Project Report

Liyang Jingzhan | Shahe Bridge

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Abstract: The Jingzhan·Shahe Bridge in Liyang City is located in the Tianmu Lake scenic area of Liyang, Jiangsu Province. It is an essential part of Liyang City's No. 1 tourist highway in Jiangsu Province. Surrounded by mountains and water with shimmering waves, the design of the bridge is inspired by the landscape. The main structure of the bridge adopts a "Mountain-Steel Arch" and "Water-Winding Bridge Surface" concept, reflecting the green mountains and clear waters of Liyang. It resonates with the theme "Natural Harmony in Liyang", showcasing Liyang's cultural confidence and creating a unique "business card" for the city.

Citation: Zheng, B. Li X.; Chen, Y. Liyang Jingzhan | Shahe Bridge. *Prestress Technology* **2023**, *2*, 72-78. https://doi.org/10.59238/j.pt.2023.02.007

Received: 10/05/2023
Accepted: 18/05/2023
Published: 25/06/2023

1 General Layout

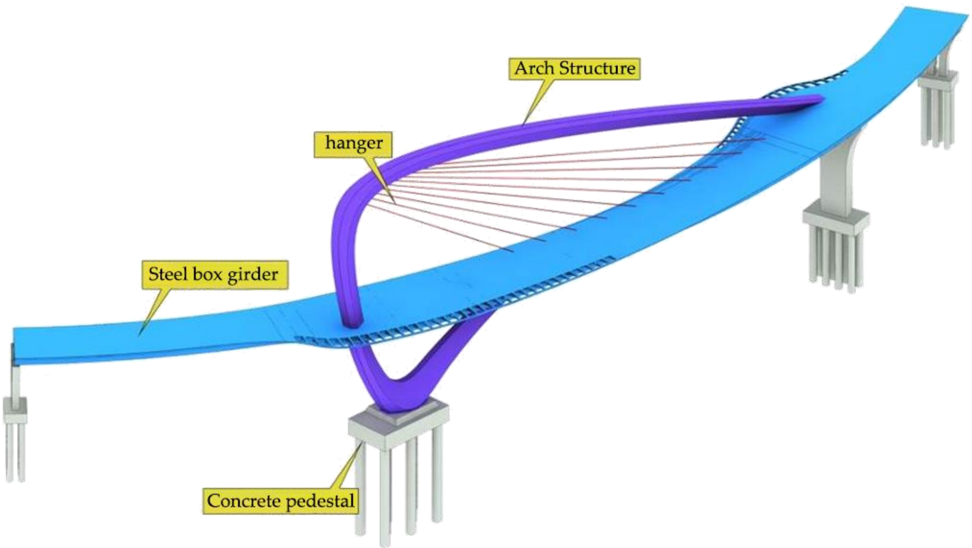
The Shahe Bridge adopts a continuous spatial asymmetrical arch beam combination structure system. Its design inspiration is derived from the landscape, integrating seamlessly with the bridge's environment and reflecting Liyang's unique urban appearance.

(a) The inspiration for the bridge's innovative design comes from landscape

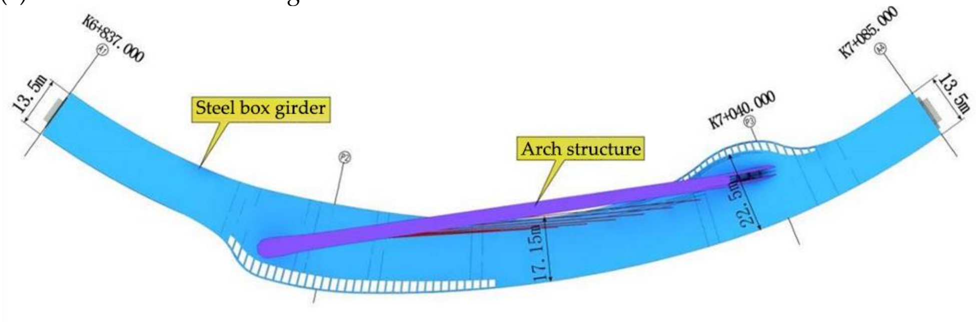
(b) Conceptual illustration of Shahe Bridge

