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Research on Design and Construction Technology of Pedestrian Bridge

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Abstract

Based on the design and construction of the Bailu River pedestrian cableway bridge, the structural design and construction of the pedestrian cableway bridge and its anchoring system are studied. The structural design of the cable-stayed bridge anchorage system is analyzed, and the pull-out safety, anti-sliding and anti-overturning are checked. The cableway bridge is built according to the geometric nonlinear finite element method of the cable-stay composite structure. The meta-model is used to calculate the nonlinear static force of the finite element model of the cableway bridge. The overall force of the cableway bridge meets the requirements and can provide reference for similar projects.

Keywords

Pedestrian cableway bridge, structural design, anchoring system, mechanical property, construction technology.

1. Introduction

The cableway bridge is a kind of flexible suspension system bridge with steel wire rope and anchorage as the main force component, steel beam and wood board as the local force component [1]. With low investment, fast erection, simple construction and large span, it is widely used in the southwest mountainous area and is mainly used as a temporary passage for road, railway and water conservancy projects. However, the cableway bridge is a typical flexible structure. When load passes, the deformation of the cableway bridge is large, the geometric nonlinear effect is obvious. At present, there is no specification for the design and construction in China [2]. There are a few researches on the cableway bridge, but there are many researches on suspension bridges with similar structural forms [3-5]. The literature of cable bridges [6,7] mainly focus on the research of carriage bridge. Seldom literature study the small width-to-span ratio, light structure and geometric nonlinear effect. This paper takes the design and construction of Bailuhe cableway bridge as an example, which is the temporary construction facilities of the Jiayan Water Conservancy Project and the North Main Canal in the northwest of Guizhou Province.

2. Project Overview

The Baiyun River inverted rainbow pipe cross-river arch bridge locates in a narrow "V"-shaped deep oblique valley which is about 410m wide and 210m deep. The two banks are steep whose slope is 40 °-50 °with part of rock wall. The upper part is a platform with a slope. The slope of the imported shore is 3 °~5 °, the slope of the steep is 15 °~20 °, and the slope of the exit slope is 20 °. The dip angle of the rock layer varies greatly. There is no cross-strait bridge on both sides of the strait. To get to the opposite bank, 63-kilometer crossing of the Bailu River is needed. In order to facilitate the construction of the Baiyu River cross-river arch bridge, the Baiji River Cableway Bridge was constructed.

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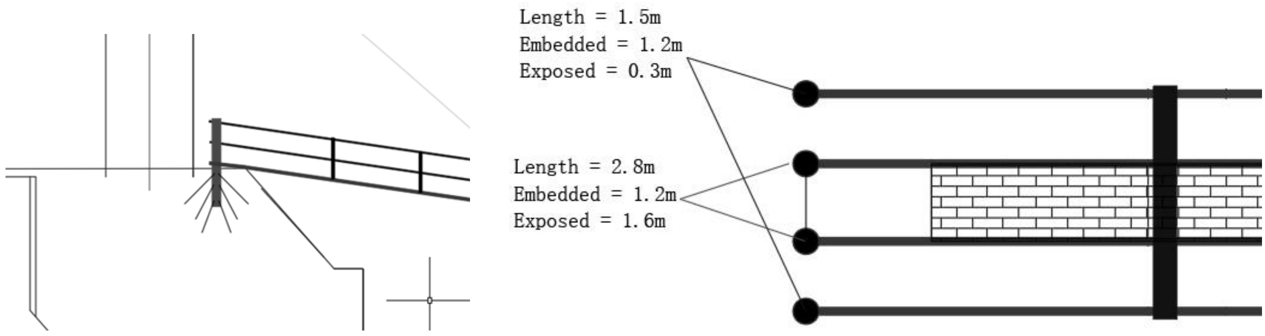
3. Anchor structure design and calculation

3.1 Anchor structure design

The imported shore adopts the form of gravity anchorage structure, that is, the existing pedestal concrete structure is used, and four φ325×12 cylindrical steel pipes with a depth of 1.2m are embedded in the interior. The inner two steel pipe need to be tied with the handrail rope to expose the height whose value is 1.6m. The outer two steel pipe exposed is filled with concrete, whose height is 0.3m. Then steel wire rope is directly bolted to the four column steel pipes. Figure 1 shows the structure of the inlet anchorage of the Bailuo river cableway bridge.



