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Static Loading Test and Assessment of Cable-stayed Bridge Which Specialized for Rail Transit

Xiao Yang-Jian[1*], Zhou Lei[2] and Li Xiao-Gang[1]

[1]School of Civil Engineering and Architecture, Chongqing Jiaotong University, Chongqing 400074, China.
[2]Guizhou Province Zhi'an Traffic Engineering Monitor and Testing Center Co. Ltd., Guizhou 550000, China.

Authors' contributions

This work was carried out in collaboration between all authors. Author XYJ designed the study, wrote the protocol, wrote the first draft of the manuscript. Author ZL managed the literature searches, analyses of the study performed the spectroscopy analysis. Author LXG managed the experimental process and identified the species of plant. All authors read and approved the final manuscript.

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Case Study

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ABSTRACT

The Caijia Jialing river bridge which specialized for rail transit is a concrete cable-stayed bridge with main-span 250 m, two pylons and double cable planes. The static loading test includes the following contents: measurement of the initial state of the completed structure, appraisal loading test for the design loading capacity. The assessment analysis based on the tests and theoretical calculations showed that the strength and rigidity indicators for each of the control sections of the bridge satisfy the design requirements.

Keywords: Large span cable-stayed bridge; specialized for rail transit; static loading test; test and assessment.

**Corresponding author: Email: 631909003@qq.com;*

1. INTRODUCTION

The Caijia Jialing river bridge which specialized for rail transit is a concrete cable-stayed bridge with main span 250 m and tower beam consolidation system(as shown in Fig. 1). Orbit design load standard for subway - B type car, 6 a marshal, design speed 100 km/h. The bridge girder adopted single box single room of concrete box girder, beam height of 3.5 m and 15 m wide, double track traffic (as shown in Fig. 2). The diamond bridge tower was adopted, with 183 m. The bridge started to construct in November 2010 and opened by the end of 2013, as the world's second largest special cable-stayed bridge across the track. The main purpose of the bridge load test [1-4]:

(1) Check the bridge design and construction quality, verify the reliability of structure, and provide the necessary technical basis for the bridge completion acceptance.
(2) Get the actual stress state of the structure under test load, evaluate the performance of structure under design load, and inspect the bearing capacity and functional performance of the bridge through the load test.
(3) Provide scientific basis for the future operation and maintenance of bridge, and accumulate a reliable data for the same type bridge design and construction at the same time.

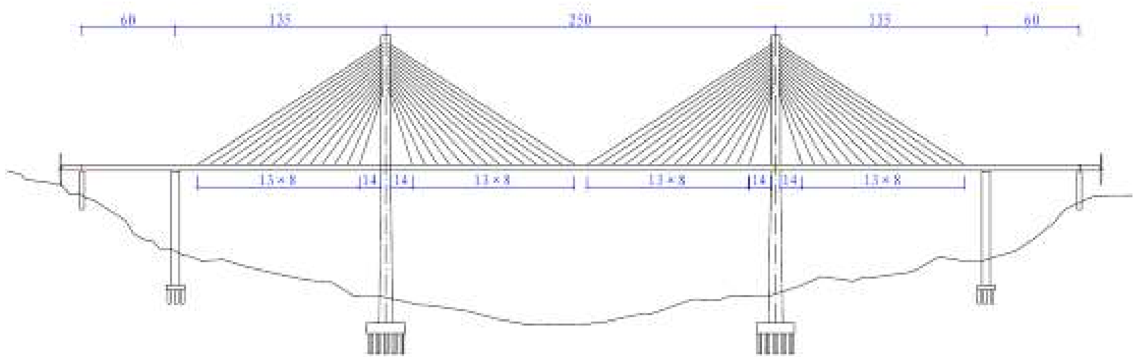

Fig. 1. Cable-stayed bridge elevation layout (unit: m)

