

Load Testing in Bridge Maintenance

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Abstract: Highway bridges are a crucial component in road transportation networks. These bridges must be maintained according to usage requirements regularly. Test results must be considered before devising a maintenance plan. Load testing is a vital method of assessing the quality and performance of highway bridges. The outcomes of these tests facilitate the formulation of maintenance plans. This article examines the definition of load testing, its significance, and the process of execution, with the goal of providing support for bridge inspection and maintenance.

Keywords: Highway bridge; Load test and inspection; Bridge maintenance

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1. Introduction

Load testing is important for ensuring the quality of maintenance work on highway bridges. By analyzing the test results, relevant personnel can gain insight into the bridge's bearing capacity and structural characteristics and clarify its operating status. This information is crucial in developing effective maintenance and construction plans for the future. However, it is important to note that different load test methods have varying technical requirements. Therefore, relevant personnel need to explore and understand the application of load tests to ensure proper maintenance and safe operation of the bridge.

2. Description of load testing

Load testing is a method used to assess the performance of a bridge structure under various loads. It involves applying loads to the entire bridge or specific areas and measuring the resulting strain or displacement. By analyzing these parameters along with factors like stability, engineers can evaluate the bridge's bearing capacity. This comprehensive evaluation also extends to assessing the overall condition of the highway. Upon completion of load testing for a highway bridge, the inspection results provide valuable insights for formulating repair or maintenance plans. These results guide decision-making processes aimed at ensuring the safety and longevity of the bridge infrastructure.

Load testing serves as an indicator to comprehensively analyze the bearing capacity of the bridge

structure. It involves static load tests, dynamic load tests, and other tests. The static load tests analyze the bridge structure's static load. This test type is used to analyze the bridge stiffness and section strength comprehensively. Dynamic load tests are conducted to analyze how bridges respond to dynamic loads. These tests employ various methods such as wheel-locking tests, bump tests, vehicle field tests, and fluctuation tests to gather data on the bridge's behavior under dynamic loads. Parameters like fluctuation data, impact coefficient, maximum dynamic deflection, natural frequency, damping ratio, and vibration response are measured during these tests to assess the bridge's structural performance under dynamic loading conditions ^[1].

3. Significance of highway bridge maintenance work

With the rapid development of cities, the number of highway and bridge project constructions has gradually increased. The improvement in transportation infrastructure has also made highway transportation more convenient. Highway bridge maintenance is an important measure to extend the service life of road bridges and prevent serious structural cracks. Over time, may develop various issues that pose serious risks to traffic safety. Increased traffic usage accelerates structural aging, while exposure to environmental factors like wind and water erosion can further diminish the bridge's bearing capacity. As a result, load tests become essential during bridge maintenance to assess the current condition of the structure accurately. By conducting load tests, inspectors can thoroughly evaluate the bridge's structural integrity and identify specific maintenance requirements. These tests provide valuable insights into potential areas of concern, allowing for targeted maintenance operations aimed at preserving the safety and functionality of the bridge.

4. Significance of load testing in bridge maintenance

(1) Extend the service life of roads and bridges

Maintenance work is essential to ensure that highway bridges are in good condition. The quality of maintenance determines the safety of highway bridges, which makes choosing a highly feasible maintenance plan important. Proper and timely maintenance ensures the structural safety and longevity of road bridges. Load testing plays a significant role in inspecting bridge performance during operation. By analyzing the bridge's resonance characteristics, stress conditions, and other factors, load tests provide valuable measurement data for assessing structural strength, traffic performance, and bearing capacity. Additionally, load testing facilitates systematic testing of bridge structures, enabling objective comparisons of operational and maintenance data. This helps identify issues, formulate preventive maintenance plans, reinforce and repair structures, and ultimately prolong the service life of bridges.

(2) Ensuring traffic safety on roads and bridges

With the increasing frequency of use and number of vehicles on the highway, the load of the bridge structure may exceed the design standards, which increases the risk of accidents. Besides, the construction of highway bridges is complex and can be affected by various environmental factors. In this regard, regular maintenance is required to ensure the safety of highway bridges. Load testing is performed during maintenance. Road and bridge engineering maintenance plans are formulated based on the test results. By doing so, safety hazards can be discovered promptly, ensuring the overall safety of the road and bridge structures ^[2].

5. Application of highway bridge load testing in bridge maintenance

(1) Clarifying the items of inspection

Load testing technologies can improve the efficiency and quality of bridge maintenance. However, the objectives of each inspection should be outlined before adopting suitable technologies so that the test results can be accurately analyzed. This facilitates the formulation of maintenance and construction plans. Experimental inspections are classified into regular inspections, special inspections, and periodic inspections. Among these, special inspection work poses unique challenges. Upon obtaining special inspection results, they must be integrated with regular inspection findings to assess the bridge's condition over its service life and estimate its remaining lifespan. Load testing is particularly useful when bridge project data is lacking. By conducting load tests, maintenance personnel can obtain crucial information about bridge structure and performance, enabling them to develop effective work plans. Over time, the load-bearing components of bridges may deteriorate, compromising their capacity and safety. Load tests allow technicians to evaluate structural safety and identify areas requiring reinforcement or treatment. For instance, if traffic conditions exceed design specifications and vehicle weights surpass limits, load tests can professionally assess whether structural reinforcement or other measures are necessary. Considering these factors, load testing encompasses various aspects, including bridge structure and performance parameters, damage to load-bearing components, and compliance with design traffic conditions. Based on these test results, highway bridge maintenance plans can be formulated effectively ^[3].