Figure 1 The inspiration for the bridge's innovative design comes from landscape

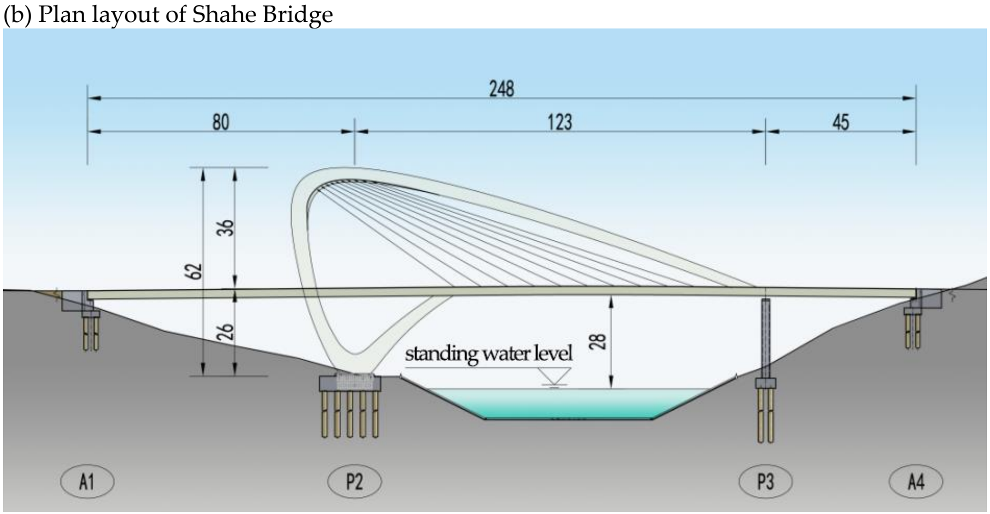
The span arrangement of the Shahe Bridge is 80 m + 123 m + 45 m = 248 m, adopting an arch-beam consolidation system. The arch rib has a hexagonal steel box section, while the beam has a single box multi-chamber section. The bridge has a total of 10 hangers centrally anchored in the arch-top, with an 8 m spacing between the hangers on the main beam. The foundation uses a rock socketed pile foundation. The main bridge of this project has a novel and unique architectural shape, which is aesthetically pleasing. However, the structural system is complex, and the constitution of key connection joints is complicated. The overall layout of the bridge is shown in Figure 2.



(a) 3D model of Shahe Bridge



(b) Plan layout of Shahe Bridge

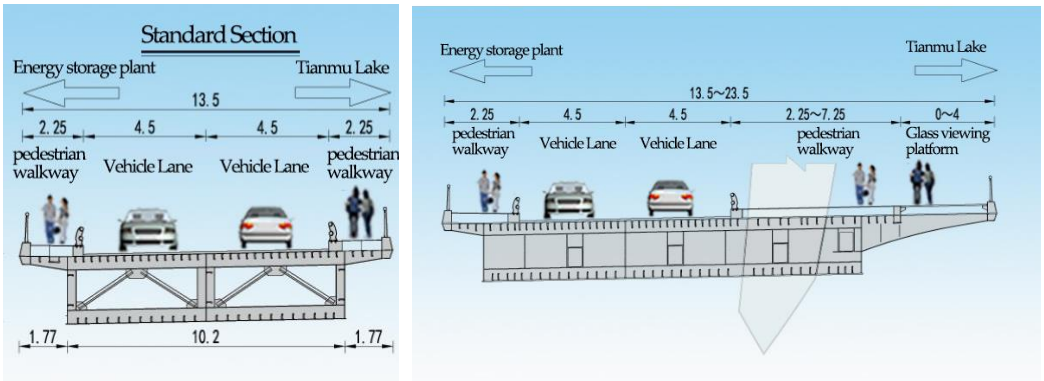


(c) Elevation layout of Shahe Bridge

Figure 2 Layout of the Shahe bridge (Unit: m)

1.1 Bridge Cross-Section Design

The standard width of the bridge is 13.5 m, with two lanes for vehicles in both directions, and each lane is 4.5 m wide. On both sides, there is a 2.25 m pedestrian walkway. At piers P2 and P3, the width of the pedestrian walkway gradually increases with the addition of a glass viewing platform. The cross-section is shown in Figure 3 below.



