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Ecological Corridor Bridge Design for Honggang Park, Shenzhen: Kunpeng Trail Bridge No. 3

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Abstract: As a core node project of Shenzhen's "Mountain-Sea-City Connectivity Plan," Kunpeng Trail Bridge No. 3 is located in Qingshuihe Subdistrict, Luohu District. The bridge represents an innovative approach to enhancing ecological connectivity in a high-density urban environment. It adopts a cable-assisted continuous steel truss structure that spans Qingshuihe 3rd Road and Metro Lines 14 and 17. By connecting the western and eastern Maling areas of Honggang Park, the bridge effectively mitigates ecological fragmentation caused by transportation infrastructure barriers. This paper systematically presents the design concepts and key technological innovations associated with the bridge, including its overall layout, structural system, stay cables and anchorage systems, human-induced vibration control, ecological protection and durability measures, and incremental launching construction methods. The study provides valuable technical references for the design and construction of similar long-span ecological corridor bridges.

Keywords: ecological corridor bridge; cable-assisted steel truss; external cable anchorage; ecological protection; incremental launching method

Project Report

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1 Project Overview

Kunpeng Trail Bridge No. 3 is located in Qingshuihe Subdistrict of Luohu District, Shenzhen, and spans Qingshuihe 3rd Road to connect the eastern and western Maling areas of Honggang Park. As a key component of the Honggang Park Renovation and Ecological Corridor Construction Project (Phase II), the bridge addresses the ecological fragmentation caused by transportation infrastructure that divides the park. Its primary objective is to restore ecological connectivity and establish a continuous regional ecological corridor.

The bridge site presents several complex environmental constraints. The bridge crosses Qingshuihe 3rd Road, a major urban arterial roadway, as well as Metro Lines 14 and 17. Sensitive facilities, including a counterterrorism center, are located beneath the eastern approach, along with dense underground utility networks. In addition, a 500 kV high-voltage power line crossing the bridge alignment diagonally imposes strict limitations on the structural depth and construction methods (Figure 1). As a key component of Shenzhen's "Mountain–Sea–City Connectivity Plan," the bridge is required not only to provide ecological connectivity but also to integrate ecological conservation with urban spatial design [1-3]. The plan layout of Kunpeng Trail Bridge No. 3 is shown in Figure 2.

2 Key Technical Standards

· The design loads comply with the *Pedestrian Overhead Bridge and Corridor Design Standard* (SJG 70—2020), with a pedestrian live load of 5 kPa.

· The ecological planting zones utilize lightweight planting soil with an average thickness of 0.5 m and a saturated unit weight not exceeding 13 kN/m^3), corresponding to a design load of 6.5 kPa.

· Construction and maintenance load: 0.5 kPa [4].

· Seismic Design Criteria: Basic Intensity VII; Peak ground acceleration (PGA): 0.10 g; Site classification: Class II; Seismic importance category: C; Seismic Design Method: A.

· The bridge is designed for a service life of at least 100 years, and the corrosion protection system for the steel structure is designed for a service life of at least 25 years.

