SUST, 2026, 6(2): 000108

Sustainable Structures
ISSN: 2789-3111 (Print); ISSN: 2789-312X (Online)
http://www.sustain-dpl.com/journal/sust
DOI: 10.54113/j.sust.2026.000108

CASE REPORT

Design and construction of a two-story laminated bamboo lumber structure in Hong Kong

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Abstract: This paper presents a technical case study on the structural design and assembly of a two-story community liaison center utilizing Laminated Bamboo Lumber (LBL) as the primary structural and architectural material. To guarantee structural integrity and economic optimization, a hybrid design methodology was implemented during the component cross-section phase, combining preliminary mechanics-based calculations with iterative finite element analysis for verification. Adopting Design for Manufacture and Assembly (DfMA) principles, the structural components were prefabricated off-site under factory-controlled quality conditions and subsequently transported for rapid on-site erection. This parallel workflow significantly reduced the construction time and minimized environmental disruption. Ultimately, this project establishes a scalable, empirical framework for the engineering deployment of LBL, validating its viability as a high-performance, low-carbon alternative for sustainable civil infrastructure.

Keywords: laminated bamboo lumber, finite element simulation, construction, green construction, low-carbon material, sustainable

1 Introduction

With the increasing awareness of environmental protection, low-carbon and sustainable development have gradually become one of the primary focuses of modern civilization. Engineering requirements for building materials are not only focused on mechanical properties but also on green environmental protection, comfort and sustainability[1][2]. There is an urgent need to find green and sustainable material to replace traditional fossil-based building materials [3][7]. Strength-to-weight ratio is often used as key indicator to compare materials used in construction; bamboo and engineered bamboo products offer superior strength-to-weight ratio when compared to concrete and timber. In addition, the tensile strength of bamboo along the grain is comparable to that of ordinary steel while its

Received: 28 December 2025; Received in revised form: 24 May 2026; Accepted: 28 May 2026
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compressive strength along the grain is better than that of ordinary brick masonry despite significantly lighter than both steel and brick masonry [8][9].

Due to the inherent geometrical constraints of raw bamboo in terms of material, structural stability and biological properties, its application in structural engineering applications is relatively scarce [10]. To overcome the shortcomings of the original bamboo such as small diameter, large differences in the stability of internode hollow structure and short service life, researchers have developed various engineered bamboo products that ensure high structural stability and consistent material properties suitable for engineering practice. Laminated Bamboo Lumber (LBL) is an engineered bamboo product that is widely used in engineering practice due to its good material properties and beautiful appearance. LBL is made by splitting raw bamboo into strips, then peeling off the skin of the strips, grinding the strips to a fixed width and thickness, and finally gluing and hot-pressing the strips together, as shown in **Fig. 1** [11].

In recent years, with ongoing research and development of bamboo-based composites, various researchers have investigated the performance and suitability of existing design rules of this type of green building material, providing key theoretical knowledge for its large-scale engineering application [12]. In terms of the natural properties of raw bamboo, there are obvious changes in mechanical properties along its longitudinal axis; from the base to the tip, the bending and compressive strength of the bamboo shows a decreasing trend [13][14]. This characteristic directly determines the logic of material selection for bamboo processing. In actual production, engineers give priority to using the superior base bamboo for key load-bearing components such as trusses, main beams and load-bearing columns, while the tip bamboo is mostly used for secondary load-bearing structures or non-load-bearing components to achieve efficient resource utilization. At the same time, as a natural structure formed during the growth of bamboo, the nodes, although giving it unique mechanical toughness, are also natural defects that affect performance stability; experimental data show that the flexural modulus of bamboo samples with nodes is lower than that of the unjointed parts, and the tensile strength is also reduced by 15% to 29% [15][18]. Engineered bamboo not only possess the green, low-carbon and lightweight advantages of natural bamboo, but also have improved mechanical properties through process optimization. Their successful application in load-bearing structures provides new material options for the development of green buildings[19][21]. With the continuous development of related processing techniques, the gradual improvement of structural design specifications, and the increasing demand for sustainable buildings, the application of such high-performance material in the construction field is bound to be even broader. It is expected to play a more important role in future lightweight buildings, large-span structures, bridge engineering and other relevant fields[22]. **Fig. 2** shows some examples of LBL usage in construction that have been designed by Haitao Li's team such as the Sentai Bamboo Research and Development Center Building in Ganzhou City, Jiangxi Province [11], the Sentai Office Building in Ganzhou City, Jiangxi Province [17], the bamboo facade renovation project in Shaowu City, Fujian Province [23], and the Shuangjiazi Bridge in the campus of Nanjing Forestry University in Nanjing City, Jiangsu Province [27].

