Project Report

Landscape Design of the Fujiang River Bridge on Sci-Tech City Avenue in Mianyang, Sichuan

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Abstract: The Fujiang River Bridge on Mianyang Sci-Tech City Avenue, located in Sichuan Province, is a critical node project of Sci-Tech City Avenue. Its main bridge, spanning the Fujiang River, is a single-span 255-meter under-slung basket-type steel box tied-arch bridge. Based on the design principle of "structure as landscape", the design adopts the theme "playing strings and composing rhymes". It extracts "lines" as landscape design elements, integrating bridge functionality, visual aesthetics, and force characteristics. The arch ribs are designed with a 1.9-order parabolic shape, while the stay cables are arranged radially. The deck uses steel box girders to achieve tie rod functions, forming an image of "strings-bow body-harp base". The bridge plaque is themed "Riding the Waves of the Fujiang River", featuring a curved design. Night scene design employs dynamic lighting to enhance the imagery of harp strings through the interplay of light and shadow on the arch ribs and stay cables. Through integrated structural-landscape design, the project has become a technological culture landmark in Mianyang, enhancing traffic efficiency and urban imagery.

Keywords: bridge landscape design; thrustless basket-type arch bridge; structural aesthetics; night scene design

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1 Introduction

The Fujiang River Bridge on Mianyang Sci-Tech City Avenue is located approximately 1.5 km upstream of the Fujiang River Bridge on the Mianyang-Guangyuan Expressway. The project starts at Longmen Town (Fucheng District) on the west bank and ends at Shima Town (Youxian District) on the east bank, with a total length of 1,100.6 meters. It is planned as an urban expressway with a design speed of 60 km/h, featuring a bidirectional six-lane configuration, and includes nonmotorized vehicle lanes and pedestrian walkways on both sides.

As a critical transportation hub within the Mianyang Science and Technology City Concentrated Development Zone, the bridge connects the northern and southern sections of Sci-Tech City Avenue across the Fujiang River, serving as a rapid transit corridor. Additionally, through its architectural design and landscape integration, the bridge has become a significant project for enhancing a city's overall image [1].

2 Bridge Landscape Design

2.1 Analysis of Surrounding Bridges

The Fujiang River flows through Mianyang city, where more than ten bridges have been constructed to date, showcasing a diverse range of bridge types. By investigating the geographical and environmental characteristics of the surrounding bridges, this study analyzes their structural forms and landscape integration. The findings provide a basis for determining the most suitable bridge design and aesthetic approach for this project.

Table 1 Constructed Bridges in Mianyang (Partial)

Initial construction year	Bridge name	Bridge type	Span arrangement
1955	Baoji-Chengdu Railway Fujiang River Bridge	Simply supported steel truss girder bridge	Main span 44 m
1967	Dongfanghong Bridge	Deck arch bridge	3×80 m
1986	Hongyan Power Station Bridge	T-beam girder bridge	15×20 m
1997	Fule Bridge (Fujiang Third Bridge)	Half-through truss arch bridge	46 m+202 m+46 m
2012	Sanjiang Bridge	Cable-stayed bridge	100 m+200 m+100 m
2015	Hanlong Bridge	Continuous rigid-frame bridge	85 m+150 m+85 m
2018	Chuanjiao Bridge (Mianxi Expressway)	Continuous girder bridge	165 m + 2×85 m
2019	Fujiang Great Bridge	Continuous girder bridge	75 m+128 m+75 m
2021	Science City Bridge	Under-slung arch bridge	120 m+280 m+120 m
2023	Fulin Bridge (Peach Blossom Island Bridge)	Continuous girder bridge	65 m+110 m+65 m

