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Static Load Test Detection of Continuous Rigid-Frame Railway Bridge

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Abstract: The quality of the continuous rigid-frame railway bridge is related to the safety of train operation, so it is necessary to test its stiffness, strength, and other indicators. Static load test is a common technique for bridge inspection. This article summarizes the purpose of the static load test for a continuous rigid-frame railway bridge, including the required equipment, operation methods, etc., and lists examples to analyze the operation process and precautions of static load test, hoping to provide reference information for relevant personnel.

Keywords: Railway bridge; Rigid-frame; Static load test

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1. Introduction

In recent years, China's railway construction has made great progress, and the number of continuous rigid-frame railway bridges has increased significantly. The bearing capacity, stiffness, and stability of continuous rigid-frame railway bridges can have a great impact on the safe and stable operation of trains. Therefore, it is necessary to adopt effective methods to detect and evaluate its quality, and properly handle quality problems. The main function of the static load test is to determine the bearing capacity of the bridge and evaluate the degradation through the changes in structural strain and deflection. It can determine whether there are quality problems in the continuous steel structure railway bridge, thereby ensuring the safety and stability of train operation.

2. Concept and purpose of static load test for continuous rigid-frame railway bridge

The static load test of the continuous rigid-frame railway bridge mainly refers to applying a static load on the designated position of the bridge according to the predetermined test purpose and test plan, measuring the static strain, static displacement, settlement, cracks, and other indicators of the bridge structure, and determining whether the working performance and bearing capacity of the bridge structure under load are up to standard according to relevant regulations and specification requirements. The author believes that the static load test of a continuous rigid-frame railway bridge can judge whether the stiffness, strength, bearing capacity, and stability of a continuous rigid-frame railway bridge meet the requirements of relevant standards, and effective construction measures can be taken for railway bridges that do not meet the requirements of relevant standards, thereby ensuring the safe and stable operation of trains [2].

3. Continuous rigid-frame railway bridge static load test instrument and loading method

The devices required for the static load test of the continuous rigid-frame railway bridge are as follows:

(1) Reaction device: To accommodate a design bearing capacity of 200 kPa, a reaction force device with a capacity of 60–80 tons is required. Technicians must prepare by constructing brick walls in advance and placing I-beams above them to serve as a load platform. Soil bags are then piled onto this platform and filled with sand to create the load-bearing surface [3].

(2) Force measuring device: The force measuring device employed is a hydraulic jack with a capacity of 100 tons. It should have a minimum lifting height of 180 mm, and a maximum height not exceeding 335 mm.

(3) Load plate: Load plates such as square steel plates or circular steel plates are utilized as load-bearing elements. To avoid deformation of the load plate, an additional load plate can be placed on top of it if necessary [4].

(4) Deformation measurement device: The deformation measurement device must be capable of providing precise measurements with an accuracy of 0.01 mm.

In terms of the testing procedure, the common loading method for a continuous rigid-frame railway bridge involves a gradual, continuous loading scheme. Technicians add the next level of load only after each preceding load level has reached a stable state. Subsequently, they perform staged unloading once the test piles exhibit signs of damage. Depending on the specific circumstances, technicians can also adapt alternative loading and unloading methods, such as the multi-cycle loading and unloading approach and the rapid maintenance load method. Those variations can be employed in combination with the actual conditions encountered during testing.

4. Static load test method for continuous rigid-frame railway bridge

4.1. Reasonable determination of test pier and control section

In the static load test of a continuous rigid-frame railway bridge, technicians can choose 1–3 representative piers to complete the test. The criteria for selecting piers including the piers are not conducive to the calculation of force, the construction quality is poor, there are many issues, and it is easy to erect scaffolding [5]. Meanwhile, technicians need to select an appropriate control section in combination with specific test items. In the process of selecting the control section, it is necessary to consider the relevant requirements for measuring the bearing capacity of the bridge, analyze and study the most unfavorable stress state of the bridge, and then determine the control section. If the structure of the continuous steel railway bridge is relatively simple, one control section can be selected, otherwise multiple control sections can be selected.

