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Static Load Test Study on Long-span Continuous Rigid Frame Bridge with V-shaped Pier

ZHANG Fei^{1, a}, WANG Yan¹

¹College of Engineering, Fujian Jiangxia University, Fuzhou 350108, China

^aCorresponding author: 597586597@qq.com

Abstract. Taking the main bridge of the shuidong bridge in Youxi country of Fujian province as background, this paper develops the static characteristic analysis and static load test study on long-span prestressed continuous rigid frame bridge with V-shaped pier. By the analysis and comparison between the measured data and FEA results, it evaluates the working condition of the bridge. The results show: Firstly, each evaluation indicator tested meets the requirements of “Test methods for large-span concrete bridges”; Secondly, the strain efficacy coefficient of measured points in top plate of each control section is within 0.65~0.74, and that of the measured points in bottom plate is within 0.64~0.73, the residual strain of the measured points is less, therefore, the safety stock of the bridge is sufficient, and it is on the flexible working condition basically; Finally, the measured value and the theoretical value of deflection curves along the longitudinal bridge is compatible, the efficacy coefficient of vertical deformation is within 0.55~0.85, and the severity of the practical structure is more.

1. Introduction

The continuous rigid frame bridge with V-shaped pier shortens the span of the girder, and the appearance is light and beautiful, with the loading characteristics both on continuous rigid frame bridge and slant-legged rigid frame bridge^[1]. For years, a considerable number of engineering examples of continuous rigid frame bridges with V-shaped pier have been built in China, the test detection and stress evaluation should be conducted aiming at the old bridges that are used in long-term overload during operation^[2-3]. Based on the finite element analysis of MIDAS/Civil, this paper takes the main bridge of the shuidong bridge in Youxi country of Fujian province as background, and it conducts the site static load test, which obtains the test evaluation indexes, including: calibration coefficients for strain and deflection, relative residual strain and transverse increase coefficient of strain and so on, finally, it evaluates the bearing capacity of the structure, stiffness characteristic and working conditions.

2. Engineering background

The main bridge of shuidong bridge in Youxi county, Fujian province is a four-span V-shaped pier continuous rigid frame bridge with a span of (42+65+65+42)m. The main girder is a double-box trapezoidal box girder with variable section, the height of the root girder is 3.4m, the height of the mid-span girder is 1.9m, the curve of the bottom girder is a quadratic circle curve. With the bottom V-shaped pier joint force, V-shaped pier support height of 5.5 m, thickness of 1.20 ~ 1.45 m, the angle between center line of the V-shaped pier supports and the vertical pier center is about 47.5 °.



3. Establishment of finite element model

3.1 Finite element model

The finite element model is established by the bridge analysis software MIDAS/Civil. The main beam is divided into units according to the beam section in the cantilever cast-in-situ construction, and each segment is divided into 2 units. Because block 0 is long, and the local force is complex, it is divided into 12 units and the closed section is divided into 2 units. For the V-shaped pier, the inclined support is divided into 6 units, and the bottom vertical pier is divided into 10 units. The whole bridge is divided into 197 beam elements and 207 nodes. The bridge calculation model is shown in Fig. 1.

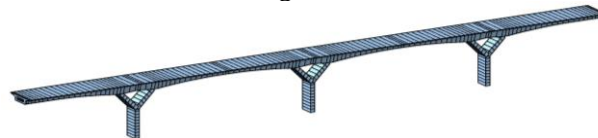


Figure 1. Finite element model of bridge

3.2 Boundary conditions and loads

The consolidation state of the joint between the V-shaped brace and the main beam is simulated by the “rigidity” in the “elastic connection” project. Sliding hinge bearing is used to simulate the rubber bearing on the top of pier No. 0 and pier No.4. Since rock-socketed pile is adopted, the geometric size of pile foundation cap is much larger than the section size of vertical pier, fixed constraint is adopted in the model to simulate the boundary condition of V-shaped pier bottom^[4].

Bridge structure dead weight is calculated by the program automatically, and the second stage constant load is applied according to uniformly distributed load, the prestress is edited according to the layout shape of the steel bundle in the design drawing. It is applied by the “prestressed load”^[5].