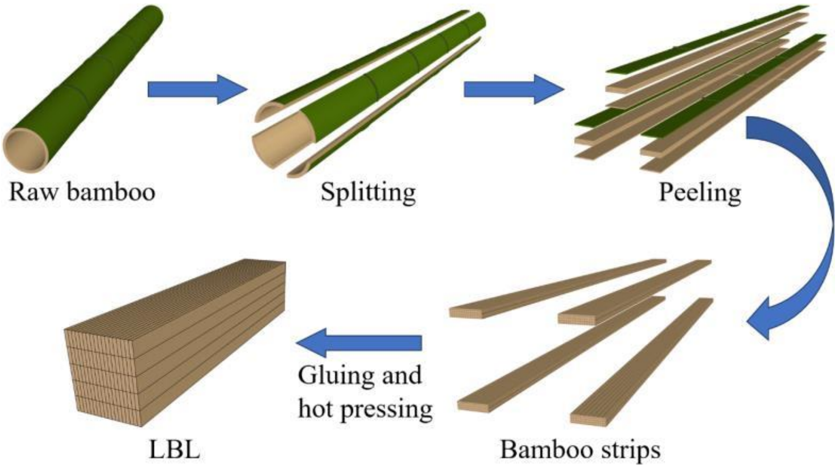


Fig. 1. Manufacturing process of LBL [11]

(a) Sentai Bamboo Research and Development Center Building [11]

(b) Sentai Office Building [17]

(c) “Bamboo Cube” [23]

(d) “ShuangJiazi” Bridge [27]

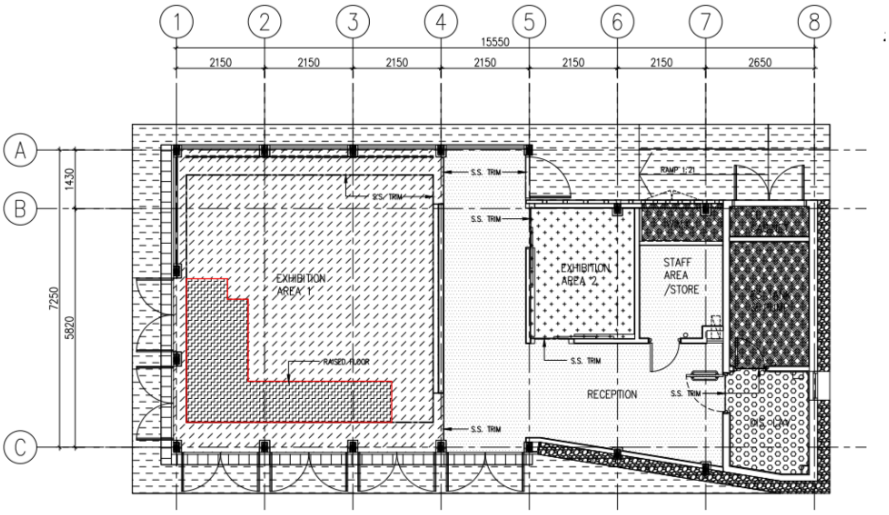
Fig. 2. Engineering application of laminated bamboo lumber

LBL is increasingly recognized for its good mechanical properties and beautiful appearance, and its engineering applications are also becoming more widespread. This paper takes the first LBL building in Hong Kong, China as an example to systematically introduce the entire process from structural analysis, schematic design to on-site construction. Construction of the building began in December 2025 and has been completed in 2026 highlighting significantly less time required for construction of LBL buildings.

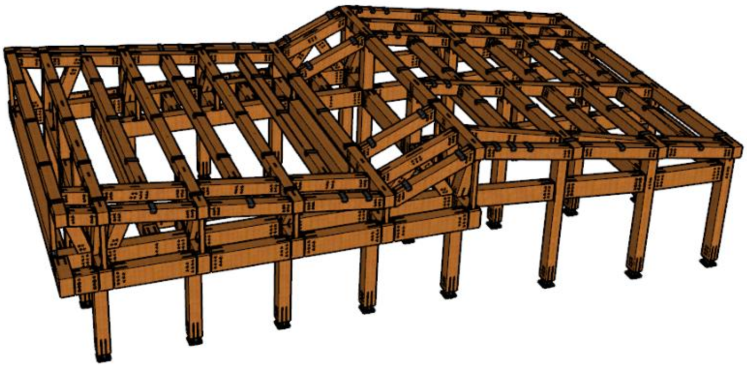
2 Layout and structural form of the structure

The case study project is a two-storey LBL community liaison centre, framed with a total area of 147 square meters, located in Ma Liao Shui, Sha Tin District, Hong Kong Special Administrative Region, China. The structure of the project consists of a rectangle on the left and a trapezoid on the right, as shown in the floor plan of the first floor in **Fig. 3** (a); the roof is predominantly used for installing solar photovoltaic panels and transparent glass panels. The main material of the structure is LBL produced by Sentai Bamboo Co., Ltd. To ensure aesthetics and sufficient indoor natural lighting, the walls of the rectangular frame on the left as well as the doors are made of glass panels. The roof at the top of the corridor between the rectangular frame and the trapezoidal frame is also a transparent glass roof.