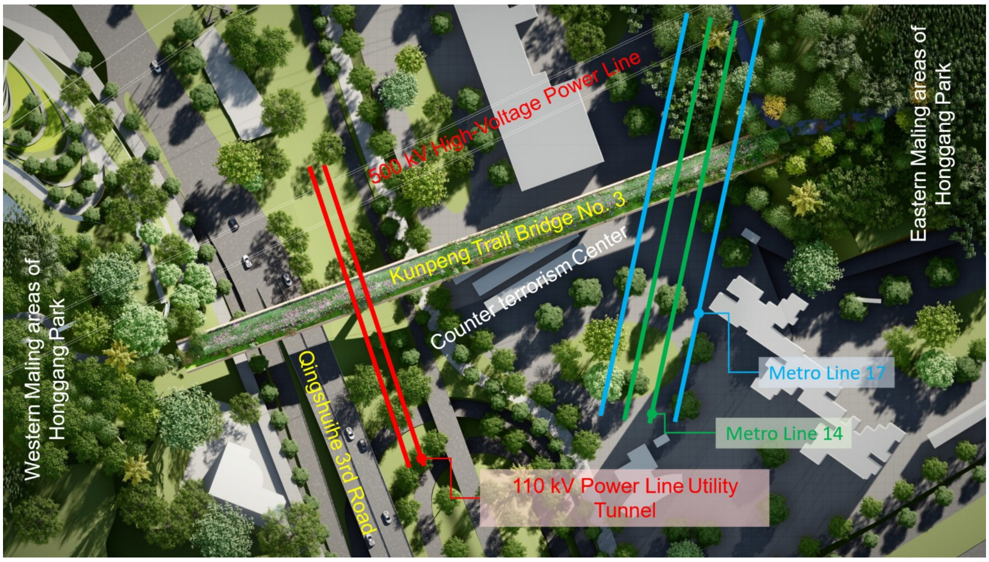


Figure 1 Design constraints of Kunpeng Trail Bridge No. 3

Figure 2 Rendering of Kunpeng Trail Bridge No. 3

3 General Layout

Considering topographical constraints, ecological requirements, and structural efficiency, the bridge adopts a continuous steel truss system with a span arrangement of 1.58 (cantilever) + 70 + 83 + 62.83 m. The total bridge length is 217.41 m, with an 83-meter main span, making it the longest completed ecological corridor bridge in Shenzhen (Figure 3). The bridge is located on a straight alignment, with a cross-section comprising 0.9 m (drainage gutter) + 4.0 m (pedestrian/bicycle path) + 8.0 m (ecological planting zone) + 1.1 m (drainage gutter), totaling 14 m in width (see Figure 4). The planting zone accounts for approximately 65% of the total bridge width, highlighting the ecology-first design philosophy.

The variable-depth truss ranges from 6.75 m at the intermediate supports to 3.75 m at midspan and transitions smoothly through circular curves. This configuration optimizes structural efficiency, minimizes the structural envelope to satisfy clearance requirements beneath the high-voltage power lines, and creates a visually lightweight appearance.

