by using M16 anchor bolts. The connection between the curved LBL and the foundation at the landing position adopted the same design with some difference in steel connectors to facilitate the required certain inclination angles as shown in **Fig. 7**.

Fig. 7 Design of the LBL (bamboo) column base

4.1.3 Design of the connection

The connection between LBL members was made of steel connectors and M16 anchor bolts. Since the members in the bamboo frame were mainly curved, the size and shape of the steel connectors that need to be processed and manufactured varied depending on the inclinations of the connectors. On the other hand, as the bamboo frame was a symmetrical structure, only half of the structural steel connectors needed to be designed. The connection between the LBL members is shown in **Fig. 8**(a).

(a) (b) (c)

Fig. 8 Connections in LBL

In addition to steel connectors and anchor bolts, the side connection between the bamboo frame and the main structure also needed to be embedded in the steel plate by inserting chemical anchor bolts at the corresponding position of the main structure, as shown in **Fig. 8** (b). The steel connectors were welded to the steel plate to make the side connections complete.

The LBL strip connected the LBL grille in the bamboo frame through angular steel pieces made of Q235B steel (as shown in **Fig. 8** (c)) and the grille was connected to the LBL member by using M5 self-tapping screws.

4.2 Design of steel frames

All steel frames were made of Q235B H-section steel. To reflect a wavy design in the renovated façade design, curved beams were used on the side of steel frames as shown in **Fig. 9**. According to the engineering requirements, it was necessary to preserve the position of the Light-Emitting Diode (LED) screen when installing the grille in the steel frame part.

Fig. 9 Curved beams of the steel frame

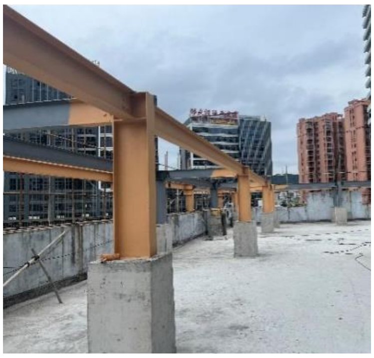


Fig. 10 Design of steel column base on the roof

4.2.1 Design of the column base

Roof beams were designed on top of the main structure to provide support to the newly designed steel frames for façade renovation. Roof beams were fixed to the roof columns, which also had RC foundations as shown in **Fig. 10**.

4.2.2 Design of curved beams

Once the steel columns were complete, specially designed steel brackets were welded at specified locations to install the curved beams. Stiffening ribs were also installed at the bracket to provide additional support to the curved beams, which were prefabricated in the factory and later transported to the construction site. All curved beams were hoisted to the bracket position of the corresponding cantilever column by a crane on site and were connected to the brackets by using bolts.

4.2.3 Design of connections

The connections between members in the steel frame were bolted and welded, and the bolt type was M20. To ensure safety, the connections were installed after the steel column was fixed and the concrete had been cured for 28 days. The strength of the connecting plate and the cover plate in the weak axis direction of the H-section steel needed to be strengthened, and hence Q345B steel was selected to ensure the connection strength in the weak axis direction.

Fig. 11 Design of the bamboo grille

The side connection between the steel frame and main structure also needed to be embedded in the steel plate using chemical anchor bolt at the corresponding position of the main structure. The H-section steels connected to the steel plates on the side of the steel frame were connected through bolts and welding, and stiffeners were used to further strengthen those connections.

The LBL grille in the steel frame was made of LBL strips connected by right-angled steel brackets made of Q235B steel (as shown in **Fig. 11**). To form the facade effect reflecting a wave form with staggered stacking, the extension length and the fixing position of each of the grille elements was different. Each grille was connected to the upper and the lower curved beams through a fixed member of Q235 steel. The fixed members were pre-welded at the corresponding position and the grille elements were locked by M5-304 stainless steel self-tapping screws.

5 Construction

5.1 Foundation and column base

According to the detailed design, the first step in constructing the entire "Bamboo Cubic" project was to excavate the bamboo frame foundation pit, embed the side connecting plate, and remove the original structural layer at the column base position. Scaffolds were also being erected simultaneously.

The foundation pit required vertical excavation to avoid disturbing the old soil around the foundation. After the excavation depth reached the design foundation depth, the soil at the bottom and the surrounding area were compacted to achieve the design bearing strength. After the foundation pit excavation was complete, the construction of independent foundations were carried out immediately. Concrete was poured after the steel bar arrangement was completed. The minimum strength of concrete used in the foundation cushion was C30, whereas that for the foundation and column pier was C40. After the concrete pouring was completed, the formworks were removed after seven days of maintenance. After 28 days, the soil around the foundation was backfilled and rammed to ensure that the compaction coefficient was not less than 0.94.