4.2. Setting of test points

Technicians need to set test measuring points on the premise of ensuring accurate test results and controlling the overall number of test measuring points. The same measuring point can be tested using different testing methods. In the process of setting the main measuring points, technicians need to provide the maximum stress and maximum displacement of the inspected spans and adjacent spans, and each span needs to set 3–5 measuring points. In the process of measuring the stress and strain of the facility structure, it is necessary to ensure that each measuring point can measure the lateral and vertical stress distribution of the internal force control section [6]. In the process of setting the vertical measuring points of the beam section, it is necessary to set more than 5 measuring points along the height of the section and ensure that there are measuring points at the sudden change of the section. For cross-section bridges, it is necessary to set strain measuring points in areas with high stress. The locations of the measuring points are the upper and lower edges of the cross-section, and the number of measurement points should not be less than 3.

4.3. Static load test

During the static load test, technicians must adhere to the following operational plan:

(1) Preload test: Before the static load test of the continuous rigid-frame railway bridge is officially carried out, the technicians need to complete the preloading operation in order to find possible problems in the test and ensure the smooth completion of the static load test. During the preloading test, technicians need to set the load to 30%–50% of the maximum test load. The load of the reinforced concrete structure should be lower than the cracking load, and it needs to be maintained for 10 minutes after completing the first-level record [7].

(2) Static load test: During the actual static load test, technicians must rigorously adhere to operating guidelines, gradually increase the load and internal force of the section, and closely monitor the loading process to control the displacement of the measuring point. If the following situations occur during the loading process, the loading needs to be stopped in time: the displacement of the abutment is greater than the allowable range and cannot maintain stability; the deflection and strain of the measuring point under a certain load force exceed the check calculation control value or the limited range; the strain at the control point increases and becomes unstable; cracks occur during the loading process, and the crack width is greater than the limited range; the bridge structure is damaged during the loading process, affecting its normal use [8].

4.4. Static load test result analysis

After the static load test is completed, technicians need to analyze and study the test results, focusing on the analysis of the maximum crack width, maximum deflection, and other indicators, and evaluate the difference between the actual measured value and the theoretically calculated value of the control point, and then determine the safety and stability of the continuous rigid-frame railway bridge. At the same time, it is also necessary to compare and analyze the difference between the actual measured value of the control point and the specified allowable range, and then judge whether the working state of the continuous rigid-frame railway bridge is normal [9].

4.5. Precautions for static load test

During the static load test of a continuous rigid-frame railway bridge, technicians need to master the following precautions. Firstly, during the static load test, technicians need to choose a suitable location to paste the sensor and avoid sticking the sensor to the crack area of the structure, so as to accurately evaluate the stress state of the steel bar. Secondly, during the static load test, a PVC cable equipped with a protective sheath and a metal shielding device can be selected as the sensor test wire, and the wire diameter should not be too small to ensure the anti-interference performance of the sensor [10]. Lastly, technicians need to wait for the load on the structure to stabilize before collecting data to save data collection time.

5. Case analysis

5.1. Basic information about the case

The continuous rigid-frame railway bridge examined in this study has the following specifications: it spans a total length of 14 m + 18 m + 18 m + 14 m. It adopts a well-digging foundation structure, featuring a T-shaped cross-section beam with uniform dimension. The entire beam has a height of 1.05 m equally, bottom width of 9.38 m, and top width of 11.24 m. The flange plate possesses an edge thickness of 12 cm, while the root thickness measures 35 cm. The pier body, which has a rectangular cross-section, is reinforced with ribs in the pier joint area. The ribs have a length of 140 cm and a height of 45 cm. Both the pier body and the beam are constructed using C40 concrete, while the foundation is made of C25 concrete. The steel bars employed in this construction are of HRB335 and Q235 varieties [11].

5.2. Static load test points

The static load test of this continuous rigid-frame railway bridge is based on the design load to detect the actual working performance of each structure in the upper area of the bridge. During the test, technicians adopted the scheme of equivalently loading the vehicle load to trigger changes in the strain and deflection of the structures in the upper area of the bridge, measured the relevant values, and compared them with the standard values to determine whether the bearing capacity of the bridge meets the requirements [12]. The static load test items of the continuous rigid-frame railway bridge include the original crack and new crack expansion status of the bridge, the deflection of the typical area, and the stress status of the reinforced concrete in the typical section area of the bridge span, the stress distribution and the changing trend.