4. Analysis of static characteristic

According to the stress characteristics of V-shaped pier continuous rigid frame bridge, the mid-span section of the main beam, the fulcrum section, the section at the bottom of the V-shaped brace, the section at the top of the pier and the section at the bottom of the pier are selected as the unfavorable sections under stress. The maximum positive bending moment and maximum negative bending moment of the structure caused by vehicle load are shown in Fig. 2.

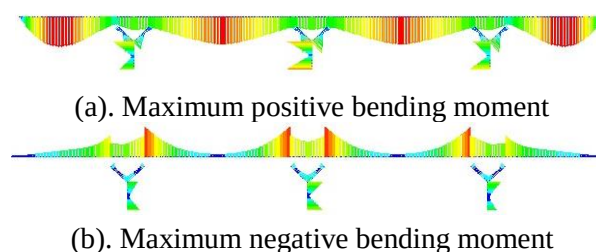


Figure 2. Maximum internal force of the structure caused by the vehicle

It can be seen from Fig. 2: The maximum positive bending moment at the side span of the structure is greater than that at the middle of the main span. The maximum positive bending moment section of the side span is 16.5m away from the center of No.0 pier, which is roughly at the position of 0.4L section. The negative bending moment of the mid-span fulcrum section is greater than that of the side span fulcrum section. The maximum section of negative bending moment of main beam fulcrum appears at the fulcrum of V support of middle pier.

In the practical structure, there is a transverse diaphragm in the box girder at the fulcrum of V support, which affects the force on the section of the box girder. To compare and analyze the measured value of the static load test with the calculated value of the theoretical model, the section with a certain distance from the fulcrum of the V support is selected as the section with the most unfavorable

negative bending moment. The test control section is shown in Fig. 3, and the influence line of bending moment of each control section is shown in Fig. 4.

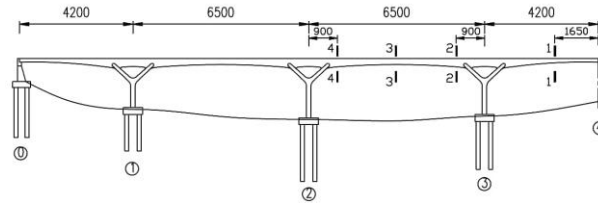


Figure 3. Test control section (cm)

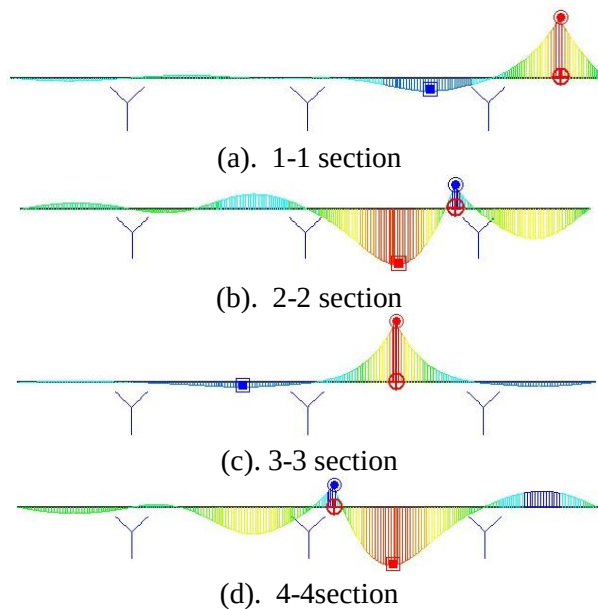


Figure 4. Influence lines of bending moments of each control section

5. Static test

5.1 Test item

In the static load test of the main bridge of Youxi shuidong bridge, the left main beam is selected as the test object. The test items mainly include the measuring point strain and vertical deformation of each control section under various test conditions. Four control sections for strain test is shown in Fig. 3, and nine locations for deflection test is shown in Fig. 5.

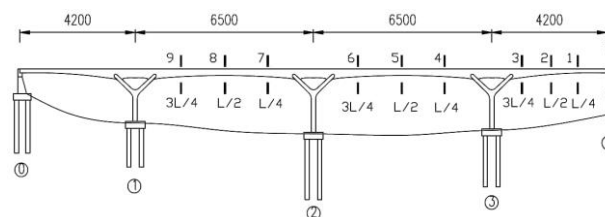


Figure 5. Deflection test section (cm)

5.2 Test case and load distribution

Static load test uses 4 trucks with the capacity of 40 tons to simulate the highway-II class cars. According to the influence line of bending moment of each control section in the finite element

analysis, the load distribution form of the loading vehicle in the test case is drawn up, as shown in Fig. 6.