The project model was accomplished through the collaborative use of planar modeling software and 3D modeling software; the 3D model is shown in **Fig. 3** (b). To ensure the safety and reliability of the model, a finite element model was developed based on the design drawings and all possible load combinations were applied to the model to simulate the actual loads to observe whether the internal forces and deformations of the structure met the specification requirements. If not, the cross-sectional dimensions and structural forms were continuously modified. The optimal section dimensions and structural forms of beams and columns were determined through finite element analysis and manual calculation, taking into account requirements such as circuits and fire protection.



(a) Plan of the first floor



(b) Three-dimensional model of the LBL frame structure

Fig. 3. Architectural drawings of the floor and the bare structural frame

The main frame of the project was made of LBL. To understand its basic mechanical properties, tests on the LBL were conducted according to ASTM D143 [24], and **Table 1** lists its basic mechanical properties.

Table 1. Mechanical Properties of LBL [26]

	Bending resistance f_{m}	Compressive resistance along the grain $f_{\mathrm{c,0}}$	Tensile resistance along the grain f_{t}	Shear resistance along the line f_{v}	Transverse crease resistance $f_{\mathrm{c,90}}$
Strength /MPa	42.3	31.2	34.6	4.3	7.9
Elastic modulus/ MPa	Poisson's ratio	Coefficient of thermal expansion ℃$^{-1}$	Shear modulus MPa	Weight density N/mm^3	Mass density g/mm^3
8200	0.25	6.500×10^{-6}	$G_{12} = 1200$ $G_{13} = 1200$ $G_{23} = 500$	7.350×10^{-6}	7.500×10^{-10}

3 Development of the finite element model

3.1 Setting material parameters

Before building the model, appropriate care was taken to find a suitable material model form finite element software. To capture the orthotropic nature of LBL, a new set of material properties was established to simulate LBL. In the current project, key material properties that were modified based on LBL's test results are the elastic modulus, Poisson's ratio, coefficient of thermal expansion, shear modulus, weight density and mass density.

3.2 Setting of cross-sections

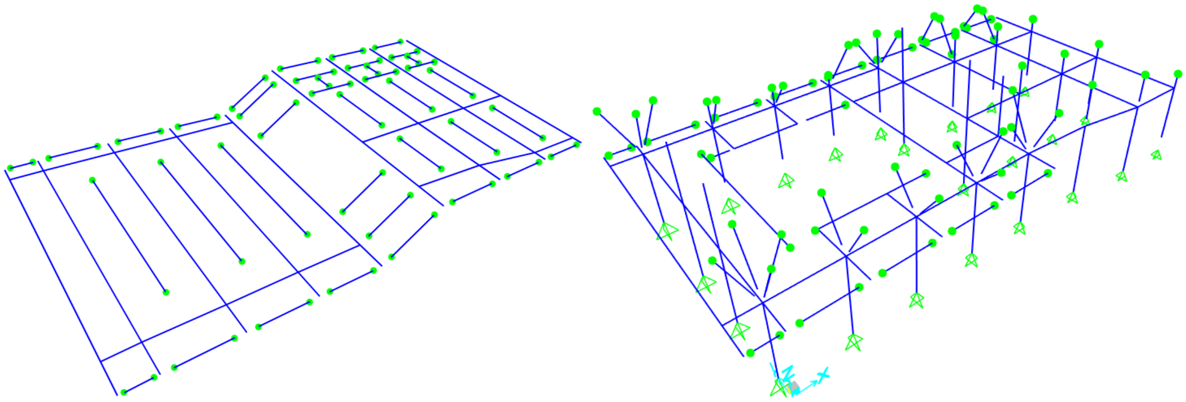
Before building the model, preliminary dimensions were set for the required beams and columns, which are mainly rectangular sections requiring estimated width and depth to initial simulation and analysis. The size of the rectangular section determines the bending stiffness of the beam and the compressive stiffness of the column. By constantly changing the size of the cross-section and the form of the structure, the strength and deformation requirements of the structure were met while achieving optimized section sizes.

3.3 Building the 3D model

After setting the material parameters and section dimensions, to the 3D model was built according to the design drawings. Special care was taken to make sure appropriate sizes were input for numerous beams and columns.