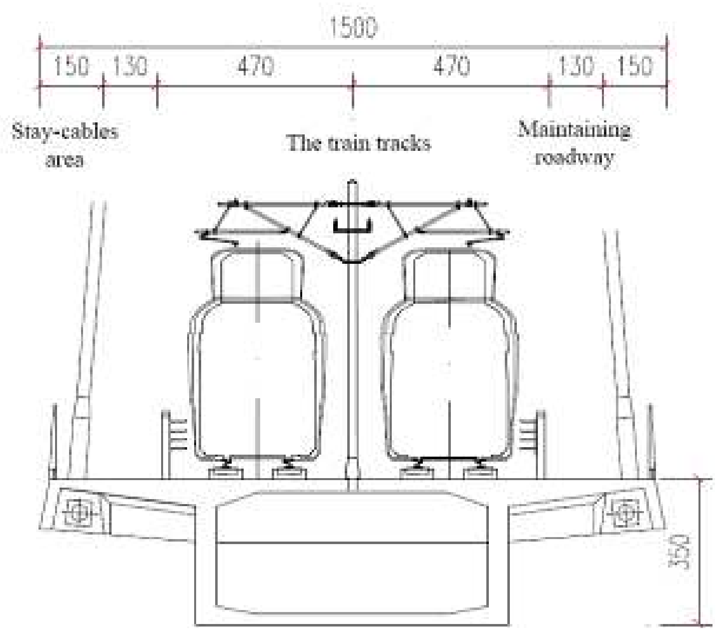

Fig. 2. Cable-stayed bridge cross section diagram (unit: cm)

2. INITIAL STATE INSPECTION OF COMPLETED STRUCTURE

We can test the quality of the bridge structure from two aspects [5-8]: first, whether or not a bridge structure into linear is consistent with the design; second, whether the cable force is consistent with the design or not under the action of dead load.

2.1 Detection Method

A bridge line and tower coordinate were measured by using of the bridge construction control network at the best moment. Adopted DiNi03 precision level to measure the bridge line from closed leveling according to the national second-class level and used thermometers to measure surface temperature of control point for considering temperature effect. The cable force measurement of the completed bridge state used the method of vibration.

2.2 Test Results and Evaluation

Through the measurement of the initial state, the analysis and evaluation of the test [9] result, the following conclusions could be obtained:

(1) The main girder linear is smooth (as shown in Fig. 3), with upstream and downstream height difference up to 4.8 cm; the mid-span theoretical pre-camber of main girder is 15 cm, and the actual pre-camber is 14.9 cm, which is in good agreement with the design value.
(2) The stay cable force distribution along the longitudinal is the same as the theoretical calculation results, on both sides of the cable force is almost the same (as shown in Fig. 4). The cable force measured maximum deviation of 8.0% which was compared with the theoretical value.