(a) Standard section (b) Section with glass viewing platform

Figure 3 Section layout (Unit: m)

1.2 Main Beam

The steel beam uses a single-box multi-chamber section, with a total width of 13.74 m at both abutments, including 1.77 m cantilevers on both sides and a 10.2 m single-box chamber in the middle. At piers P2 and P3, the width of the beam section expands to 23.74 m and 22.74 m, respectively, with the largest cantilever being 5.77 m. The bridge deck uses an orthogonal anisotropic deck panel. The thickness of the top plate is between 16 mm and 40 mm, and the bottom plate is also between 16 mm and 40 mm, while the web plate thickness ranges from 16 mm to 32 mm. The top plate's stiffening ribs are spaced 300 mm apart, while the bottom plate's stiffening ribs have a spacing of 400 mm. There is a standard partition every 6 m, and every 2 m, there is a truss-style partition.

The bottom edge of the cantilever is a combination of straight lines and arcs. Different lengths of cantilevers use the same bottom edge shape to ensure a neat appearance.

1.3 Arch Rib

The total height of the arch rib is 62 m, approximately 36 m above the bridge deck and 26 m below. The arch rib exists in a flat plane in space and consolidates with the diagonal leg on top of P2. The main arch plane and the diagonal leg plane have an angle of approximately 15°. The outline of the arch rib is approximated using hook functions and arc functions. The arch rib has a hexagonal cross-section. The angles between the side panels and the top and bottom panels are constant. The top web plates and top panel angle are 45°, while the bottom web plates and bottom panel angle are 66.6°.

The cross-sectional height of the arch rib at pier P3 is 5 m with a width of 3.4 m. At the arch top, the height is 6 m, and the width is 5.2 m. At the left side of the arch-beam consolidation near P2, the height is 4 m, and the width is 3 m. At the foot of the main arch, the height is 6.6 m, and the width is 5.6 m. At the V-pier diagonal leg and the main beam consolidation, the height is 3.25 m, and the width is 3.5 m.

Multi-angle external ear plate joints are set on the arch rib to anchor the hangers. The thickness of the top and bottom plates of the arch rib ranges from 32 mm to 40 mm, while the web plate thickness ranges from 24 mm to 40 mm. Stiffening ribs are added to the arch rib section. The standard spacing between the arch rib cross slabs

 https://doi.org/10.59238/j.pt.2023.02.007

is 3.0 m, and the thickness of the cross slab is 12 mm. The cross-slab direction is always perpendicular to the top plate of the arch rib.

1.4 Hanger

The bridge has a total of 10 hangers. The hanger type is prestressed anchorage steel strand hangers. Except for the #9 and #10 hangers, which are of the specification GJ15-22, the rest are all GJ15-25. The upper end of the hanger is anchored to the arch rib using an ear plate, and the lower end is anchored inside the main beam using an anchor box (Figure 4). The hangers are evenly distributed on the beam, with a spacing of 8 m along the centerline of the road. The cable surface structure of the hangers is arranged in a fan shape, with a maximum cable force of 2700 kN.