The load efficiency is calculated according to the actual load distribution in the test conditions, and the load efficiency of each case is shown in Table 1. It can be seen that the test efficiency under various working conditions is between 0.92 and 1.01, meeting the requirements of static load test.

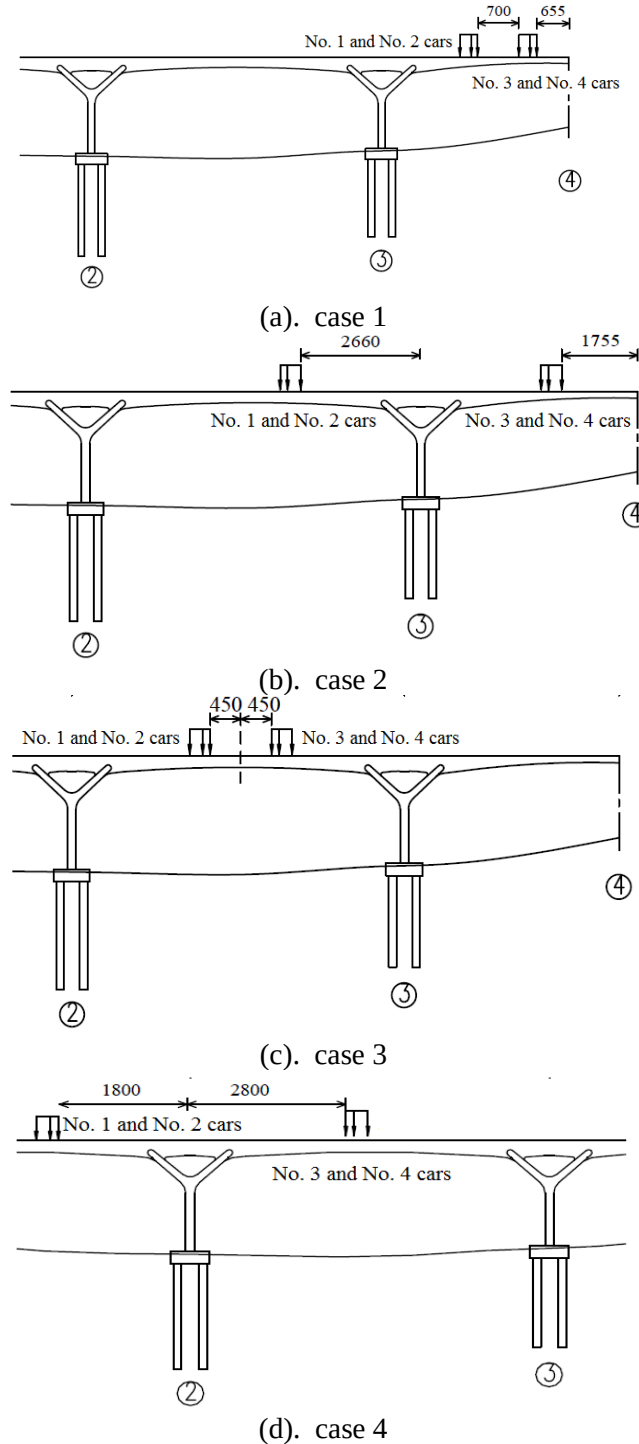


Figure 6. Loading vehicle layout (cm)

Table 1. Load efficiency of each case

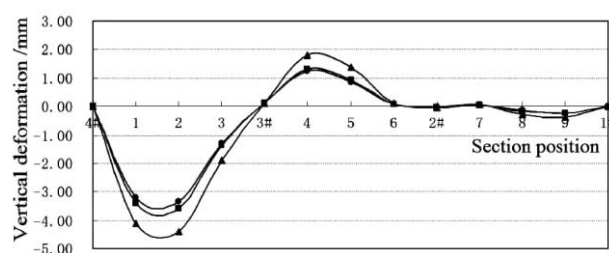
Case	Control section	Structure effect	Test load (kN·m)	Design load (kN·m)	Efficiency coefficient
1	1-1	Maximum positive bending moment	5900	5850	1.01
2	2-2	Maximum negative bending moment	-7310	-7960	0.92
3	3-3	Maximum positive bending moment	5410	5400	1.00
4	4-4	Maximum negative bending moment	-7540	-8090	0.93