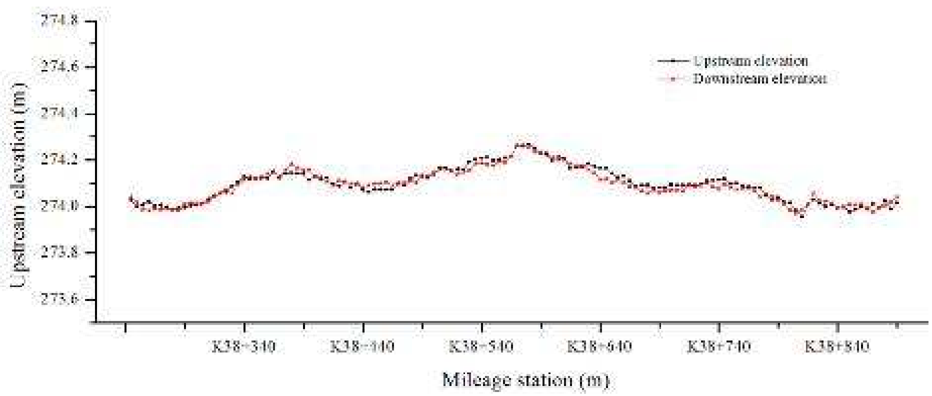

Fig. 3. The measured line shape of the girder

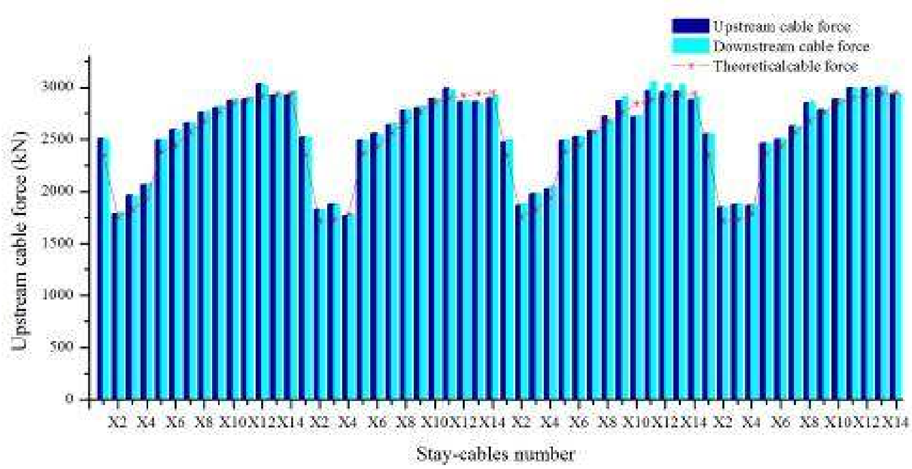

Fig. 4. Stay cable force distribution map

3. THE STATIC LOAD TEST

3.1 Test Item

Static load test is mainly used to test the degree that the main bearing component control section deflection or stress is consistent with design expectations under the action of the most unfavorable live load. Loading test is aimed at the following projects: main girder ends maximum longitudinal displacement, main girder control section maximum vertical deflection, main girder control section maximum stress, the largest cable force, the tower maximum longitudinal offset and control section stress, structural temperature.

3.2 Load Test Implementation

Loading ways of the static load test was in the form of subway B1 type load (as shown in Fig. 5). In terms of a specific test project (section), the number of vehicles required and load position was got by the principle of equation (1) [10] with the equivalent conversion, according to the most adverse internal force or displacement values which was produced by the design standard live load on the project (section).

$$0.80 < \eta = \frac{S_{state}}{(1+\mu)\cdot s} \leq 1.00 \qquad (1)$$

In the formula: η —static load test efficiency;

S_{state} —internal force or displacement maximum calculation effect of control section on a load test project (section);

S —the most adverse effect of the control section's internal force or displacement to the load test project (section), with design standard live load without shock loading;

$(1+\mu)$—Impact factor of the design calculation.

3.3 Observation Project and Measuring Method

The observation of the load test project was divided into seven parts: main girder ends maximum longitudinal displacement, main girder control section maximum vertical deflection, main girder control section maximum stress, the largest cable force, the tower maximum longitudinal offset and control section stress, structural temperature. The control section stress of main tower and main girder was measured by using of table stick vibrating string type strain and matching the data collection and analysis system; The main tower longitudinal displacement was observed by using of GPT-7500 total station; Both ends of main girder longitudinal displacement was measured by the dial indicator; The test method of control section vertical displacement of girder and suspension cable force was the same with the foregoing section 1.1.

3.4 Test Section and Loading Position

In order to reach the goal of load test and the relevant requirements, the load test was divided into 14 load conditions; The working condition of test section, test content and the loading position was shown in Table 1. Test section layout position was shown in Fig. 6.