Table 1 shows that the bridges built over the Fujiang River in Mianyang city are relatively rich in bridge types, including concrete girder bridges, arch bridges, and cable-stayed bridges. The main structural forms of the built bridges in Mianyang city are listed in Figure 1, among which the simply supported girder bridges, continuous girder bridges, under-slung steel truss bridges and deck arch bridges lack towering structures above the decks, resulting in relatively monotonous and flat visual characteristics. Although they meet the basic transportation function requirements, their landscape performance is rather bland, making it difficult to form a visual focus that echoes the surrounding environment or urban culture, and the overall landscape effect is not ideal. This project is located in Science and Technology City. To highlight the importance of Mianyang's 'science and technology' and to consider the spanning capacity and advanced nature of the project, this project proposes a basket-type arch bridge scheme with a span of 255 m across the Fujiang River (structural schematic diagram in Figure 2). By utilizing soaring arch ribs and a radial layout of stay cables, a significant vertical visual element is formed above the bridge deck, creating a striking contrast with the horizontal deck. This structural form with vertical height not only makes the bridge visually more dynamic and iconic but also strengthens the interaction between the bridge and the city skyline, highlighting the vertical hierarchy and rhythm of the bridge landscape.

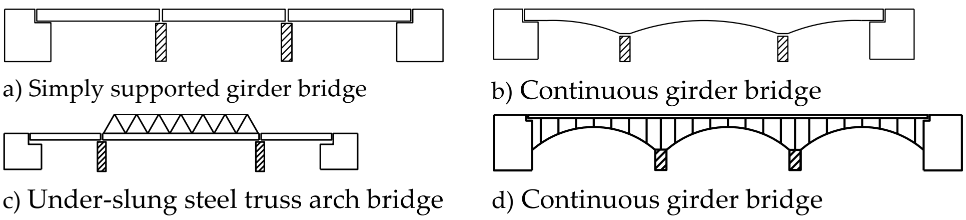

Figure 1 Schematic diagram of existing bridge structures in Mianyang city

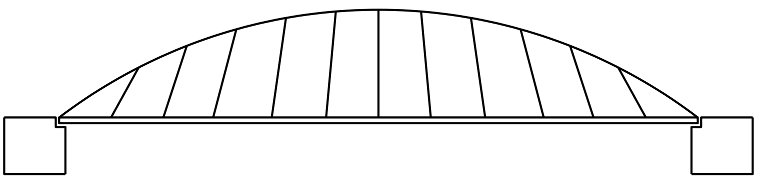

Figure 2 Diagram of the project's structural form

2.2 Design Philosophy

This proposal adopts the core design philosophy of "structure as landscape" [2], emphasizing the structural form itself and minimizing unnecessary decorative elements. This concept perfectly aligns with the clean and efficient load-bearing structure of arch bridges. As an ancient bridge type, arch bridges inherently convey a minimalist aesthetic in their structural behavior, particularly tied-arch bridges. Their force distribution is straightforward (see Figure 3), with no redundant components—each element serves a functional purpose: the arch ribs bear compression, hangers bear tension, and the bridge deck bears vehicular traffic while also functioning as a tie to balance the thrust at the arch ends. The beauty of balance is presented in a dynamic interplay between tension and relaxation. A rendering of the project is shown in Figure 4.

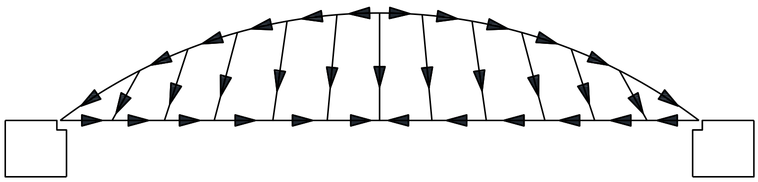

Figure 3 Tied arch force distribution diagram

Figure 4 Project rendering (aerial view)