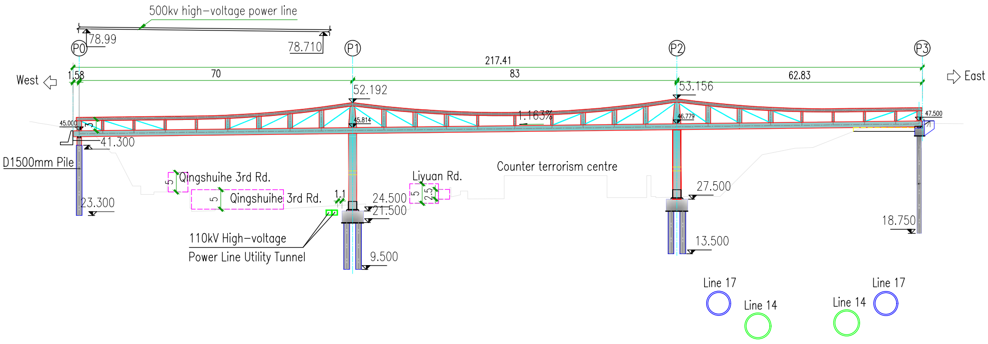


Figure 3 Elevation layout of Kunpeng Trail Bridge No. 3（unit：m）

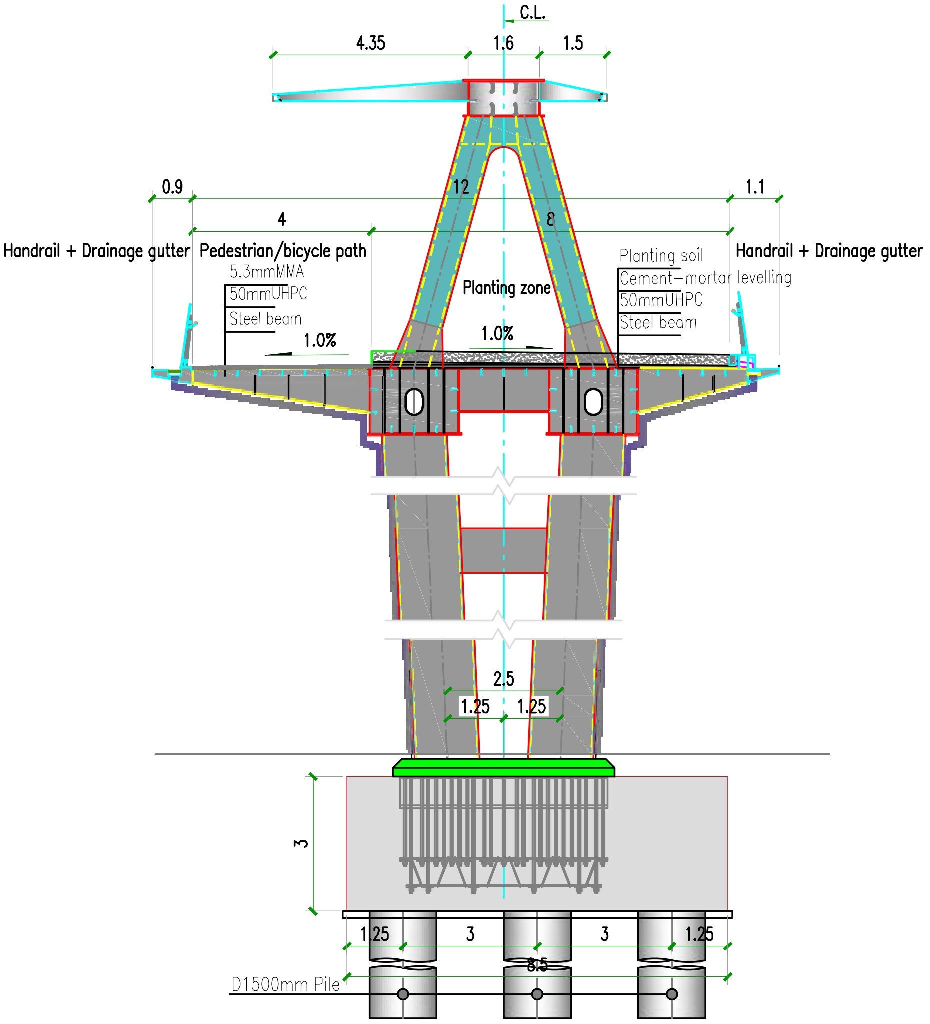


Figure 4 Typical cross-section of Kunpeng Trail Bridge No. 3（unit：m）

The superstructure adopts a cable-assisted continuous steel truss system (Figure 5). The top chords, bottom chords, and vertical members utilize box sections, whereas the diagonal members consist of tension-only stay cables, forming a collaborative beam-truss-cable load-bearing system. This hybrid structural system combines the stiffness advantages of girder bridges with the load-carrying efficiency of truss bridges. The cable assistance reduces internal forces and structural self-weight while maintaining structural transparency and aesthetic appeal.

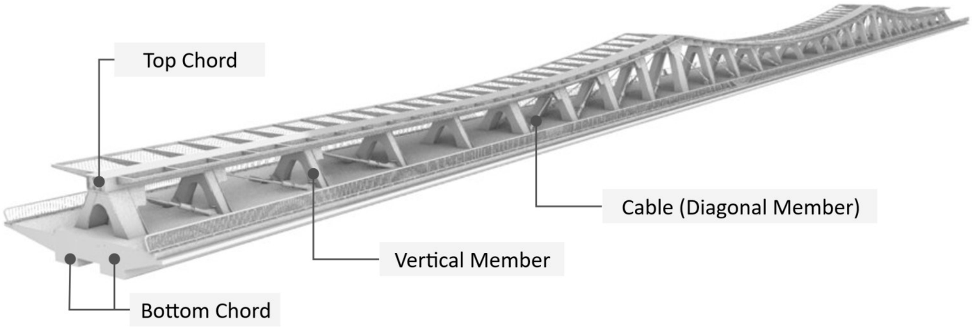


Figure 5 Cable-assisted truss structural system

The substructure consists of steel-column piers with rigid pier–girder connections. Individual columns measure 2, 100 × 1, 350 mm, with flange and web thicknesses ranging from 30 mm to 40 mm. Pier P0 utilizes a pile-column foundation with a diameter φ of 1,200 mm, whereas abutment P3 adopts an embedded configuration that integrates seamlessly with the surrounding terrain. Because of the restricted construction site conditions, manually excavated piles with diameters ranging from 1,200 to 1,500 mm were adopted. These piles are socketed into moderately weathered and slightly weathered granitic bedrock with minimum socket depths of four times the pile diameter (4D) to ensure adequate bearing capacity and structural stability.

4 Stay Cable and Anchorage Design

4.1 *Cable Selection and Arrangement*

Structural analysis indicated that the cable forces at the completion stage range from 1,240 kN to 1,850 kN. The diagonal members therefore utilize PES7-139 galvanized high-strength steel strands, which provide high tensile strength and excellent corrosion resistance [5] (Figures 6 and 7). The tension-only design converts compression members in conventional trusses to tensile elements, leveraging the high tensile strength of the steel to minimize cross-sectional dimensions and enhance structural transparency. The cables are arranged diagonally throughout the truss, forming stable triangular load-transfer units with the top and bottom chords, thereby improving overall structural stiffness and lateral stability.