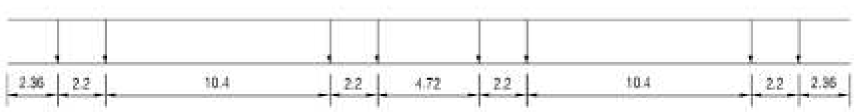

Fig. 5. Test load vehicles schematic diagram (unit: m)

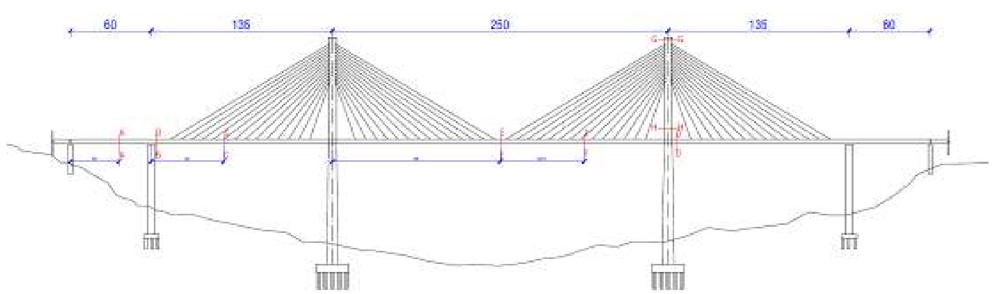

Fig. 6. The test section layout diagram (unit: m)

Table 1. Static loading test condition project list

Working condition	Loading position	Test content	Control section
1	The maximum bending moment of normal load	deflection, stress, cable force	E-E
2	The maximum bending moment of eccentric load	deflection, stress, cable force	E-E
3	L/4 in the cross of normal load	deflection, stress, cable force	F-F
4	L/4 in the cross of eccentric load	deflection, stress, cable force	F-F
5	The most-positive bending moment in side span of normal load	deflection, stress, displacement	A-A
6	The most-positive bending moment in side span of eccentric load	deflection, stress, displacement	A-A
7	The most-positive bending moment in abutment span of normal load	deflection, stress, cable force	C-C
8	The most-positive bending moment in abutment span of eccentric load	deflection, stress, cable force	C-C
9	Tower negative bending moment of normal load	the main girder stress, cable force	D-D
10	Tower negative bending moment of eccentric load	the main girder stress, cable force	D-D
11	The pier top negative bending moment in side span of normal load	the main girder stress, cable force	B-B
12	The pier top negative bending moment in side span of eccentric load	the main girder stress, cable force	B-B
13	The tower longitudinal displacement/The largest cable internal force of normal load	displacement of tower, section stress of tower, cable force	G-G /X14
14	The tower longitudinal displacement/The largest cable internal force of eccentric load	displacement of tower, section stress of tower, cable force	G-G /X14

3.5 Test Results and Evaluation

Compared measured results with finite element calculation results, we can got the following conclusion:

3.5.1 Loading efficiency

The static load test of the bridge load efficiency was between 0.91 and 0.96, which could meet the requirements of the relevant the test method of the long-span concrete bridge (railway group YC4-4/1978 of the scientific research project). At the same time, it shows that the most unfavorable effect (internal force and displacement) that was generated by test load could reflect the characteristics of the design specification of basic variable load effect.

3.5.2 Deflection test results

The measured deflection calibration coefficient on the control section of tower and girder was between 0.60 and 0.89, that the measured values were less than the calculated value, and it showed that the vertical stiffness could meet the design requirements; The measured maximum relative residual deformation was less than 20%, which indicated that structure was in a state of good flexibility to work [11]. Vertical deflection of the measured value: mid-span upstream side was 137.9 mm, and mid-span downstream side was 131.1 mm, for design calculation value of 0.88 and 0.84 times. In the most unfavorable design of main girder under the influence of live load the vertical deflection was less than the largest design expectations, and the vertical stiffness of main girder could meet the design requirements; the measured maximum longitudinal displacement of tower was 59.3 mm, and the theoretical calculation value was 72.2 mm. The measured deflection calibration coefficient of tower was 0.82. In the most unfavorable design of main tower under the influence of live load the stiffness could meet the requirements.