(a) (b)

Figure 1. The structure of anchor block for the entry port of Baifu river cable bridge

The exit port adopts the prestressed rock anchor structure. Three prestressed rock anchor cables are drilled, worn and filled on the back-rock mass of the arch according to the design position, and three diamonds are drilled on the φ630×12 cylindrical steel pipe. Through the cable hole, the 3 bundles of steel strands reserved in front are passed through the corresponding holes and lead to the other side, and then the φ630×12 cylindrical steel pipe with a length of 3.1 m is anchored to the back rock of the abutment through the clip anchor plate. In the end, concrete is finally backfilled inside the cylindrical steel pipe. The structure diagram of the Baiyu River anchor is shown in Figure 2.

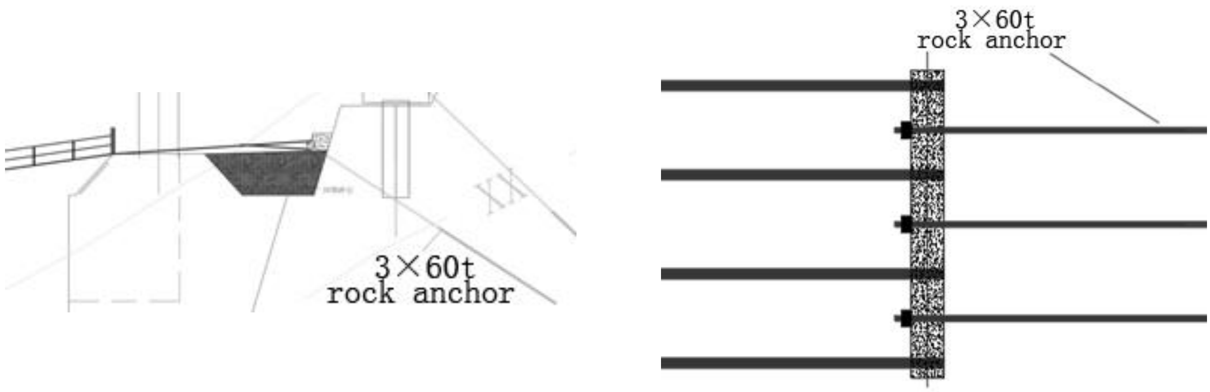


Figure 2. The structure of anchor block for the export port of Baifu river cable bridge

3.2 Anchor structure calculation

The cable-stay force of the Bailu River anchor is 840KN, and the tension of each wire rope is 21t. According to the requirements of the specification, it is necessary to check the anchoring structure for pull-out safety, anti-sliding and anti-overturning.

(1) Inspection of import shore anchors

Because the imported shore is made of the imported shore arch concrete structure, and the concrete quantity reaches more than 1800 squares, the imported shore anchor itself is resistant to the drawing

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force, and there is no possibility of slipping and overturning. It is only necessary to check the strength of the embedded structure itself and its bond strength with the concrete.

Strength calculation of concrete-filled steel tubular columns: According to the Technical Specification for Concrete-filled Steel Tubular Structures, the shearing forces and bending moments of the solid concrete structures of Φ325*12 can be:

$$V_u = 0.71 f_{sv} A_{sc} = 0.71 \times 45.1 \times 82915 = 2655 KN \quad (1)$$

$$M_u = 1.2 f_{sc} W_{sc} = 1.2 \times 46 \times 3.14 \times 162.5 \times 162.5 \times 162.5 / 4 = 185.94 KN \cdot \mathrm{M} \quad (2)$$

Among them, f_{sv} is the shear strength of concrete filled steel tube, f_{sc} is the flexural strength of concrete filled steel tube; by calculating each steel tube concrete can resist 265.5t shearing force and resist bending moment of 18.6tm bending moment, so the steel wire rope tied to the bottom of concrete filled steel tube can meet Strength requirements. In addition, in order to ensure that the concrete at the back of the steel pipe is not crushed, some steel mesh is placed at the back of the steel pipe when the steel pipe is embedded.

(2) Checking the calculation of the export shore anchor

Because the exit anchor structure is a prestressed rock anchor structure, there is no slip and overturn of the gravity anchor structure, and only the pullout force of the anchor structure needs to be accounted for.

Three sets of prestressed rock anchors are set up at the port anchors. The anchorage length of each beam anchor cable is 10m and the anchor hole diameter is 130mm. According to the structural design of the anchoring section in the Design Code for Hydraulic Prestressed Anchorage (SL212-2012), the single-hole prestressed anchor cable can provide the tensile force when the length of the anchoring section is 10m.

$$T_w = \pi d \tau_r L / S_f = 3.14 \times 0.13 \times 0.4 \times 10 \times 1000 / 2.5 = 65.3\mathrm{t} \quad (3)$$

Among them, the bonding strength between the grouting body and the rock wall, the value of this place is 0.4MPa, the 3 beam rock anchor cable can provide 196t drawing force, and the anchoring safety factor reaches 2.33.

