Reliability Analysis of Zipline Project in A Mountainous Ecotourism Scenic Spot

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Abstract. In order to study the reliability and safety of the zipline project of an ecological cultural tourism scenic spot, Zhenxiong County, Zhaotong City, Yunnan Province, based on the field investigation and data collection, the three-dimensional model of the project is constructed by Midas civil, and the reliability of the zipline structure under pedestrian load is calculated. The calculation results show that after the completion of the zipline, the overall maximum combined displacement is concentrated in the middle of the span, the displacement is small, and the overall combined displacement of the zipline decreases to both ends of the tower; under the action of human load, the stress of the zipline and the cable tower increases, and the displacement of the main components also increases obviously, but it is within the acceptable range as a whole. The research results provide a reference for the normal operation of the project.

1. Introduction
As a kind of thrilling and exciting entertainment project, the sliding rope has been carried out for more than 10 years in China [1-2]. It takes the sliding force formed by human gravity and natural fall as the driving force for sliding [3-4]. It can cross mountains and rivers, and transport personnel and materials in various complex terrain. In recent years, with the development of tourism, the sliding rope has become a new kind of amusement facilities, also known as "sliding rope", "rapid descent", "flying man", etc., which is one of the special equipment for safety supervision [5]. In recent years, with the development of tourism industry, more and more scenic spots implement the project of sliding rope [6-8]. However, due to the fact that the ziplines are usually installed in the dangerous terrain between the canyons, the safety risk is also very large. It is very important to evaluate the reliability of the ziplines before the operation of the project. Based on the zipline project of an ecological cultural tourism scenic spot in Zhaotong City, Yunnan Province, this paper analyzes its structural reliability by Midas civil. The research results are of great significance for the operation safety of the project.

2. Design parameters and calculation model of sliding rope
The design total length of the slide rope is 201.6m, which is composed of four main steel wire ropes. The upper site platform is 37m higher than the lower site platform. The overall model of the zipline is shown in Fig.1. The load-bearing cable is 6×19S+IWR-φ16.

Midas civil, a special finite element program, is used to simulate the cable. Midas civil is used for geometric nonlinear analysis. Considering the geometric nonlinear effect of ground anchored suspension bridge, according to the form and stress characteristics of each bridge component, two kinds of elements are adopted: cable element (automatically converted into space truss element in dynamic analysis) and space beam element. The bridge tower model of the upper and lower stations is shown in Fig.2 and Fig.3.

**Figure 1.** Calculation model diagram.

**Figure 2.** Model drawing of upper pylon. **Figure 3.** Model drawing of lower pylon.

The main cable is simulated by cable element, and the main girder is simplified as a multi segment catenary clue unit concentrated in the center of the main cable. The anchor point, loose cable sleeve, sling, cable hoop and theoretical ip point are used as segmentation nodes. The main cable between nodes adopts one catenary clue unit. The two cables along the bridge direction on a cable clamp are merged into a sling in its center, and a catenary clue element is used to simulate. The space beam element is used to simulate the bridge tower, and the fixed bearing is used to simulate the foundation.

### 3. Calculation parameters

The section parameters of main beam, cable tower, side pier, bent cap and cross beam is shown in table 1.

| Component type | Elastic modulus (MPa) | Cross section area (m²) | $I_{zz}$ (m⁴) | $I_{yy}$ (m⁴) | $I_{xx}$ (m⁴) | Coefficient of linear expansion (m/m·℃) |
|----------------|---------------------|------------------------|---------------|----------------|---------------|----------------------------------|
| Pylon          | $2.0 \times 10^5$   | 1.423                  | 157.6         | 4.01           | 7.233         | $1.2 \times 10^{-5}$               |

The section parameters of main cable and sling are shown in table 2.

| Component type | Elastic modulus (MPa) | Cross section area (m²) | $I_{zz}$ (m⁴) | $I_{yy}$ (m⁴) | $I_{xx}$ (m⁴) | Coefficient of linear expansion (m/m·℃) |
|----------------|---------------------|------------------------|---------------|----------------|---------------|----------------------------------|
| Main cable     | $2.0 \times 10^5$   | 0.1214591              | 0             | 0              | 0             | $1.2 \times 10^5$                  |
4. Reliability analysis of zipline considering human load

4.1. Force analysis of cable structure

4.1.1. Stress analysis of cable and pylon. It can be seen from Fig.4 that the main span cables are under uniform stress and bear tensile stress, but the forces on the left and right side of the cables are not equal, and the anchorage section has the largest stress. The force on the main span of the left cable is about 562.056MPa, and the stress on the anchorage section is about 686.935MPa; the stress on the main span of the right cable is about 249.857MPa, and the stress on the anchorage section is about 562.056MPa.

The calculation results of cable tower stress under crowd load show that the upper cable tower is under uniform stress, the maximum value is about 5.052MPa; the middle diagonal brace of lower cable tower is under tension, the maximum value is about 2.817MPa, the maximum pressure on cable saddle is about 40.466 MPa, and the pressure on other parts of the tower is about 5.052MPa.

![Figure 4. Stress distribution of cable](image)

4.1.2. Internal force analysis of zipline. The internal force of the zipline under crowd load is shown in Fig.5. It can be seen from the figure that the main span of the zipline is under uniform stress and bears tensile stress, but the force of the left and right side of the zipline is not equal, and the anchorage section has the largest stress. The force on the main span of the left slide cable is about 45.473KN, that of the anchorage section is about 62.522KN, and that of the right side is about 22.741KN, and that of the anchorage section is about 45.473KN.