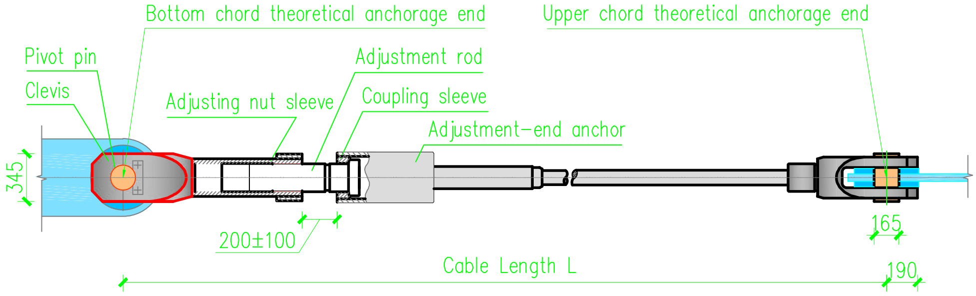


Figure 6 Stay cable configuration（unit：mm）

4.2 *External Cable Anchorage Assembly*

To address the challenges associated with limited installation space and complex construction requirements at the upper ends of the diagonal members, an external cable anchorage assembly was developed (Figure 8). In this configuration, the cable lug is positioned between two external anchor plates and secured by welding. The external anchorage plates are then welded directly to the anchorage beam or column. The fully exposed anchorage configuration features a simple structural configuration and excellent constructability, eliminating the complex

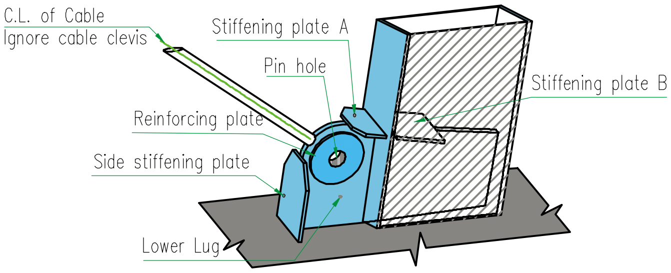


Figure 7 Lower anchorage detail

detailing and difficult field welding operations typically associated with conventional embedded cable-lug anchorage systems.

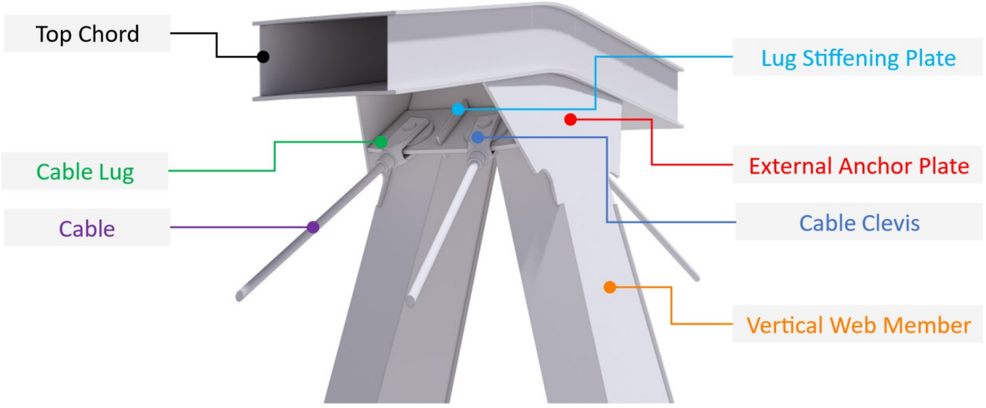


Figure 8 Embedded anchorage assembly at the upper node

4.3 Structural Analysis of the External Cable Anchorage

All steel plates used in the externally mounted cable anchorage assembly are fabricated from Q420D structural steel, with a maximum plate thickness of 40 mm. Local finite element analysis indicated a maximum local stress of 320 MPa under the governing load combinations (Figure 9). The peak stress occurred at the weld termination between the cable lug and the external anchorage plates. Because this stress concentration is confined to a highly localized region, the analysis confirmed that the anchorage assembly satisfies all structural performance requirements. Furthermore, the exposed anchorage configuration facilitates future inspection, maintenance, and replacement operations, thereby contributing to an extended service life of the cable system.