The strength of the concrete filled steel tube is the same as that of the imported shore. The solid concrete structure of the round steel pipe with the exit Φ630*12 can meet the strength requirements. In addition, in order to ensure that the steel pipe does not tilt, the wire ropes on both sides of the steel pipe center should be tightened simultaneously during the tightening process of the rope bridge.

4. Cableway Bridge Design and Calculation

4.1 Cableway Bridge Design

The Baiyun River Cableway Bridge has a net span of 192 m. There are 8 main cables in the whole bridge, including 4 bridge cables and 2 stabilizer cables on each side. The main cable adopts Φ37 steel wire rope, and the structure of the rope is 6×19WS+IWR, and its standard strength is 1870MPa. The cable-stay bridge span ratio is 1/28, and the sidewalk net width is 1.0 m. The bridge cable and the bottom stabilizer cable are connected by [8 channel steel beams and non-slip wood strips, and the steel mesh is placed on it (Φ5, 25×25). 0.2m is provided with a non-slip wooden strip, and every 3m setting [8 channel steel beam is connected to the load-bearing cable. The cableway bridge design load is 1.25KN/m. Figure 3 and Figure 4 are elevational and plan views of the structure of the Baiji River Cableway Bridge, respectively.

A non-slip wooden strip is placed every 0.2m on the bridge surface of the cableway bridge, and one [8 channel steel beam is placed every 3m to connect the load-bearing cable. Two Φ17 steel wire ropes and Φ3 (50×100) protective mesh layers are arranged on both sides of the bridge deck, as shown in Figure 5 .

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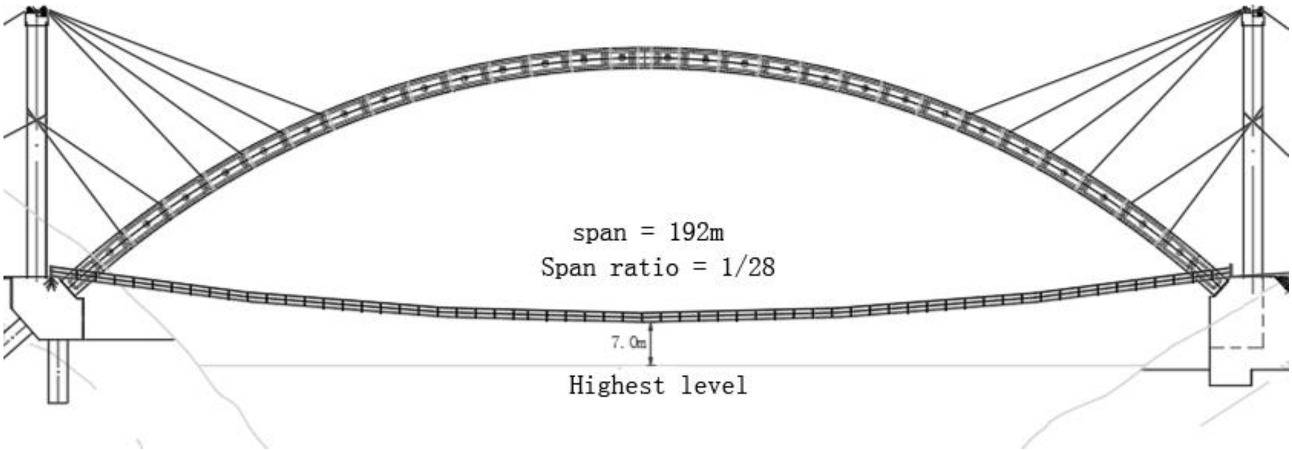