2.3 Bridge Landscape Design Elements

Historically, Mianyang has had a rich cultural heritage in **guqin** music, an ancient Chinese zither. Evidence of this tradition includes the guqin-playing figurine unearthed from the Eastern Han Dynasty Hejiashan Cliff Tomb (a 112 cm seven-string gray pottery guqin) [3], the "Baxi County-made" rosewood tuning peg from the Tang Dynasty tomb at Kaiyuanchang (8th century AD) [4], and the 24 guqin compositions preserved in the national intangible cultural heritage "Wenchang Dongjing Ancient Music" [5]. These artifacts collectively attest to Mianyang's millennium-long guqin tradition since the Han and Tang dynasties. Inspired by this cultural legacy, the design adopts the theme "playing the strings and composing rhymes", with the "line" as the core design element. This approach not only aligns with the minimalist design philosophy but also complements the structural characteristics of the under-slung tied-arch bridge. The "line" serves as the central expressive form throughout the bridge's landscape design, combining "straight lines" and "curves" to embody the beauty of "movement and stillness" and "rigidity and softness" in the structure.

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The design language of the "line" is realized through the linear arrangement of the hangers, arch ribs, and bridge deck contours, achieving a unified balance of visual and functional aesthetics. The arch ribs, as the primary load-bearing components, are the core embodiment of "curves". Their arc-shaped design and relatively large dimensions not only convey a dynamic expression but also transmit the balance of forces and structure. The arch ribs resemble the bow of a giant harp, echoing the hangers that symbolize the strings. The slender bridge deck adopts horizontal "straight lines" parallel to the water surface, evoking a sense of balance and creating a striking contrast with the curved arch ribs. Simultaneously, it functions as the "bowstring", balancing the horizontal thrust at the arch ends. The hangers, as "straight-line" elements, are the main force-transmitting components of the structure. Arranged in a radial pattern, each cable's angle and length are meticulously designed to harmonize with the curves of the arch ribs, creating a cohesive visual effect. The interplay of straight hangers, the bridge deck, and the curved arch ribs generates strong visual tension, showcasing a balance of dynamic and static beauty in the bridge's visual hierarchy. The conceptual evolution process of this project is shown in Figure 5.

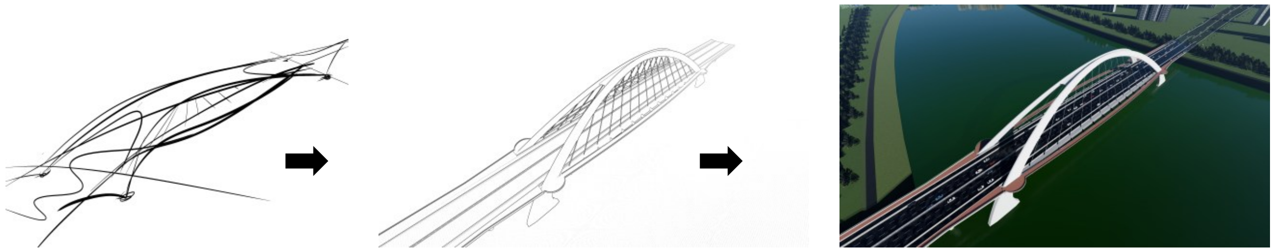

Figure 5 Evolution of project conceptualization

In the design of the arch ribs, a 70° inward tilt was incorporated to form a basket–handle arch structure. This not only enhances the bridge's mechanical performance but also strengthens its visual impact. By controlling the inward tilt angle, the lateral stability of the structure is improved while visually creating centripetal dynamic momentum. The elevation rendering of the project is shown in Figure 6.

Figure 6 Project elevation rendering (elevation view)

2.4 Bridge Component Design

2.4.1 Arch Rib Design

The arch ribs, hangers, and bridge deck form the structural system of a thrustless tied-arch bridge. As the most critical structural and aesthetic element of the arch bridge, the design of the arch ribs follows the principles of "proportional harmony, rational force distribution, and lightweight components" [6]. The design of the arch ribs must achieve a balance between shape formation, structural safety, and constructability, meeting both mechanical and aesthetic requirements.