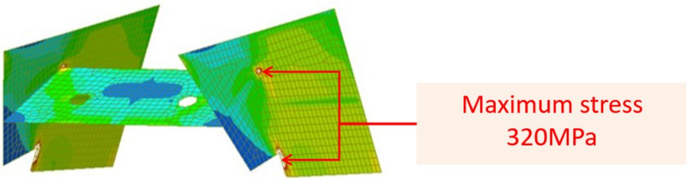


Figure 9 Local stress distribution in the cable anchorage assembly

5 Ecological Protection and Durability Design

5.1 Durability Measures

A multilayered protection system (Figure 10) was developed to ensure long-term durability while supporting the bridge's ecological function:

(1) A 50-mm-thick UHPC layer is applied to steel surfaces that are in direct contact with planting soil, including the bridge deck within the ecological planting zones (◎), climbing-plant troughs (◎), and embedded portions of the truss diagonal members (◎). This layer prevents direct corrosion from soil and moisture while

effectively inhibiting root penetration, thereby ensuring structural integrity.

(2) The portions of the steel columns embedded in the ground ◎ are encased in C40 concrete to provide enhanced corrosion resistance and impact protection.

(3) Stainless steel mesh ◎ is installed on the exterior sides of the truss diagonal members. The mesh supports the growth of climbing vegetation while preventing direct attachment of plant roots to steel surfaces, thereby reducing the risk of corrosion.

(4) Both internal and external steel surfaces are protected by a long-life corrosion protection system designed to provide a service life of at least 25 years.

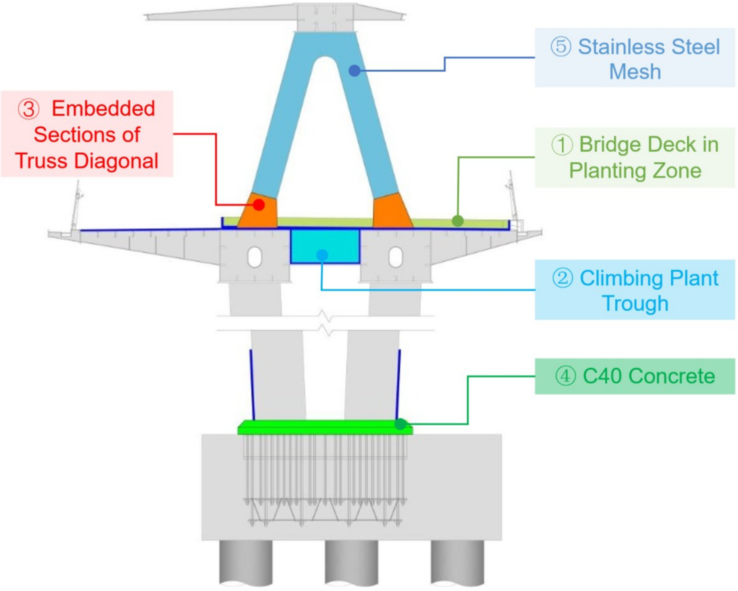


Figure 10 Durability protection details

5.2 *Multifunctional Drainage System*

An efficient drainage system is essential for maintaining ecological functionality, structural durability, and user safety. To facilitate future inspection and maintenance, the project incorporates an innovative multifunctional drainage system (Figure 11) that integrates ecological drainage, maintenance access platforms, debris containment, and aerodynamic wind fairings. The drainage channels are located through a combination of filtration units, transverse drainage pipes, and longitudinal drainage troughs. Removable grating covers allow convenient access for routine inspection and maintenance [6].