3.4 Lateral System

As the building is rectangular in plan, lateral stability is governed by the short direction. Following coordination with the design team, no shear walls or bracing systems were incorporated; therefore, the lateral load-resisting system is designed as a moment-resisting frame. To avoid heavy beam–column rigid moment connections, semi-rigid connections were adopted to eliminate the expose of steel plates and bolts. Semi-rigid connections allow limited rotation and moment. For construction efficiency, column bases are designed as fixed. With fixed-base columns, temporary bracing is not required after column erection and before the frame action is fully established. Although many connections could theoretically be designed as simple pinned connections, there are also cantilevers, braces etc. Therefore, they were standardized to simplify construction, ensure consistency in bolt sizing, and achieve a uniform appearance. The fixity of nodes is shown in **Fig. 4**.



(a) Semi-rigid connections in 3D model

(b) Diagram of the rigid-hinged connection between the column and the first floor beam and the diagonal brace

Fig. 4. Rigid joints at the column bases in the 3D model

Note: A green dot at the end indicates that the end release constraint is a semi-rigid connection, and a connection without a green dot at the end indicates a rigid connection.

3.5 Application of load

3.5.1 Wind load (WIND)

Hong Kong Wind Code was used for to determine the wind load for this building [28], simplifying the wind load on one surface into a line load and applying it to the outermost beam of the frame. The input wind load was 4.4 kN/m for the first floor and 1.9 kN/m for the second floor. Roof wind loads are applied in the form of surface loads, with a vertical upwind load value of 3.31 kN/m^2 acting on top and a vertical downwind load value of 0.452 kN/m^2 acting on top.

3.5.2 Additional dead load (SDL)

The SDL includes the constant load of the curtain wall acting on the frame as well as the fixed constant load of the mezzanine and top floor. The loads of the curtain wall acting on the frame are shown in **Fig. 5**. The SDL linear load value of the top frame is 1.2 kN/m, that of the first frame is 4.8 kN/m, 1.2 kN/m on the outside and 3.6 kN/m on the inside of the cantilever. The additional dead loads acting on the mezzanine and the top floor are applied in the form of surface loads, with a value of 1.5 kN/m^2.

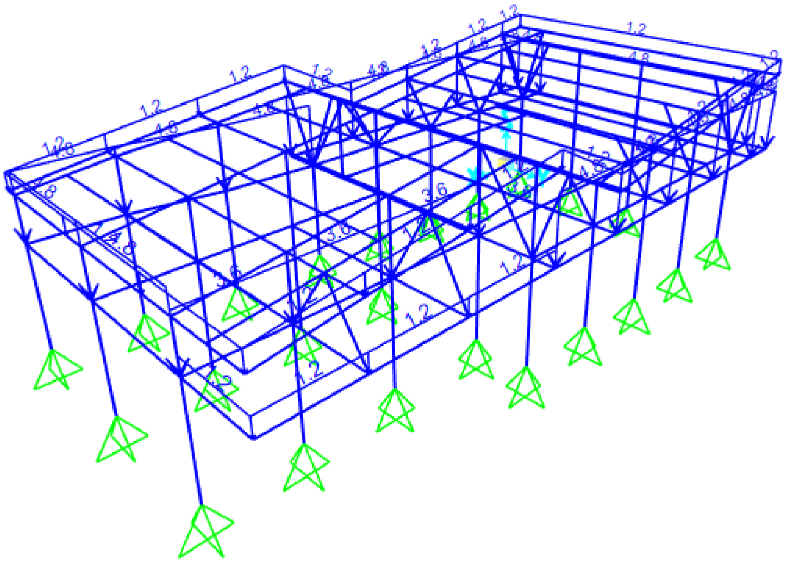


Fig. 5. Frame SDL Load input diagram (unit: kN/m)

3.5.3 Live load (LL)

Live loads are determined based on Code of Practice for Dead and Imposed Loads 2011 [28] was used for live loads as shown in **Fig. 6**. The live load at the mezzanine is 5 kN/m^2, and the live load for maintenance purpose at roof is 0.75 kN/m^2.