3.5.3 Stress test

The measured stress calibration coefficient on the control section of tower and girder was between 0.54 and 0.91, that the measured values were less than the calculated value, and it showed that the strength of the structure could meet the design requirements; The measured maximum relative residual deformation was less than 20%, which indicated that structure was in a state of good flexibility to work. The measured stress structure calibration coefficient about the most-positive bending moment of section L/4 and L/2 was between 0.64 ~ 0.64 and 0.64 ~ 0.87. It showed that the actual stress of control section was smaller than design expectation in the most unfavorable design of girder under the influence of live load, and structural strength could meet the design requirements; the measured stress calibration coefficient of tower was between 0.58 and 0.84. It suggested that the strength of tower could meet the requirements in the most unfavorable design of main tower under the influence of live load.

3.5.4 Cable force test

The measured cable force increment calibration coefficient was between 0.67 and 0.90. It showed that cable force could meet the design requirements; the measured maximum relative residual deformation was less than 20%, which indicated that cable was in a state of good flexibility to work.

3.5.5 Structural cracks observation

Each work condition of load test before loading, any crack was not found on all of the test sections; in load project, there was not a new crack found on each of the test section, it showed that the structure was in good state of flexible work and could meet the design requirements.

3.5.6 Effect of eccentric load test

Experiment confirmed that the effect of eccentric load about vertical displacement of girder and cable force was obvious under transverse eccentric load. Loading condition 1 and conditions 2, the measured mid-span vertical displacement lateral deviation of girder was 6.8 mm and 36.2 mm respectively, and the theoretical mid-span vertical displacement lateral deviation of girder was 0.0 mm and 37.4 mm respectively. The measured eccentric load effect of structure differed with the theory of 3.2%. At the same time it can be concluded that the structure had good symmetry or anti-symmetry performances under symmetrical or anti-symmetry load.

4. CONCLUSION

In this paper, we conducted a comprehensive inspection with the initial state of Caijia special railway cable-stayed bridge, and completed the load bearing capacity test. All results reflected that the construction quality and precision of main girder, stay-cables and tower were good; The structure internal force state of completed bridge was consistent with the design expectation; The strength of main girder and the vertical stiffness index could meet the design requirements; the strength of stay-cables with good elastic performance could meet the design requirements; The main tower longitudinal displacement and tower control section stress could meet the design requirements.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wei-xin Ren. Ultimate behavior of long-Span cable一Stayed bridges Journal of bridge engineering; 1999.
2. Adeli H, Zhang J. Fully nonlinear analysis of composite girder cable-stayed bridges. Computers & Structures. 1995;54(2):267-277.
3. Yan YJ, Cheng L, Wu ZY, et al. Development in vibration-based structural damage detection technique [J]. Mechanical Systems and Signal Processing. 2007;21(5):2198-2211.
4. Ni YQ, Zhou HF, Chan KC, et al. Modal flexibility analysis of cable - Stayed Ting Kau Bridge for damage identification [J]. Computer-Aided Civil and Infrastructure Engineering. 2008;23(3):223-236.
5. Xu Z, Wu Z. Simulation of the effect of temperature variation on damage detection in a Long-Span Cable-Stayed Bridge [J], Structural Health Monitoring. 2007;6(3): 177-189.
6. Caieedo JM. Comparision of modeling techniques for dynamic analysis of a cable-stayed Bridge[C]. Proceedings of the

Engineering mechanics specialty conference [A]. Austin, Texas; 2000.
7. Yang QW. A new damage identification method based on structural flexibility disassembly [J]. Journal of Vibration and Control. 2011;17(7):1000-1008.
8. Zhu XQ, Law SS. Moving load identification on multi-span continuous bridges with elastic bearings [J]. Mechanical Systems and Signal Processing. 2006;20(7):1759-1782.
9. Beijing construction engineering quality third testing co. LTD. The completed bridge loading test report of Caijia Jialing River Bridge which Specialized for Rail Transit. 2013;12.
10. The ministry of communications highway science institute. The test method of large-span concrete bridge. 1982;10.
11. Zhou MH. Civil engineering structure testing and detection (version 2). Nanjing: Southeast University Press. 2010;304.

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