Figure 3. Elevation of Baifu river cable bridge

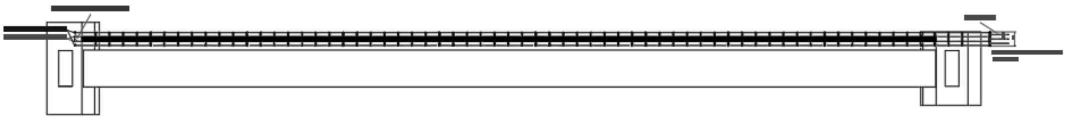

Figure 4. Structural plan of Baifu river cable bridge

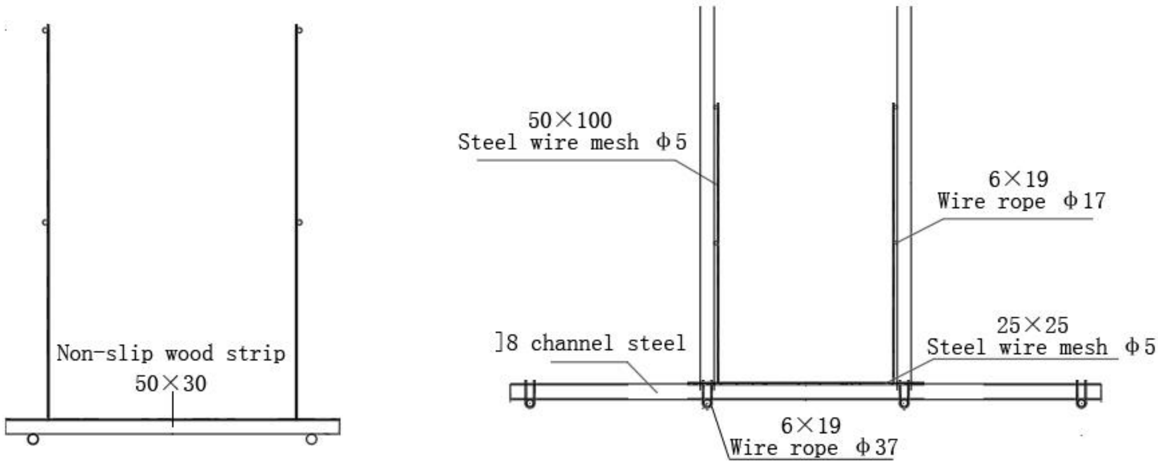

Figure 5. Crocs section of Baifu river cable bridge

4.2 Cableway Bridge Calculation

4.2.1 Calculation and arrangement of wire rope quantity

(1) Load

The weight of the whole bridge is 18 people, the bridge length is 192m, the crowd is evenly distributed, each person has a weight of 80kg, and the live load per length is 0.075kN/m.

The dead load of the cableway bridge is: the total weight of the bridge span is 16.5t, and the calculated span is 192m, so q is 0.86kN/m. Combined load can be calculated according to eq.4 and the parameters is listed in Table 1.

$$S_{ud} = \gamma_0 \left(\gamma_G S_G + \varphi_c \gamma_{Qj} S_{Qjk} \right) \tag{4}$$

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Table 1 Parameters of Calculation

Dead Load(kN/m)	Live load(kN/m)	γ_0	γ_G	φ_c	γ_{Qj}	Sud(kN/m)
0.86	0.075	1.1	1.2	1.0	1.4	1.25

(2) Calculation of cable tension

The load-bearing cable wire is Φ37mm, the model: 6×19ws+IWR-1770, and the minimum breaking force is 761kN. Considering the safety factor of K=2.5, the allowable tension of a cable is obtained as eq.5, and the parameters of cable tension calculation is listed in Table 2.

$$\left.\begin{aligned} H &= \frac{M}{f_{\max}} = \frac{ql^2}{8f_{\max}} \\ H_1 &= \frac{[H]}{K} \\ n &= \frac{H}{H_{1`}} \\ H_2 &= \frac{H}{n} \end{aligned}\right\} \tag{5}$$

Table 2 Parameters of cable tension

fmax	H(kN)	K	H(kN)	H1(kN)	n	H2(kN)
192	840	2.5	761	304.4	4	210

(3) Cableway bridge section and wire rope arrangement

According to the theoretical analysis, the load of the full-bridge load-bearing cable and the stabilizer cable are basically the same, but the more the number of stabilizer cables, the more favourable it is to reduce the lateral inclination of the bridge and prevent the torsion. According to the actual experience, the number of stable cables is generally taken. 1/4 to 1/2 of the main cable, take 2 here.

The average load-bearing cable is arranged within the width of the bridge deck. The cable pitch on both sides of the bridge centreline can be slightly larger. The average cable pitch is $s = \frac{B}{n-1}$ 。 B is bridge deck width and n is the number of soles.

4.2.2 Finite Element Analysis of the Overall Model of Cableway Bridge

According to the structural characteristics of the cableway bridge, considering the joint action of the cable and the beam, the LINK10 rod unit is used to simulate the main cable and the anti-wind cable, the BEAM189 beam unit is used to simulate the steel beam, and the finite element calculation of the cable-stayed beam structure is established in the numerical finite element software ANSYS. The model, the iterative method is used to obtain the finite element model of the cableway bridge into the state of the bridge as shown in Fig. 6. Fig. 7 is a partial enlarged view of the cableway bridge.