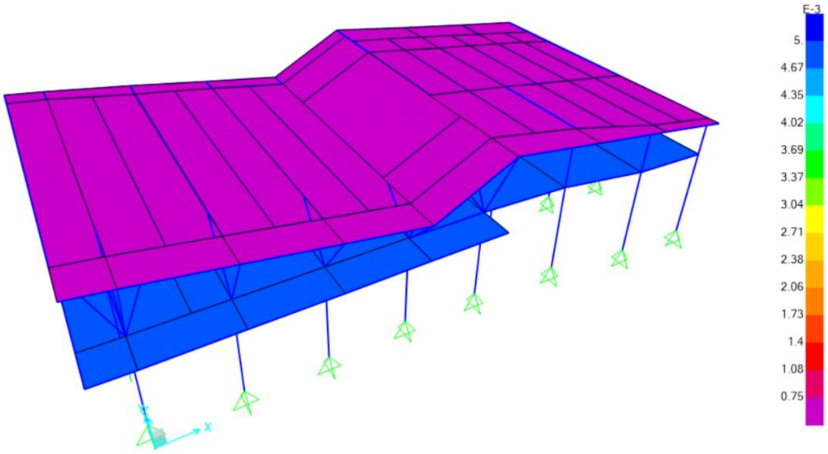


Fig. 6. LL Load Input Diagram (unit: kN/m^2)

3.6 Regulations and Design Codes

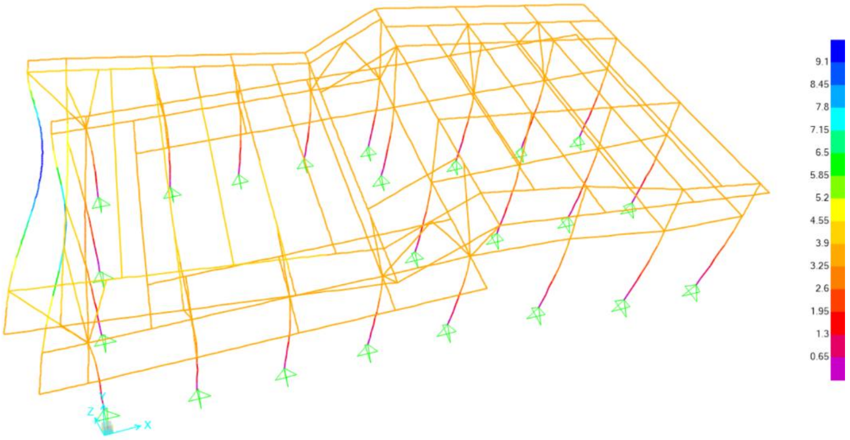
As the structure is located in Hong Kong, it must comply with the Building Regulations and relevant Codes of Practice. In the absence of specific local standards for timber and bamboo structures, the design adopts Hong Kong requirements for dead and imposed loads, wind loads, and load combinations. For member design, as well as material sampling and testing requirements, reference is made to DB32/T 5080-2025 [26]. This design approach was agreed upon with both the client and the relevant authorities prior to commencement of the design.

4 Results and analysis

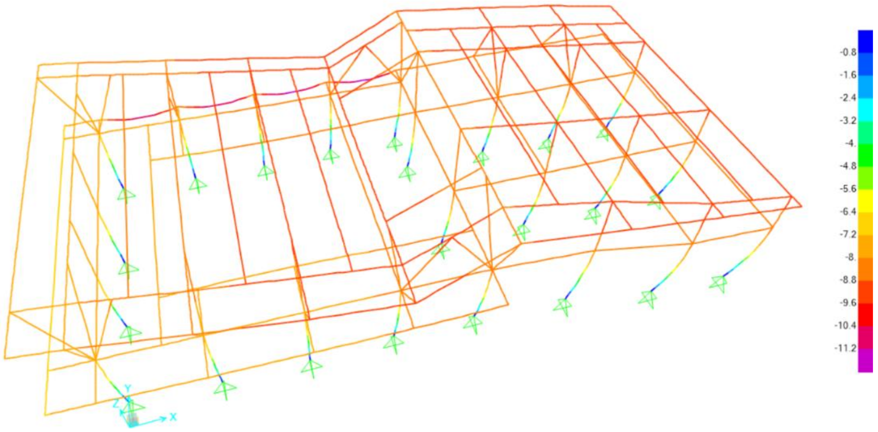
4.1 WIND load condition output

After the structural model was completed, the model was analyzed separately under self-weight, additional dead load, live load, and wind loads in six directions. Deformation, axial force, shear force and bending moments were carefully monitored to make sure they meet the design requirements. Special emphasis was given on the results under wind load since they produced large deformations.