5.3. Selection of measuring point

According to the characteristics of the continuous rigid-frame railway bridge, technicians set the measuring points in the mid-span, quarter-span, and fulcrum areas of the second span.

5.4. Test content of different test conditions

During the static load test, technicians used two diesel locomotives (model DF4) to implement double-line loading operations and completed the static load test according to the operating specifications. The test items of the static load test under different test conditions are as follows:

(1) The first working condition is the fulcrum loaded with the maximum negative bending moment. The test content includes the fulcrum crack, the maximum tensile stress of the fulcrum steel bar, and the maximum compressive stress of the fulcrum concrete [13].

(2) The second working condition is the maximum positive bending moment loading on the mid-span section. The specific content of the test includes the maximum tensile stress and compressive stress of the mid-span concrete structure, the crack situation of the mid-span, and the deflection of the mid-span.

(3) The third working condition is the maximum shear loading fulcrum section, and the test content includes the crack and shear stress of the fulcrum section.

(4) The fourth working condition is a quarter-span section loaded with high shear force, and the test content includes the shear stress and cracks generated after loading.

5.5. Static load test process

The static load test process of the continuous rigid-frame railway bridge is as follows. Technicians initially prepared various instruments and equipment in advance, conducted performance tests, completed the preload test according to the operating specifications, properly handled the problems existing in the preload test, and conducted the static load test after confirming that there was no abnormality. During the static load test, technicians then completed the test operations of the four working conditions one by one. The actual interval of the static loading time of different working conditions was 20 minutes. Technicians arranged the test vehicle to reach the predetermined position, turned off the engine in time, and dynamically recorded various data.

5.6. Modeling calculations and data organization

After the static load test data collection is completed, technicians combined the design drawings, took the overall structure of the continuous rigid-frame railway bridge as the analysis and research object, used specialized software to complete the modeling, determined the theoretical values under different working conditions through calculations, and compared them with the actual measured values. After the modeling was completed, technicians sorted out and analyzed various values. Among the measured values of the maximum compressive stress of concrete, the measured average value of the fulcrum was 3.75 MPa, the calculated value was 7.20 MPa, and the calibration coefficient was 0.52. Among the measured values of the maximum tensile stress of steel bars, the measured average value of the fulcrum is 81.55 MPa, the calculated value is 137.9 MPa, and the calibration coefficient is 0.58, the measured average value of the mid-span is 83.22 MPa, the calculated value is 136.9 MPa, and the calibration coefficient is 0.63. Among the maximum shear stress measurement values, the measured average value of the fulcrum is 0.71 MPa, the calculated value is 0.95 MPa, and the calibration coefficient is 0.77; the measured average value of the 1/4 span is 0.46 MPa, the calculated value is 0.66 MPa, and the calibration coefficient is 0.72. The test results of the maximum deflection in the mid-span show that the measured average value is 2.94, the calculated value is 5.12, and the calibration coefficient is 0.55. During the static load test of the continuous rigid-frame railway bridge, technicians observed the cracks at the top of the fulcrum, the bottom of the beam, and the variable cross-section area. The results showed that the original cracks in the cross-section remained stable under different working conditions, and no new cracks occurred.

5.7. Static load test result analysis

Analysis and research on the static load test results of the continuous rigid-frame railway bridge are as follows. Firstly, the static load test results show that the mid-span deflection calibration coefficient ranges from 0.55 to 0.65, which meets the requirements of relevant standards. The measurement results show that the maximum deflection at the bottom of the mid-span section beam is 2.90 mm, and the relevant regulations require a vertical deflection-span ratio of 8.42 mm, which meets the requirements of the relevant regulations. Based on this, it can be considered that the rigidity of the continuous rigid-frame railway bridge is normal and has no adverse effects on the safety of train operations. Secondly, the static load test results show that the maximum compressive stress of the concrete structure of the continuous rigid-frame railway bridge is 3.75 MPa, which is lower than the 16.2 MPa required by the relevant specifications, and the calibration coefficient is 0.54, which is in line with the range of 0.45–0.55 required by the relevant specifications. The maximum tensile stress of the steel bar is 83.22 MPa, which is lower than the 180 MPa required in the relevant specifications, and the calibration coefficient is 0.63, which is in line with the range of 0.55–0.65 required by the relevant specifications. The maximum establishment of the cross-section is 0.71 MPa, which is lower than the 1.34 MPa required in the relevant specifications, and the calibration coefficient meets the relevant requirements. The original cracks of the continuous rigid-frame railway bridge were stable during the static load test, and no new cracks occurred. Through the analysis of the above data, it can be seen that the rigidity, strength, stability, and bearing capacity of the continuous rigid-frame railway bridge all meet the requirements of relevant standards, which can ensure the safety of trains. In order to avoid accidents, technicians need to conduct static load tests regularly and conduct appearance inspections, material defect inspections, etc., so as to find and effectively deal with various problems in time [15].