After comprehensive consideration, the arch rib curve adopts a 1.9th-order parabola, with a theoretical span of 243.6 m, an in-plane rise of 52 m, and a rise-to-span ratio of 1:4.6846. The arch ribs are inclined inward at 70°, with a transverse spacing of 39 m at the base and 3.43 m at the crown. The arch ribs are constructed via a steel box structure with an octagonal cross-section. The steel box has a uniform width of 2.6 m, while its height varies linearly along the arch axis, transitioning from 3.0 m at the crown to 8.0 m at the arch foot. The internal transverse diaphragms are installed every 3 m or 2.5 m within the arch ribs. The variation in arch rib height corresponds to the axial force distribution, achieving a harmonious unity of strength and beauty. The cross-sections of the arch rib at the crown and foot are shown in Figure 7.

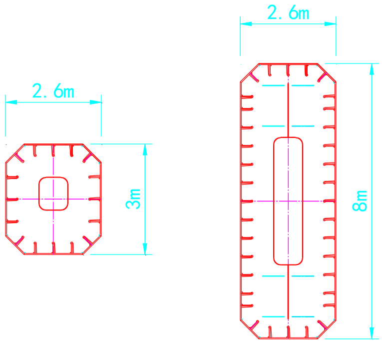

Figure 7 Cross-sections of the arch rib at the crown and foot

2.4.2 Hanger Design

As linear components, hangers convey a sense of strength, resembling taut harp strings or fully stretched sails and embodying resilience and rigidity. The bridge is equipped with 15 pairs of hangers, with a longitudinal spacing of 15 m on the main girder and a horizontal spacing on the main arch arranged as follows: (15 + 14 + 11 + 2×10 + 4×9 + 2×10 + 11 + 14 + 15) m. This radial arrangement structurally avoids stress fatigue issues in the shorter end cables while enhancing the bridge's longitudinal and transverse stiffness. Visually, it creates an upward, centripetal effect, conveying a sense of uprightness, strength, and elevation [7]. The inclined hangers form a "plane" above the bridge, resembling a light, translucent veil floating in the air. The double-cable spatial arrangement radiating from arch ribs evokes the image of a tent canopy over the bridge, creating a unique spatial experience. The hanger cables are made of parallel steel wires protected by a double-layer coextruded PE sheath. The inner PE layer is black, whereas the outer layer is colored. The wires are made of ϕ7 mm galvanized high-strength steel with a standard tensile strength of no less than 1,770 MPa. A rendering of the bridge from a driver's perspective is shown in Figure 8.

Figure 8 Project rendering (driver's perspective)

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2.4.3 Main Girder Design

The main girder, as the horizontal component for vehicular traffic, defines the overall alignment of the bridge. Its slender design minimizes the visual weight over the river, creating an impression of soaring lightness. This sleek profile not only reflects advancements in bridge technology but also resonates with Mianyang's identity as a "Sci-Tech City." Additionally, the main girder functions as a tie member, balancing the horizontal thrust at the arch ends.

The main girder adopts a steel box girder with closely spaced crossbeams. The total width of the bridge deck is 57.7 m, with a center-to-center distance of 39 m between the edge box girders and a standard girder height of 3.2 m. The edge box girders feature a steel box structure, with a width of 2.6 m (consistent with the arch ribs) and a height of 3.2 m. The top plate of the box girder is flat, while the web plates are inclined at 70°, matching the inclination of the arch ribs to facilitate rigid connections at the arch feet.

The bridge deck system employs a closely spaced crossbeam + orthotropic deck plate structure. The deck system has a width of 33.6 m, with crossbeams installed every 3 m longitudinally. The horizontal arrangement of the bridge deck is 3.75 m (sidewalk) + 0-5.19 m (cantilevered hollow zone) + 3.34 m (hanger anchorage zone) + 0.5 m (guardrail) + 4 m (non-motorized lane) + 0.5 m (guardrail) + 11.75 m (motorized lane) + 0.5 m (guardrail) + 11.75 m (motorized lane) + 0.5 m (guardrail) + 4 m (non-motorized lane) + 0.5 m (guardrail) + 3.34 m (hanger anchorage zone) + 0-5.19 m (cantilevered hollow zone) + 3.75 m (sidewalk). The total width varies from 48.18 m at the arch foot to 58.56 m in the middle of the span. The cross-section of the main girder is shown in Figure 9.