The side connecting plate was connected to the main concrete column by anchor bolt. Before the anchor bolt was installed, the floating ash and dust in the hole were removed using air pressure blowing pipe and other tools to keep the hole clean. Then, the chemical anchor liquid was filled, and the anchor bolt was drilled. The subsequent operations were delayed until the liquid hardened. The side connecting plate needed to be treated with hot galvanized to ensure anti-corrosion and anti-rust treatment surface, and the thickness of the galvanized layer was not less than 80 μm.

The original structural layer of the roof was chiseled off prior to casting the column bases at the roof. Once the construction was completed, the original structural layer needed to be restored immediately to ensure that waterproof performance and thermal insulation performance of the roof would not be affected.

Fig. 12 Roof steel frame

5.2 Construction of steel frame

Steel members were transported to the construction site in batches after factory prefabrication.

After the original structural layer of the roof was chiseled out, anchor bolts were used to connect the floor slab and the steel plate at the corresponding position of the steel column. By then, the roof structure layer was restored. The H-section steel column was welded on to the steel plate, and then the roof steel column and the steel beam were connected by bolt welding, as shown in **Fig. 12**. After the roof frame was completed, the reinforced concrete outer column base was poured around steel column, and the formwork was removed after 28 days of maintenance.

After the completion of roof steel frame, the suspension column was also connected by bolt welding at the corresponding cantilever beam and side connection position, and a crane assisted the whole process. After the suspension column connection was completed, the bracket was added by welding at the corresponding lap position of the curved beam. Then the curved beam was placed in the corresponding bracket position by a crane, and the two were connected by bolts, as shown in **Fig. 13**(a). At the same time, to facilitate the subsequent connection between bamboo grille and the curved beam, the fixed parts used were pre-welded to the curved beam in the factory, as shown in **Fig. 13**(b).

Fig. 13 Prefabrication and installation of the curved beam: (a) installation; (b) prefabrication.

After the installation of the curved beam was complete, three bamboo strips of LBL were first connected with a right-angle steel to form the grille, and then it was hoisted to the corresponding position by the crane. At the same time, two workers cooperated up and down with self-tapping screws to connect the bamboo grille with the fixed parts, as shown in **Fig. 14**. During the installation process of the bamboo grille, special attention was paid to the preserved position of LED screen, as shown in **Fig. 15**.

Fig. 14 Installation of bamboo grille

Fig. 15 Installation of the LED screen

5.3 Construction of the bamboo frame

Bamboo members were prefabricated in the factory according to the designed section and size. At the same time, according to the connection design, holes and slots were drilled at the corresponding position, and prefabricated parts were transported to the site in batches, as shown in **Fig. 16**. Anchor bolts were used to connect floor and steel plate at the corresponding position of the bamboo column.

The connectors were welded on the steel plate and then connected to the bamboo columns using anchor bolts. Afterwards, concrete was poured into the formwork to cast the column pier, and the formwork was removed after 28 days.

(a) Factory production of LBL sections (b) Transportation of LBL to the site

Fig. 16 Prefabrication and transportation of bamboo members for construction

(a) Combination of arches (b) Combination of vertical members

Fig. 17 Splicing of bamboo members

Fig. 18 Installation of bamboo members

After the bamboo members were transported in place, the beam and column members required for constructing the roof bamboo frame were transported by crane first. While building the roof, the two arches at the bottom of bamboo frame, and the vertical members required to connect the arch and the roof frame were spliced directly on the ground with connectors and anchor bolts, as shown in **Fig. 17**. Once the construction of the roof bamboo frame was complete, the arch and the bottom arc members were lifted to corresponding positions by crane, which followed installation of the vertical members using spliced connections to the ground. The large curved beam in the middle of the bamboo frame was installed at last, as shown in **Fig. 18**. Once the main bamboo frame was complete, bamboo grille was connected by self-tapping screws.