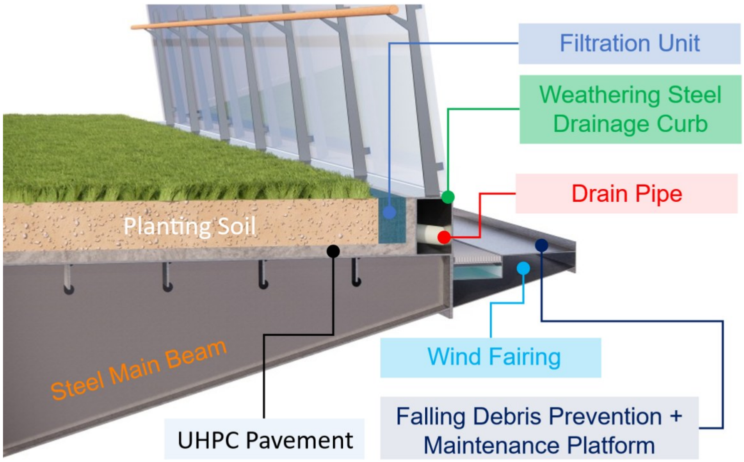


Figure 11 Multifunctional drainage configurations

6 Human-Induced Vibration Analysis and Control

6.1 *Vibration Characteristics Analysis*

Control of vibration serviceability is a critical design consideration for long-span pedestrian bridges [7]. Modal analysis of Kunpeng Trail Bridge No. 3 identified the fifth mode (1.151 Hz), seventh mode (1.542 Hz), and ninth mode (1.891 Hz) as vertical vibration modes among the first eighteen natural frequencies. The seventh and ninth natural frequencies fell within the critical frequency range of 1.25–3.0 Hz associated with pedestrian-induced vibrations and therefore required detailed comfort evaluation.

According to the *Technical Specifications for Urban Pedestrian Overpasses and Underpasses* (Draft), the pedestrian comfort should achieve a rating higher than CL3, preferably satisfy the CL1 standard. For the critical vibration modes, pedestrian-induced vibration analyses were conducted as follows:

· Case 1 (1.542 Hz): The pedestrian load function per unit area is $p_v(t)=280\times cos(2\pi\times 1.542t)\times 0.6489\times 0.077$. The calculated maximum vertical acceleration at the midspan of the side span is 0.366 m/s^2, corresponding to comfort level CL2 (satisfactory).

· Case 2 (1.891 Hz): The pedestrian load function per unit area is $p_v(t)=280\times cos(2\pi\times 1.891t)\times 1\times 0.077$. The calculated maximum vertical acceleration at the midspan of the side span is 0.607 m/s^2, corresponding to comfort level CL2 (satisfactory).

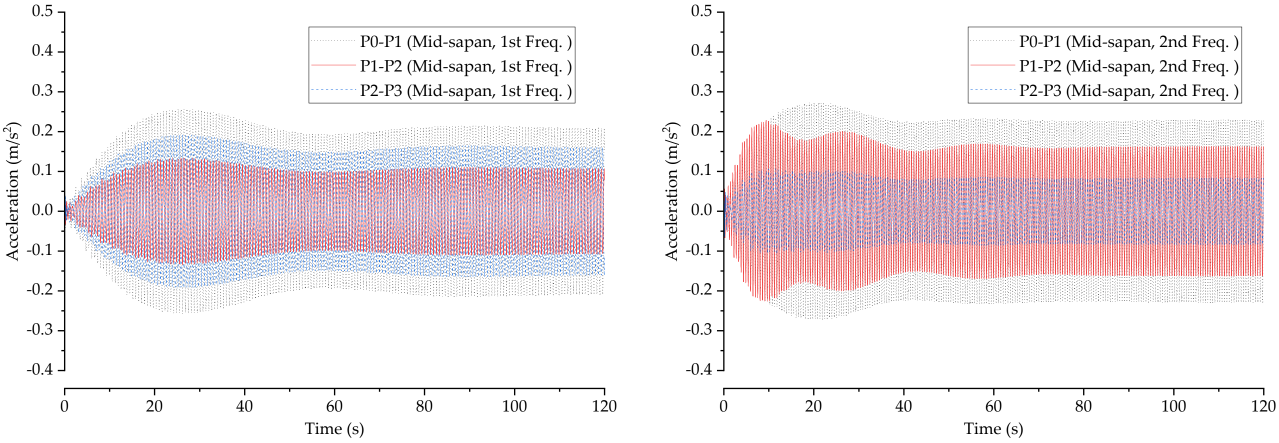
6.2 *Tuned Mass Damper (TMD) System*

To improve the vibration performance to the CL1 comfort level, tuned mass dampers (TMDs) were designed and installed.

· Main-span TMD (located at the center of the main span): mass = 10,000 kg; stiffness = 1,297,106 N/m; damping coefficient = 27,226 N·s/m.

· Side-span TMD (located at the center of the side span) mass = 5,000 kg; stiffness = 676,306 N/m; damping coefficient = 10,143 N·s/m.

Following installation of the TMD systems, the vibration reduction performance was significant. The maximum acceleration in Case 1 was reduced to 0.256 m/s^2, while that in Case 2 was reduced to 0.273 m/s^2. Both cases satisfy the CL1 comfort criteria, providing an excellent pedestrian experience (Figure 12).