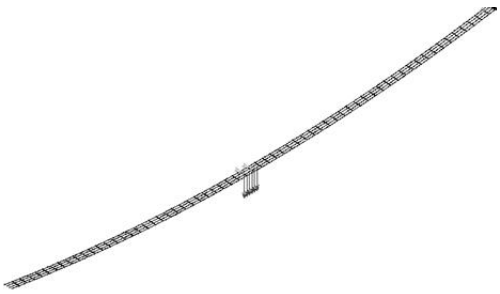

Figure 6. model of cableway bridge

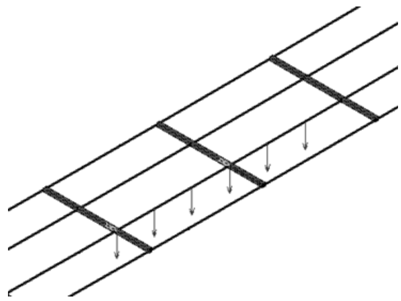

Figure 7. Cableway bridge partial enlargement

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In addition to its own weight, the Bailuo River Cableway Bridge is mainly subjected to its own personnel load, as well as external wind loads. The calculations are carried out under the most unfavourable conditions. The values are as follows:

(1) In the range of 1.0m bridge width, crowd load may occur. In this paper, 6 people are on the road, and each person is 1m apart at the edge of the ropeway bridge, each person's own weight is 80Kg;

(2) According to the “General Code for Design of Highway Bridges and Culverts”, the wind load calculation is calculated. The wind load received by the transverse bridge of the Baiji River Cableway Bridge is 28.30KN, which is evenly distributed in the span of the cableway bridge.

4.2.3 Analysis

Applying the above calculated boundary conditions, the nonlinear static calculation of the finite element model of the cableway bridge is carried out, and the main cable tension, the heel angle, the maximum stress and the maximum displacement mechanical parameters of the cableway bridge are obtained, and the static force calculation is performed. The results were imported into the modal analysis. The subspace iteration method was used to calculate the large deformation prestressing mode of the cableway bridge, and the natural vibration frequency of the cableway bridge structure was obtained. Fig. 8 and Fig. 9 are displacement diagrams and von stress diagrams of the cableway bridge along the erecting plane. It can be seen from the displacement diagram that the cableway bridge has a displacement of 0.29m under load and the maximum stress of the beam is 25.2MPa. Due to the wind load and the unbalanced load of the personnel, the cableway bridge has a lateral inclination angle α. When the heel angle is too large, Causes the entire cableway bridge to be laterally overturned, where the lateral inclination is 3.5 °, which is less than the general requirement. The ropeway bridge is fully stressed to meet the design requirements.

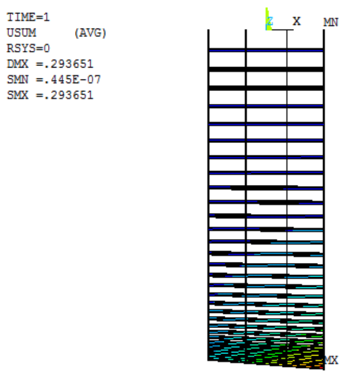

Figure 8. Displacement of cable bridge

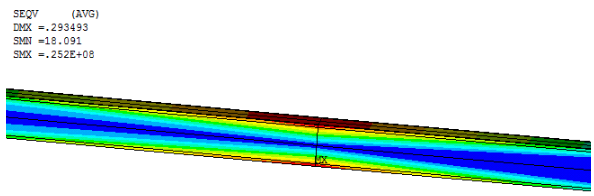

Figure 9. The stress nephogram of cable bridge

5. Conclusion

In this paper, the structural design of the cable-stayed bridge anchorage system is analysed, and the pull-out safety, anti-sliding and anti-overturning are checked. Secondly, the structural design of the cableway bridge is analysed. The geometric nonlinear finite element method is used to establish the cableway bridge. The finite element model of the bridge is used to calculate the nonlinear static force of the finite element model of the cableway bridge under the condition of the calculated boundary conditions. The main cable tension, the heel angle, the maximum stress of the beam and the maximum displacement mechanical parameters of the cableway bridge are obtained. The ropeway bridge is fully loaded to meet the requirements.

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