5.4 Surface treatment

(a) Outside (b) Inside

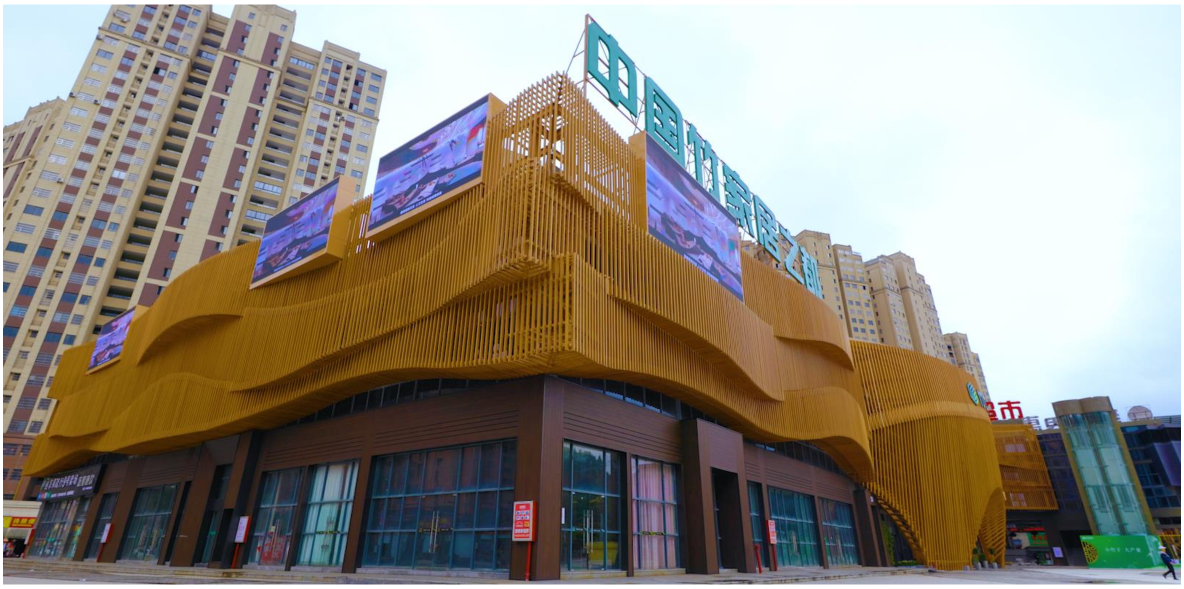
Fig. 19 The entrance of "Bamboo Cubic"

The steel surface had to be treated for rust removal, corrosion resistance, and fire protection. The surface rust removal was carried out by sandblasting, and the weld needed to be coated with protective paint. Hot-dip galvanizing was carried out on steel columns and steel beams after rust removal, and the galvanized layer was kept to be less than 80 μm. Once the steel surface was cleaned, epoxy zinc-rich paint was used as the undercoat prior to applying outdoor fire-retardant coating and fluorocarbon paint as the final surface paint. The performance, coating thickness, and quality requirements of fire-retardant coatings all met the requirements of GB/T 14907-2018 [28], and CECS 24: 90 [29]. It is worth mentioning that the selected fire-retardant coatings were compatible with anti-rust undercoat.

For the surface treatment of LBL, it was also necessary to clean the surface of bamboo first (no oil, water, dust, etc.), and then the LBL was painted the varnish prior to painting using an outdoor fire-retardant coating. The application technique of the fire-retardant coating was done following the relevant requirements of T/CECS 807-2021 [30].

The "Bamboo Cubic" was finally complete once all the aforementioned steps were finished. With the total height of 16.86 m, the entrance of the building could be seen from **Fig. 19**. The arch door with radioactive LBL members looks like the rising sun. The front and side panoramic views are shown in **Fig. 20**. The three layers of flexible bamboo around the exterior wall of the whole building are staggered. On the one hand, it means the integration of ecological, production and life, and the integration of industry and city, and the coordinated development. At the same time, it also symbolizes the interdependence of people, environment and all things which cannot be separated from each other. The main material of the structure reflects the fortitude of bamboo, and the curved shape shows the softness of bamboo, which is also the way of Tai Chi.

(a) Front panorama



(b) Side panorama

Fig. 20 Panorama of "Bamboo Cubic"

6 Conclusion

The facade renovation project of Huangqiao Square in Shaowu City, Fujian Province ("Bamboo Cubic" project) is a steel-LBL structure co-designed by Nanjing Forestry University, Chengyila (Xiamen) House Technology Development Co. LTD and Fujian Cheng'an Blue Shield Industrial Co., Ltd. This project fully reflected the assembly of steel and LBL, and showed the dual-use of LBL as both a decorative material and primary structural member. Combined with the local landscape characteristics, the project was designed using a combination of simulated models and manual calculations. All members were prefabricated in the factory, and then spliced and installed on site. The whole construction process was fast and cost effective. Some of the key innovative aspects of this project are as follows: (1) a staggered undulating structural shape was constructed in the form of curved beams and grids; (2) use of curved members of LBL; (3) diversity of LBL member connections. The successful construction of the "Bamboo Cubic" project has shown a great example of the use of LBL in structural applications. Use of steel and LBL in an innovative way showed the potential of future hybrid structures, in which bamboo can complement other structural materials to reduce the carbon footprint of future infrastructure.

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CRediT authorship contribution statement

Xin Xue: Investigation, Formal analysis, Writing – original draft. **Wenjing Zhou**: Formal analysis, Writing – original draft. **Zixain Feng**: Writing – review & editing. **Usama Sayed**: Writing – review & editing. **Yipeng Li**: Funding acquisition, Writing – review & editing. **Ziyong Huang**: Funding acquisition, Writing – review & editing. **Haitao Li**: Conceptualization, Funding acquisition, Supervision, Investigation, Formal analysis, Writing – review & editing. **Mahmud Ashraf**: Supervision, Writing – review & editing. **Rodolfo Lorenzo**: Supervision, Writing – review & editing.

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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