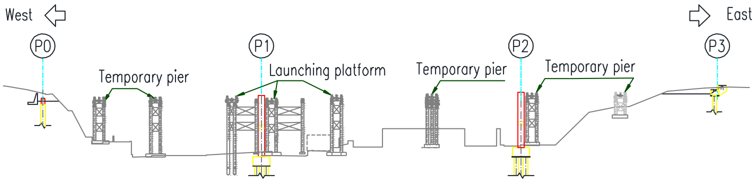
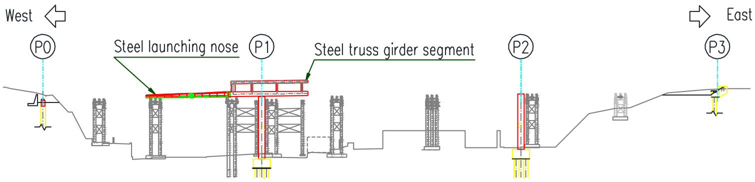
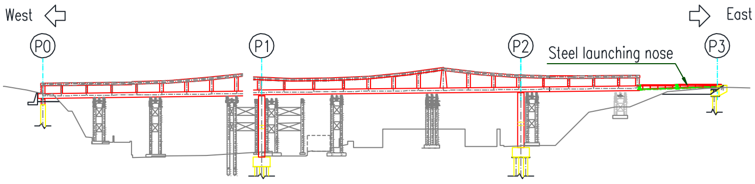
a) Case 1 b) Case 2

Figure 12 Midspan acceleration time histories under time-varying pedestrian loading with TMDs installed

7 Construction Method

Given the constrained site conditions, dense underground utility networks, and proximity to sensitive facilities such as the counterterrorism center and metro lines, conventional scaffold-supported construction would have caused significant disruption to traffic and the surrounding environment. Accordingly, the bridge was erected using an incremental launching method (Table 1). A launching platform was established at Pier P1, from which prefabricated steel truss segments were progressively launched to their final positions. This construction approach significantly reduced on-site operations while minimizing impacts on traffic, underground infrastructure, and nearby facilities.

Table 1 Construction sequences

Step 1: **(1) Prepare and level the site, construct retaining walls, pile foundations, pile caps, abutments, and related substructure elements. Simultaneously, fabricate the steel structural components in the factory.** **(2) Erect the steel columns and install the launching platform, lifting equipment, temporary piers, and other temporary construction facilities (Figure 13a)).**	
Step 2: Install the launching nose and assemble the steel truss girder segments.	
Step 3: Assemble and incrementally launch the steel truss girder segments in accordance with the construction sequence.	

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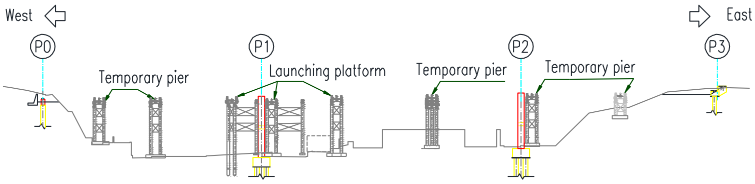
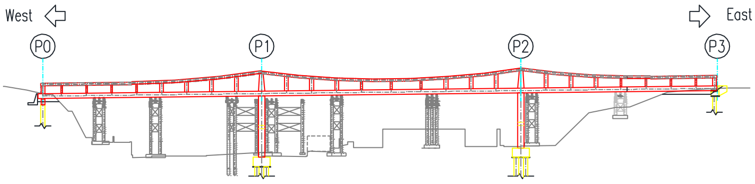
Step 1: **(1) Prepare and level the site, construct retaining walls, pile foundations, pile caps, abutments, and related substructure elements. Simultaneously, fabricate the steel structural components in the factory.** **(2) Erect the steel columns and install the launching platform, lifting equipment, temporary piers, and other temporary construction facilities (Figure 13a).**	
Step 4: Upon completion of the launching operation, remove the launching nose and complete closure of the steel truss girder. Subsequently, complete the rigid pier-girder connection (Figure 13b)).	