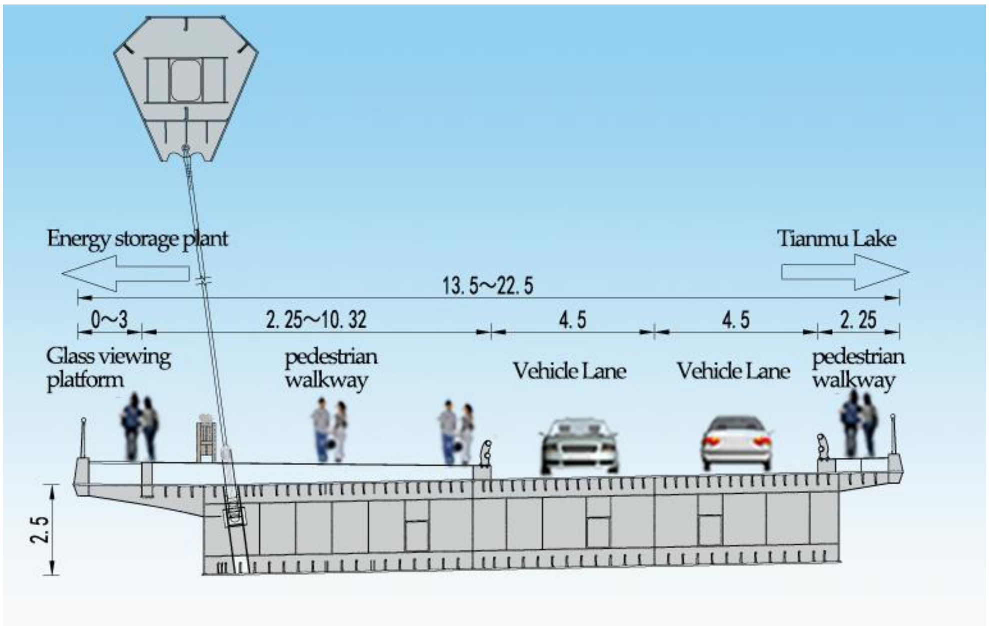


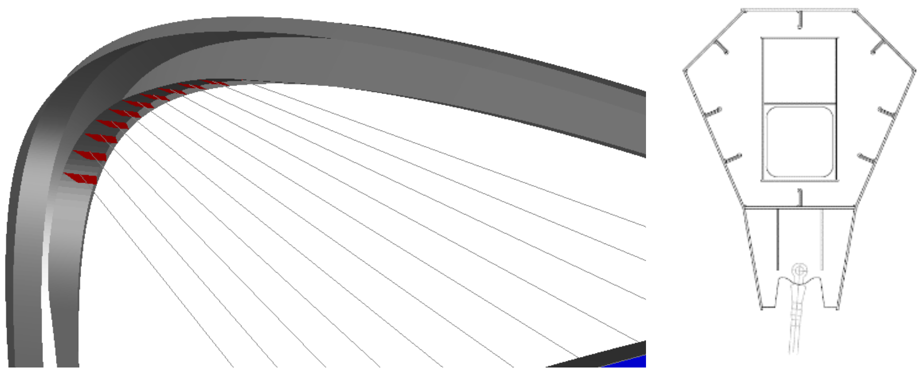
Figure 4 Structural diagram of hangers (Unit: m)

The hangers of this bridge are spatial hangers. During the tensioning process, it is essential to ensure that the force exerted on the hangers is evenly distributed. Especially after the framework is set, the deviation in the hanger cable force needs to be kept below 50 kN. Compared to the theoretical elongation, the control accuracy of the actual elongation should be maintained within ±2%.

2 Key Connection Joint Design and Construction

2.1 Design of Key Connection Joints

There are three design challenges for this bridge: first, the consolidation joint between the arch and the beam; second, the centralized anchoring joint at the apex of the arch; and third, the joint at the base of the arch. The consolidation joint between the arch and beam is designed such that the arch rib runs through and the main beam is disconnected. The top plate, bottom plate, and cross slab of the main beam all have corresponding slabs set inside the arch rib. In the joint at the apex of the arch, the bottom plate of the arch rib is lifted, and an ear plate is set up to anchor the hanger (Figure 5). At the joint at the base of the arch, a horizontal large bearing plate is placed, the arch rib is welded to this bearing plate, and the force is ultimately transmitted to the lower pedestal through the horizontal bearing plate and bolts. Below the horizontal bearing plate, a reaction frame is set up to provide effective force transmission and earthquake resistance.



(a) 3D model of hanger’s anchor points (b) Construction of ear plates

Figure 5 Construction of the ear plate at hanger's anchor points

2.2 Anchor Construction at the Beam End of the Hanger

The anchoring method of the hanger at the beam end is through an anchor box. At the beam end anchor point of the hanger, a longitudinal steel plate is placed between the two transverse partitions of the main beam and is welded to the transverse partitions and the top plate of the main beam (see Figure 4). To ensure tensioning construction, holes are set in some transverse partitions. The force transmission path in the beam-end anchoring area is: hanger → longitudinal steel plate of the anchor box → main beam's transverse partition and top plate → web plate of main beam.

2.3 Anchor Construction at the Arch End of the Hanger

The hanger is anchored to the arch rib using an ear plate method. The ear plate is fully welded to both the web plate and the bottom plate of the arch rib. A pin hole is set on the ear plate, and the hanger's upper segment is connected to the ear plate through a pin (see Figure 5). The force transmission path in the arch rib end anchoring area is: hanger → pin → ear plate → web plate of arch rib.

2.4 Lower Structure

The top of the P2 pier is consolidated with the base of the arch, anchored through a reaction frame embedded inside the pedestal. The pedestal is 4 m high, with a length of 18.3 m along the plane parallel to the arch rib and a width of 10.4 m in the other direction. At the base of the pedestal, there are 8 bored piles with a diameter of 2.0 m, each having a length of 9.5 m.