5.3 Experimental data test

Under the load of 4 test cases, the transverse distribution of strain test value, theoretical value, calibration coefficient, residual strain and strain of each measuring point on the corresponding control section is shown in Table 2, in which tensile strain is positive and compressive strain is negative. The deflection curve of the measuring points at each position of the main girder is shown in Fig. 7, in which the deflection deformation is positive upward and negative downward.

Table 2. Strain testing and analysis of each case

Item	Location of the test point	Case 1	Case 2	Case 3	Case 4
Efficacy coefficient	Top plate	0.61~0.70	0.67~0.73	0.70~0.78	0.67~0.73
	Bottom plate	0.61~0.67	0.68~0.74	0.69~0.78	0.65~0.70
Maximum strain of the top plate / $\mu\epsilon$	Measured value	-16	11	-21	11
	Calculated value	-23	15	-27	15
Maximum strain of the bottom plate / $\mu\epsilon$	Measured value	24	-14	25	-14
	Calculated value	36	-19	32	-20
Relative residual strain /%	Top plate	6.2	9.1	4.8	9.1
	Bottom plate	4.2	0	8.0	0
Lateral increase coefficient of strain	Top plate	1.07	1.03	1.05	1.03
	Bottom plate	1.04	1.05	1.07	1.02



(a). case 1

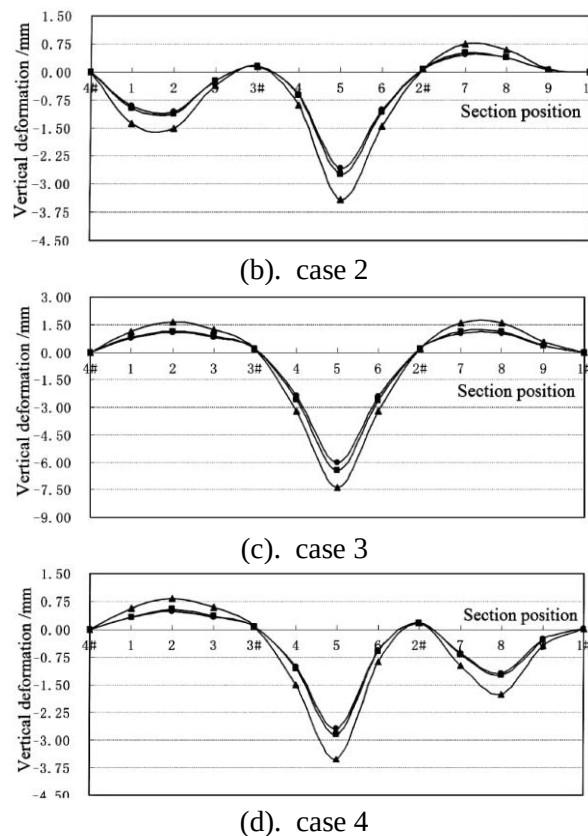


Figure 7. Deflection curves of measuring points of each case

6. Conclusion

By the analysis of the static characteristics of the V-shaped pier continuous rigid frame bridge and the static load test study, the following conclusions can be drawn:

(1) Under the four test conditions, the strain efficacy coefficient of measured points in top plate of each control section is within 0.65~0.74, and that of the measured points in bottom plate is within 0.64~0.73. The evaluation indexes meet the requirements of “test methods for large-span concrete bridges”. The residual strain of the measured points is less, therefore, the safety stock of the bridge is sufficient, and it is on the flexible working condition basically.

(2) The transverse increase coefficient is between 1.02 and 1.07, which is less than the standard value of 1.15, indicating that the torsional stiffness of the main beam is large and the overall performance of the structure is good.

(3) Under the four test conditions, the test value and the theoretical value of deflection change along the longitudinal bridge is compatible. The mean value of deflection check coefficient is between 0.55 and 0.85. The deflection test values of two test points on the same section are similar and evenly distributed.

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