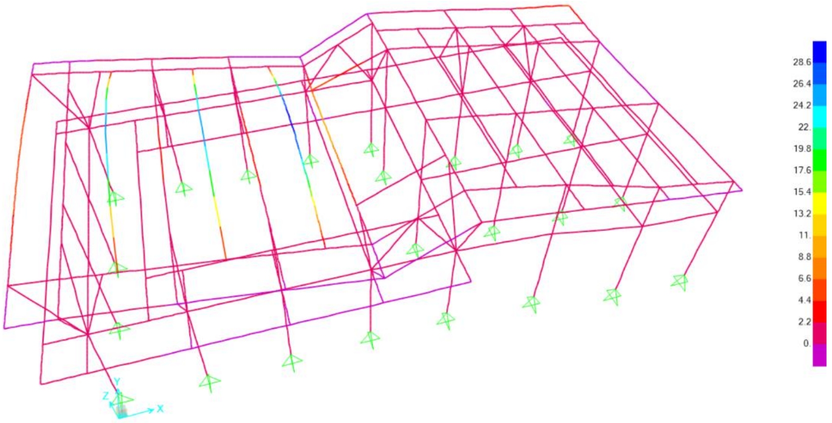
The overall displacement diagram of the structure under the X-axis forward wind load is shown in **Fig. 7**. (a), where the maximum displacement is at the middle span of the leftmost first and second floor beams of the structure, which is 9.1 mm. The overall displacement diagram of the structure under negative wind load on the Y-axis is shown in **Fig. 7**. (b), with the maximum deformation at the longitudinal beam of the first floor far from the left end of the structure, at 11.2 mm. The overall displacement diagram of the structure under the vertical upwind load is shown in **Fig. 7**. (c), and the maximum deformation of the structure is at the middle span of the top left crossbeam, which is 28.6 mm. According to the Technical Code for Engineering Bamboo Structures (DB32/T 5080-2025) [26], the horizontal inter-floor displacement of the structure under wind load should not exceed 1/250 of the structural floor height and hence the allowable value of this structure is 18 mm. The deflection limit of the structure is l/250, the allowable value of this structure is 29 mm, Therefore, the wind load deformations are in compliance with the code requirements.



(a) WINDX+ displacement diagram (unit: mm)



(b) WIND-displacement diagram (unit: mm)



(c) WINDUP displacement map (unit: mm)

Fig. 7. Wind load displacements obtained from the 3D model

4.2 Structural component verification

The bending stress envelope diagram of the structural component is shown in **Fig. 8**. The maximum stress value is at the top beam of the structure is 8.3 MPa, which is significantly less than the bending resistance of the material 42.3 MPa.

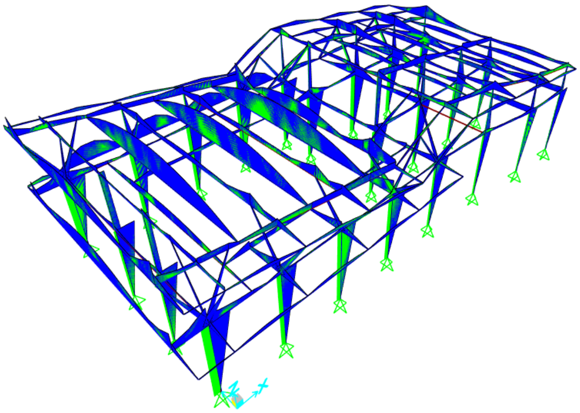


Fig. 8. ULS Bending Stress Diagram (unit: MPa)

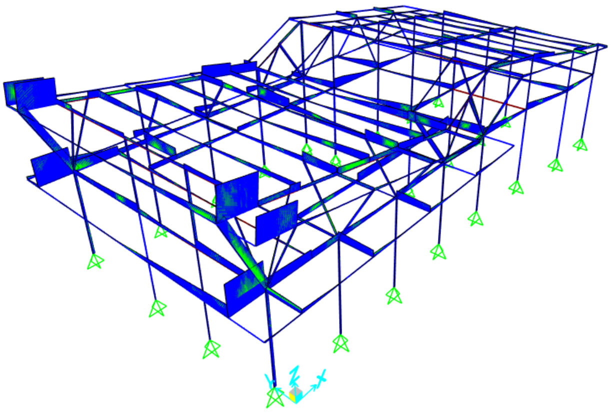


Fig. 9. ULS Shear Stress Diagram (unit: MPa)

The structural shear stress envelope diagram is shown in **Fig. 9**. The maximum shear stress is located in the longitudinal beam on the left side of the structure, with a value of 1.3 MPa, which is less than the longitudinal shear strength of the material at 4.3MPa.