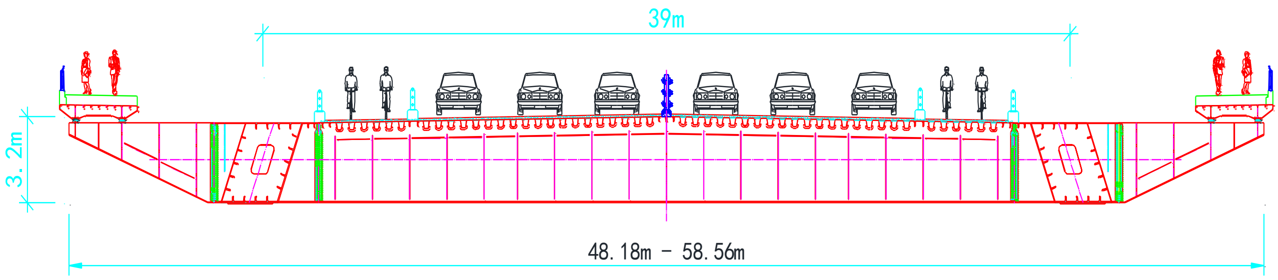

Figure 9 Cross-section of the main girder

2.4.4 Bridge Pier Design

Since the superstructure utilizes a thrustless tied-arch system, bearings are installed on the piers, significantly reducing the load on the substructure. However, to maintain the visual continuity of force transmission, decorative panels are added to the exterior of the piers. The design and dimensional variations of these panels align with the arch ribs, visually integrating the piers and arch ribs into a cohesive whole. This enhances the overall aesthetic appeal of the bridge.

The main bridge piers are constructed of C50 grade concrete and designed as an integral structure across the full width, utilizing a two-column inclined frame pier design. The columns are inclined 70° to the horizontal direction, which is consistent with the arch ribs, with a transverse center-to-center distance of 41 m at the top. The transverse and longitudinal dimensions of the columns are 3 m and 5 m, respectively. The crossbeams feature a box section measuring 3.5 × 3.5 m, with the top and bottom plates being 60 cm thick and the web plates being 60 cm thick. A rendering of the pier is shown in Figure 10.

Figure 10 Project rendering (shoreline perspective)

2.4.5 Bridge Plaque Design

The bridge plaque is an essential component of the bridge's landscape design, serving not only to identify the bridge and highlight its cultural significance but also to act as a focal point in the overall aesthetic [8]. The plaque design for the Fujiang River Bridge adopts the theme of "Riding the Waves of the Fujiang River" and uses wave-like curves as the design element. The layered, overlapping waves symbolize the spirit of forging ahead against challenges, reminiscent of numerous boats striving forward.

The plaque is strategically located at the transition zone between the main bridge and the approach, making efficient use of limited space without interfering with the arch rib design. It visually extends the arch rib's form, blending seamlessly with simple yet powerful curved arches. The color and material of the plaque match those of the arch ribs, avoiding excessive decoration and ensuring harmony with the main structure. At night, an integrated lighting system illuminates the plaque, outlining its wave-like contours with soft light and integrating it into the bridge's nighttime lighting scheme, making it more prominent. A rendering of the plaque is shown in Figure 11.