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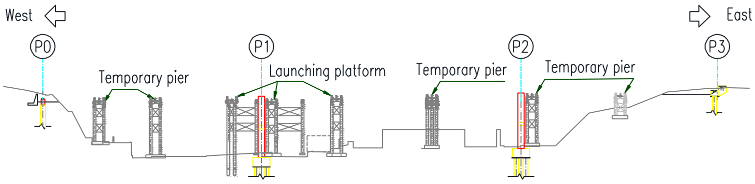
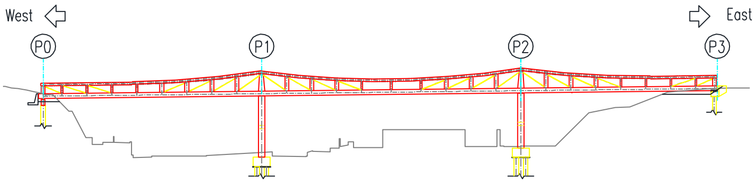
Step 1: **(1) Prepare and level the site, construct retaining walls, pile foundations, pile caps, abutments, and related substructure elements. Simultaneously, fabricate the steel structural components in the factory.** **(2) Erect the steel columns and install the launching platform, lifting equipment, temporary piers, and other temporary construction facilities (Figure 13a)).**	
Step 5: (1) Tension the stay cables symmetrically in stages, dismantle the temporary structures, lower the main structure onto its permanent bearings, and adjust the cable forces to their final design values. (2) Complete ancillary works, including the installation of gallery frames, railings, deck surfacing, and architectural finishes, and then open the bridge to service.	

a）Segment launching b）closure segment erection

Figure 13 Incremental launching process

8 Conclusions

Kunpeng Trail Bridge No. 3 successfully integrates ecological functionality with structural performance through a series of innovative design solutions.

(5) Structural innovation balancing ecological and engineering requirements: The cable-assisted continuous steel truss system combines the stiffness advantages of girder bridges with the load-carrying efficiency of truss bridges. This structural solution satisfies the primary objective of ecological connectivity while ensuring structural safety, stability, and efficiency.

(6) Optimized layout addressing multiple design constraints: The variable-depth truss configuration accommodates the clearance restrictions imposed by the high-voltage transmission line while reducing the visual impact of the structure. The composite cross-section, consisting of a "pedestrian/bicycle path and an ecological planting zone", allocates approximately 65% of the bridge width to ecological functions, fully reflecting the ecology-first design philosophy.

(7) Integrated durability and drainage systems enhancing long-term performance: A comprehensive durability protection system, including UHPC isolation layers, concrete encasement, stainless steel mesh protection, and long-life corrosion-resistant coatings, was implemented to mitigate corrosion and prevent root intrusion. The multifunctional drainage system integrates ecological drainage, maintenance access, and debris containment functions, thereby supporting long-term serviceability.

(8) Innovative solutions addressing project-specific challenges: The external cable anchorage assembly effectively resolves anchorage construction challenges in confined spaces while improving future accessibility for inspection and maintenance. In addition, the TMD vibration control system successfully improves pedestrian comfort to the CL1 level, satisfying the serviceability requirements of a long-span pedestrian bridge.

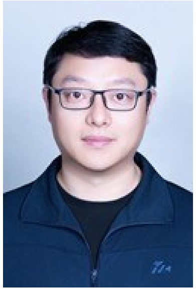
(9) Construction methodology minimizing environmental impacts: The incremental launching method was selected to address the narrow construction site and the close proximity of sensitive facilities, and underground infrastructure. This approach minimized on-site construction activities and reduced impacts on traffic, utilities, and the surrounding environment while ensuring efficient bridge erection.

The completion of Kunpeng Trail Bridge No. 3 restored the ecological discontinuity within Honggang Park and established an integrated ecological corridor that strengthens the connection between urban, mountain and coastal environments. The project also provides valuable experience in the design and construction of long-span ecological corridor bridges in high-density urban areas. Its innovative technologies and engineering practices offer practical references for future ecological connectivity projects. Some photos of the completed Kunpeng Trail Bridge No. 3 are shown in Figure 14.

Figure 14 Completed Kunpeng Trail Bridge No. 3

Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

Data Availability Statement: Data Availability**Statement**: The data that support the findings of this study are available from the corresponding author upon reasonable request.

	**Fuhai Jiang** **M.E., Professor Engineer. He Graduated from TongJi University in 2010.** **Research Direction：Bridge Design and Research.** **Email: sz22jfh@tjad.cn**		**Jiazhao Liu** **M.E., Engineer. He Graduated from Shenzhen University in 2018, Majoring in Civil Engineering.** **Research Direction: Management and Research of Building Construction and Landscaping Engineering for Government Invested Projects.** **Email: 774609921@qq.com**
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