4.3 SLS verification under normal operating conditions

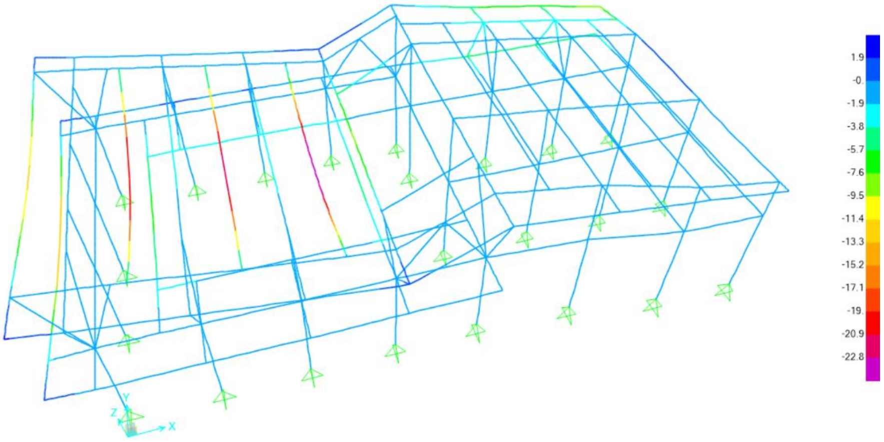


Fig. 10. SLS Displacement Diagram (Unit: mm)

The maximum deformation with a value of 22.8 mm is at the middle span of the top crossbeam on the left side of the structure, as shown in **Fig. 10**. According to the Technical Code for Engineering Bamboo Structure Buildings (DB32/T 5080-2025) [26], the deflection limit of the structure is l/250, and the allowable value of this structure is 29 mm, which complies with the code.

After finite element analysis and result verification, the cross-sectional dimensions that meet the strength and deformation requirements specified in the standard were obtained as shown in building dimensions **Fig. 11**. and component dimensions **Table 2**.

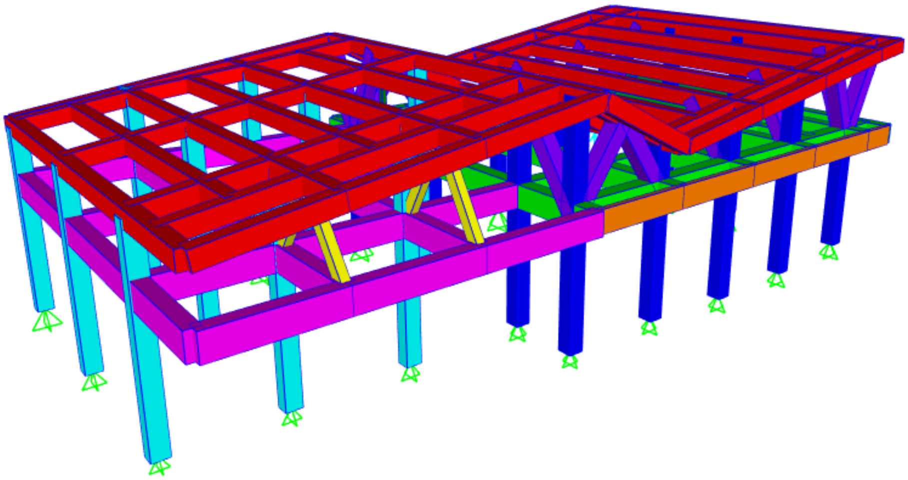


Fig. 11. Architectural Dimensions diagram

Table 2. Component Dimensions Table

Column section 300 mm×300 mm	🟦	Beam section 250 mm×450 mm	🟪	Diagonal bracing section 300 mm×300 mm	🟪
Column section 300 mm×250 mm	🟦	Beam section 300 mm×450 mm	🟩	Diagonal bracing section 200 mm×200 mm	🟨
Beam section 250 mm×300 mm	🟥	Beam section 100 mm×450 mm	🟧		

5 Construction

After determining the cross-sectional dimensions of each component and the connection form of each node based on the finite element analysis simulation, the three-dimensional construction model was developed, which included the filling plate bolt connection form at each joint, as well as the dimensions of the steel fill plate, the bolt dimensions, and the dimensions of the slotting and drilling of the components at the joints. The plans of the beams, columns and connectors were then drawn and sent to the factory for processing and production. After the components were produced, they were transported to the construction site.

Fig. 12. Connections for the bottom of columns

After the components are delivered to the construction site, reinforced concrete foundations were used to make the ground flat and ensure that the height difference between the indoor and outdoor floors is not less than 300 mm. Before the foundation works, the steel fill plate connectors were installed and connected to the ground at the column base. These connectors not only fix the columns but also act as buffer plates to prevent water and moisture from the column base and prevent the columns from being corroded. After the concrete foundation has been cured and hardened, the column was bolted to the connection piece at the bottom to fix the column, as shown in **Fig. 12**. The elevated bamboo column base is designed to prevent water accumulation during heavy rainfall or flooding events. Additional protective measures, including drainage, waterproofing, and moisture-proofing, had been implemented around the foundation to mitigate water ingress and protect the structure from moisture-related deterioration. **Fig .13** shows the erected columns with the connections on the top which are mainly for connecting beams.