4.1.3. Internal force analysis of cable tower and stiffening beam. The calculation results of bending moment in X direction of cable tower show that the positive and negative bending moment of the lower cable tower appears, and the maximum value appears on the diagonal bracing members on both sides of the cable tower. The maximum positive bending moment is about 0.602KN·m, the maximum negative bending moment is 0.349KN·m, and the bending moment value of the upper cable tower is very small. In the X-direction axial force of the bridge column connecting the cable saddle of the upper cable tower is the largest and negative axial force, the maximum value is about 99.485KN, and the axial force value of other members is very small. The maximum positive axial force is about 4.457KN and the maximum negative axial force is about 61.687KN.

The calculation results of bending moment and shear force in Y direction of cable tower show that the bending moment of upper cable tower is very small; positive bending moment appears at the saddle
of lower cable tower, negative bending moment occurs at the connection between middle part and diagonal brace, and positive bending moment is found in the rest of the whole tower. The maximum positive bending moment is about 13.321KN·m and the maximum negative bending moment is 11.717KN·m. The shear force of the upper pylon is very small. The positive shear force of the left diagonal brace and right bridge column of the lower cable tower is about 2.108KN, the positive shear force of the right beam and middle bridge column is about 1.200KN, the negative shear force of the left beam and right diagonal brace is about 1.125KN, and the maximum negative shear force of the left bridge column is about 2.884KN.

![Diagram of cable tension]

**Figure 5.** Diagram of cable tension

The calculation results of bending moment and shear force in Z direction of pylon under human load show that the bending moment of upper pylon is almost zero, and there are positive and negative bending moments in lower pylon. The maximum positive bending moment is about 2.875KN·m, and the maximum negative bending moment is about 3.741KN·m. The maximum positive and negative shear force of the cable tower occurs at the saddle of the left zipline, with the maximum positive shear force of 49.302KN and the maximum negative shear force of 53.013KN, and the negative shear force of the rest of the tower body, with the maximum value of 6.506KN.

4.2. *Displacement analysis of cable structure*

The calculation results show that the maximum total displacement of the bridge is concentrated in the middle of the span, and the maximum displacement is 11.5 mm.
Figure 6. Horizontal displacement distribution

The overall combined displacement of the bridge tends to decrease towards both ends of the pylon. Figure 6 shows the X-direction displacement diagram under human load, and Figure 8 shows the Z-direction displacement diagram under human load. From the simulation results, the maximum horizontal displacement of the cable appears in the middle of the span, which is 2.4mm, and decreases from the middle of the span to the two pylons. The maximum value of the vertical displacement of the cable appears in the middle of the span, and the maximum value is 11.3mm. Compared with the self-weight, the displacement value increases. Figure 7 is diagram of cable tension.

Figure 7. Vertical displacement distribution

5. Conclusions
After the completion of the cable, the overall maximum combined displacement is concentrated in the middle of the span, and the displacement is small, and the overall combined displacement of the cable decreases to both ends of the tower. The zipline near the saddle of the upper cable tower and the beam and bridge body of the left tower of the lower tower near the saddle are positive, and the maximum...
displacement from the middle of the span to the lower tower is negative, and the displacement is small. The maximum value of the vertical displacement of the cable appears in the middle of the span and tends to decrease towards the two pylons.

After the zipline is put into use, the stress of the cable and tower will increase under the action of human load, and the displacement of main components will also increase obviously. Therefore, after the zipline is put into use, it is necessary to strengthen the regular inspection of the main structural components, especially the wear of the main bearing cable, make maintenance records, and strengthen monitoring to prevent accidents.

Acknowledgments
This work was financially supported by Applied Basic Research Project of Yunnan Science and Technology Department (NO.2018FB075) and The Postdoctoral Science Foundation of China (NO.2017M620433).

References
[1] YUN Ping, JIANG Hongqi, LIANG Haiyan. Safety analysis of zipline with large slopes [J]. Lifting and Conveying Machinery, 2011(08):1-4.
[2] CAO Hongqing, WANG Wei. Analysis and Research on Zipline Wire Rope [J]. Technological Innovation and Application, 2015(24):156.
[3] LIU Rui. What are the requirements for safety technical requirements for strops [J]. Quality Guidelines, 2003(13): 26.
[4] ZHOU Xinnian, ZHANG Zhengxiong, GUAN Yinsheng, et al. A study on theory and application of strop ropeway [J]. Forestry Science, 2006(09): 83-88.
[5] DONG Xibin, WANG Haibiao, SONG Junshan. Cable support and foundation design [J]. Forest Engineering, 2003(03):17-18.
[6] LI Chongyang, MA Donglian, KANG Hongwei, et al. Finite element analysis and optimization of the skid support based on Inventor [J]. Machinery, 2018, 45(07): 23-24+76.
[7] ZHENG Yongzhen, JIA Guoliang. Application of landslide monitoring technology on strops [J]. Hoisting and Conveying Machinery, 2017(02): 98-100.
[8] ZHOU Xinnian, ZHANG Zhengxiong, YAO Zehua, et al. The development and prospect of zipline in my country [J]. Lifting and Conveying Machinery, 2005(07):1-5.