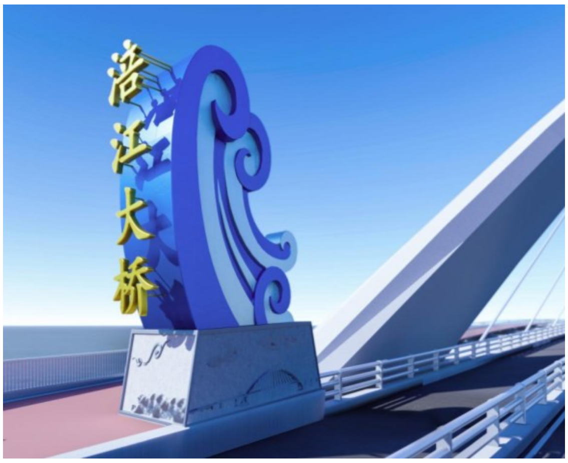

Figure 11 Bridge plaque rendering

2.5 Nightscape Lighting Design

Nightscape lighting is an indispensable element in the design of the Fujiang River Bridge. It highlights both the bridge's structural features and aesthetic expression, integrating it into the city's nighttime landscape system. It adds a unique visual highlight to the urban environment [9]. The lighting design of the Fujiang River Bridge incorporates multidimensional innovations in functionality, artistry, and environmental sustainability. With the theme of "Light of Science and Technology", the design provides distinct visual experiences during the day and night. The nightscape lighting design is based on the structural characteristics of the bridge, incorporating the modern features of Mianyang Sci-Tech City. It emphasizes the concept of "expressing structural beauty and creating cultural imagery". The lighting layout focuses on showcasing the smooth curves of the arch ribs, the radial arrangement of the hangers, and the dynamic continuity of the bridge deck, transforming the bridge into a vivid light-and-shadow painting at night. A rendering of the nightscape is shown in Figure 12.

Figure 12 Project rendering (nightscape)

As the primary structural element of the bridge, the arch ribs are illuminated on their upper and lower surfaces by a 60 W LED linear wall, which accentuates the graceful curves of the basket-type arch. The lighting gradually transitions from the base to the crown, creating an upward light flow effect that symbolizes the progressive rise of Mianyang Sci-Tech City. The hangers are illuminated via 300 W/200 W LED narrow-beam spotlights, with each cable lit from bottom to top. At the crown of the arch ribs, colored halos are formed, adding a dynamic rhythm. Variations in lighting color and intensity enhance the bridge's spatial depth and visual hierarchy. The bridge deck is outlined using 18 W LED contour lights, forming a straight and clear light strip that echoes the horizontal lines of the Fujiang River, emphasizing the bridge's static balance and harmony with its surroundings. Each pier is equipped with 150 W LED spotlights that project light at a low angle, highlighting the piers' solidity and support. This ensures that the bridge's overall form remains visually cohesive and complete at night. The lighting system uses RGBW full-color light sources and an intelligent control system, enabling dynamic light shows. During festivals or special occasions, the lighting colors, brightness, and patterns can be adjusted as needed, creating a versatile and engaging visual experience.

3 Conclusions

The Fujiang River Bridge on Mianyang Sci-Tech City Avenue, as a critical transportation hub and cultural landmark in Mianyang, demonstrates the perfect integration of mechanics and aesthetics through its basket-type arch structure. The bridge's design successfully achieves multidimensional value by addressing both functional and landscape considerations. By extracting the "line" as a core design element and harmonizing "straight lines" and "curves", the bridge embodies the beauty of "rigidity and softness, movement and stillness". While meeting regional transportation needs, the bridge enhances the visual quality of urban space through its landscape design.

The completion of the bridge strengthened the transportation link between the northern and southern sections of Mianyang Science and Technology City, providing solid support for Mianyang's spatial expansion and industrial development. Through its integration with the Fujiang River and the surrounding cultural environment, the bridge has become a model for the coordinated development of ”bridges, rivers, and cities” in Mianyang.

Conflict of interest: All the authors disclosed no relevant relationships.

Data availability statement: The data that support the findings of this study are available from the corresponding author, Tian, upon reasonable request.

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