Fig. 13. Construction of columns

Fig. 14. Assembly of prefabricated components

After the columns were installed, the other components were transported to the site, and then the beams were lifted to the corresponding positions using a small crane, with the beam ends connected by bolts, as shown in **Fig. 14**. Since the beam-column connection and beam-beam connections are in the form of steel-filled plate bolts, the fire protection of the metal connectors can be achieved by blocking the bolt holes with wooden plugs and filling with fireproof blocking materials in accordance with the provisions of GB/T 50005 [25].

Fig. 15. Main structure frame

After the main structure frame (**Fig. 15**) was installed, the project team successively carried out the installation of the glass curtain wall, the interior partition walls and roof. The design, processing, on-site installation and final acceptance of the glass curtain wall according to Hong Kong Building Regulation Chapter 123. After all the wall panels were installed in place, the interior decoration construction was immediately carried out, and the laying and installation of electrical pipelines and water supply and drainage pipes were completed simultaneously, shown in **Fig. 16**.

Fig. 16. Bolted connections

Fig. 17. The completed building

Given that the project site is located in a termite hazard zone Z4, all building components were subject to systematic protective treatment. The wooden base surface was thoroughly cleaned to ensure no oil stains, moisture or dust remained, and then transparent wood varnish was applied. Afterwards, a special insecticide and preservative were evenly applied to the surface of the components followed by application of fireproof coating as per the design requirements, and an outdoor flame-retardant coating was applied over the entire surface. The selection of materials, construction techniques and quality control of the outdoor flame-retardant coating were all in accordance with the relevant provisions of the "Code for Design of Timber Structures" (GB/T 50005—2017) [25]. **Fig. 17** shows the interior and exterior real effects after the building was completed.

6 Conclusions

This paper presents the design and construction process of two-story LBL building that is used as community liaison centre at the Ma Liu Shui Waterfront Promenade in Sha Tin District, Hong Kong Special Administrative Region. This project serves as a useful engineering case study demonstrating the structural viability and lifecycle benefits of engineered bamboo composite materials in civil engineering. To optimize structural efficiency, a hybrid analytical-numerical design workflow was implemented; preliminary cross-sectional geometries were established using manual mechanics-based calculations and subsequently validated and refined through finite element analysis to maximize material utilization. Adopting Design for Manufacture and Assembly (DfMA) principles, the primary load-bearing elements, envelope components, and connection nodes were prefabricated off-site under strict quality control conditions. This logistical strategy optimized the construction schedule and minimized the project's environmental footprint by shifting the installation critical path to rapid, low-impact on-site assembly requiring minimal field labor and low-capacity hoisting equipment. Ultimately, this deployment establishes a scalable design-and-construction framework that proves the economic and structural feasibility of utilizing engineered bamboo for low-rise civil structures and sustainable infrastructure.

Acknowledgments

Authors sincerely thanks to Civil Engineering Development Department in providing such an opportunity to allow this building to be the first permanent building in Hong Kong made by engineering bamboo. Special thanks to the architecture -Mr Tony Yip, Bamboo International Alex Chui to supply and fabricate the material, Ir Eddie Tse of Gammon as the contractor for this building. Authors also like to thanks to Wei Wei, Linhao Wu, Zeyu Zhang, Chuanxi Cheng, Sixu Hu, Junchuang Zhang, Linji Ying, Yifan Wang, Lincai Ge, Wenjing Zhou and others from Nanjing Forestry University for their assistance.

Fund Statement

This work was supported by the National Natural Science Foundation of China (No. 51878354 & 51308301); the Natural Science Foundation of Jiangsu Province (No. BK20181402 & BK20130978); 333 high-level talent projects of Jiang-su Province; and Qinglan Project of Jiangsu Higher Education Institutions. All research outcomes presented in this paper are those of the writer(s) and do not necessarily reflect the views of the foundations.

CRediT Author Contribution Statement

Peng Zhou: Investigation, Formal analysis, Writing – original draft. **Haitao Li**: Conceptualization, Funding acquisition, Supervision, Investigation, Formal analysis, Writing – original draft. **Ching Sai Chui**: Supervision, Investigation. **Jiarong Shi**: Supervision, Writing – review & editing. **Shuai Liu**: Supervision, Writing – review & editing. **Weitao Li**: Writing – review & editing. **Tianxiang Lan**: Writing – review & editing. **Mahmud Ashraf:** Supervision, Investigation, Formal analysis, Writing – original draft. **Rodolfo Lorenzo:** Supervision, Investigation. **Priscilla Omouendze Mouaragadja:** Supervision, Investigation. **Shan Zhao:** Supervision, Investigation. **Goman Ho**: Supervision, Investigation, Formal analysis, Writing – review & editing. **Zhenhua Xiong:** Supervision, Investigation.

Conflict of interest Author statement

They have no conflict of interest to report for this study.

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