2.5 Key Points of Construction

Based on the local conditions of the Liyang region and the characteristics of the bridge site being a discharge outlet for the drainage canal, the principles for formulating the construction plan are as follows:

(1) Minimize the installation of temporary supports in the water;
(2) Use the incremental launching method for main beam construction;
(3) Employ a cable-stayed tower crane method for the construction of the main arch;
(4) Taking into account the structural characteristics of the key connection joints of the main bridge and considering transport and lifting capacities, the size and weight of the components are controlled.

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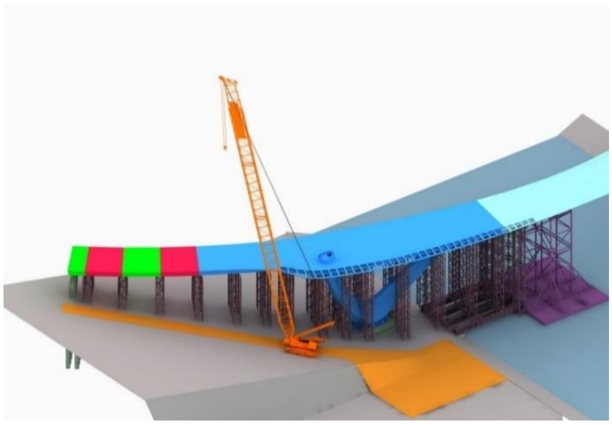
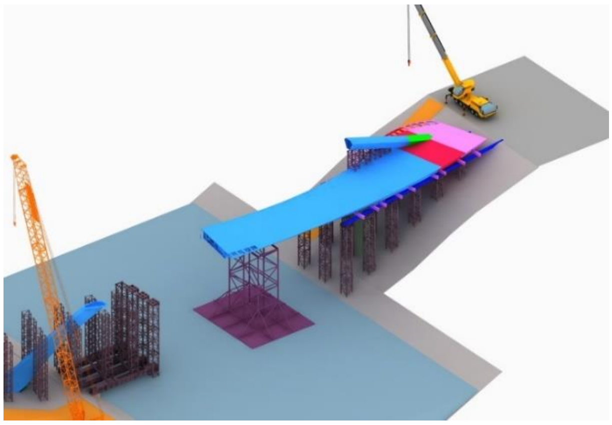
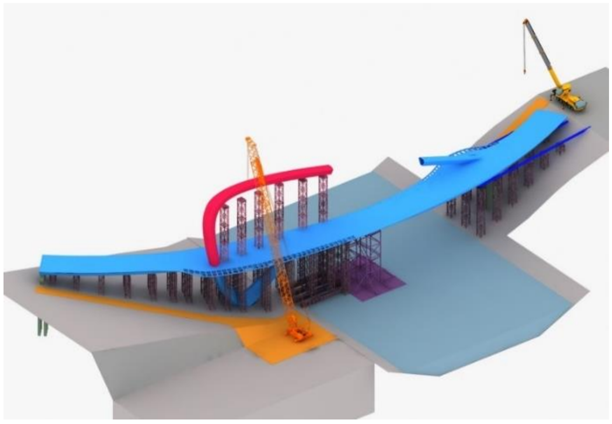
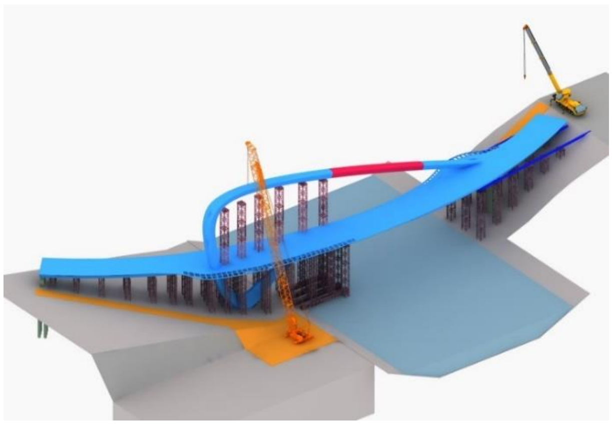
The following is an explanation of the construction steps combined with diagrams and charts:

Table 1 Construction Plan Flowchart

Step 1: Set up scaffolding to construct the arch ribs below the bridge deck and the left main beam.	
Step 2: Use large-scale floating supports to incrementally launch the right main beam.	
Step 3: Set up scaffolding and install the arch rib segments in the hanger area.	
Step 4: Lift and connect the remaining arch rib segments.	

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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https://doi.org/10.59238/j.pt.2023.02.007