6. Conclusion

The stability and safety of continuous rigid-frame railway bridges can have a great impact on the safety of train operation, so it is necessary to accurately evaluate its quality through effective detection technology. Static load test is an effective technical solution for evaluating the stiffness and bearing capacity of continuous rigid-frame railway bridges. Technicians need to master the key points of operation, complete various operations in a standardized manner, and accumulate experience in practice to ensure the accuracy of test results.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Ma M, 2023, Research on Initial State of Cable-Stayed Bridge Based on Dynamic and Static Load Tests. Urban Road Bridge and Flood Control, 2023(5): 177–181.

[2] Chen W, Zhong W, Yin R, et al., 2023, Analysis of the Operation Status of Old Urban Bridges Based on Dynamic and Static Load Tests. Municipal Technology, 41(2): 16–21.

[3] Lu D, Jin C, Qiu J, 2023, Based on the Static and Dynamic Load Tests of the Three-Tower Double-Cable-Plane Cable-Stayed Bridge, a Brief Analysis of the Influence of the Dynamic Load Test Results on the Judgment of the Bridge's Static Load Bearing Capacity. Guangdong Building Materials, 39(1): 46–48.

[4] Zhou Y, Long J, 2023, Research on Static Load Test of Xintian Yangtze River Bridge. Journal of Hunan City University (Natural Science Edition), 32(2): 6–11.

[5] Lv L, 2023, Research on Bridge Bearing Capacity Detection Based on Static Load Test. Architecture and Decoration, 2023(3): 154–156.

[6] Zhang K, 2023, Analysis of the Role of Static Load Test in the Detection of Pile Foundations of Highway Bridges. Sichuan Building Materials, 49(5): 32–34.

[7] Liu Z, 2023, Research on Static Load Test of Reinforced Concrete Highway Bridge. Traffic World, 2023(11): 178–180.

[8] Xu M, 2023, Research on Static Load Test of Feiyan Concrete Steel Tube Tied Arch Bridge—Taking the Main Bridge of Ji'an Bridge as an Example. Engineering Technology Research, 8(7): 5–8.

[9] Wang B, 2023, Analysis of the Role of Static Load Test in the Detection of Highway Bridges. Xinjiang Nonferrous Metals, 46(4): 19–20.

[10] Hu X, Wei B, Wang Y, et al., 2022, Experimental Study on Dynamic and Static Loads of Railway Hybrid Girder Cable-Stayed Bridge. Urban Road Bridge and Flood Control, 2022(9): 103–107.

[11] Liang D, 2022, Application of Optimized GM (1, 1) Model in Bridge Static Load Test. Urban Road Bridge and Flood Control, 2022(5): 202–205.

[12] Tian S, Wang L, Xia F, 2022, Evaluation of Existing Bridge Bearing Capacity Based on Static Load Test—Taking Yuxi Road Overpass Bridge as an Example. Engineering Technology Research, 7(8): 18–20.

[13] Liu C, 2022, Application of Static Load Test in Pile Foundation Inspection of Highway Bridges. Traffic World (Mid-day Journal), 2022(8): 129–131 + 134.

[14] Feng W, 2023, Analysis and Research on Static Load Test of Leaning Tower and Cable-Stayed Bridge. Heilongjiang Communication Science and Technology, 46(2): 107–109.

[15] Huo W, 2023, Evaluation of Prestressed Simply Supported Box Girder Bridge Bearing Capacity Based on Static Load Test. Gansu Science and Technology, 39(1): 21–27.