(2) Application of dynamic load test

Heavy load testing aims to simulate resonance and impact environments, evaluating bridge stability and load-bearing capacity through dynamic load tests. One such test is the vehicle bump test, which assesses structural performance parameters under dynamic vehicle loads. During this test, a vehicle is positioned slightly above the road surface to observe the bridge's vibration attenuation upon vehicle contact. Forced vibration testing involves high-frequency assessments of bridge bending, deflection, and torsion. One method is the braking test, where a vehicle is driven to the middle of the bridge and brakes suddenly, observing bridge amplitude. The vehicle must maintain a constant speed and brake urgently at the bridge's midpoint, repeated twice. Another method is the vehicle field test, where two load-carrying vehicles drive side by side, increasing speed by 10 km/h each time to analyze bridge structural changes at various speeds. These dynamic load tests provide valuable insights into bridge performance under real-world conditions.

(3) Application of static load test

The static load test involves applying a specific static load to the road and bridge to test the stress characteristics of the road and bridge. Under the same testing environment, test data and theoretical data are compared to assist personnel in understanding the force characteristics of the testing structure. The calibration coefficient is a key indicator that can reflect the stress condition of roads and bridges and the structural bearing capacity of roads and bridges to a certain extent ^[5]. During the static load test, to ensure accurate test results, the test plan should be formulated with clear content and workflow. Besides, the materials and equipment used for the test should undergo strict quality control, and the personnel involved should be experienced. Considering the particularity of the static load test, safety risks must be effectively controlled to prevent any safety issues. Establishing a regulatory department dedicated to safety management is essential during these tests. This department oversees safety matters, ensures personnel are well-versed in safety protocols, and implements on-site arrangements to mitigate

risks effectively. By prioritizing safety and implementing rigorous safety measures, potential hazards can be minimized, and the static load test can be conducted safely and effectively [6].

During the static load test, it's important to conduct the test within a temperature change range of 2°C. Surface temperature measurements should be closely monitored throughout the testing process. It is advisable to conduct the static load test between 9 p.m. and 6 a.m. the following day to minimize external factors and ensure accurate results. It is necessary to wait for the structural deformation to stabilize before the next load level can be applied. In the same level of load, when the maximum displacement of the test structure is reached, it is necessary to ensure that the displacement variable within the next 5 minutes is lower than 15% of that of the first 5 minutes or lower than the minimum resolution of the measuring instrument. All test points should be loaded with zero-level load degrees before loading. The values must be read once after a single loading and unloading. When the structural deformation is stable, read again before applying the next load level [7]. If the displacement of a specific measurement point is relatively large, readings should be taken every 5 minutes to improve the accuracy of the results. If a truck is used for loading and the load reaches full load or exceeds 80% of the full load value, the speed of the test vehicle should be controlled so that it does not exceed 10km/h. To ensure the structure's safety, test whether the internal force and deflection of the non-loaded section will exceed the limit, observe cracks in the structure, and increase the number of supports if necessary.

6. Project cases

6.1. Project overview

The length of the right side of the bridge is 254.52 m, the total length of the left side of the bridge is 169.85 m, and the overall width of the bridge is 19.18 m, including a central isolation belt of 1.8 m, a sidewalk width of 5.8 m, and a driveway width of 11.58 m. The longitudinal slope of the bridge is 2.86%. The upper structure is a steel-concrete continuous box girder and prestressed concrete structure. The main pier of the lower structure is a hollow, thin-walled pier, U-shaped abutment and double-column pier structure. The bridge deck paving material is modified asphalt concrete (SMA-13) with a thickness of 7 cm; the cold-water layer is in the middle, the material is AMP-100, the base material is polypropylene concrete with a thickness of 10 cm, the material used is C50, the crowd load of the bridge is 3.5 kN/m², the design load is City-A level.

6.2. Testing process

(1) Static load test

During the inspection, using the static load test inspection method, information such as the axle spacing, total mass, and single-axle load of the loaded vehicle was calibrated in advance. The test was conducted at night, and attention was paid to temperature control to ensure that temperature changes during the test process would not affect the test results [8]. The specific measures were as follows: 2 strain gauges were pasted at the bottom of each broken beam in the test section, 4 strain gauges were pasted on the T-shaped beam, and 1 strain gauge was pasted on the top of the beam and the horseshoe. 2 strain gauges were pasted on the bottom of all beams in the test section. During the test phase, a dial indicator for testing deflection was installed at the bottom of all beams, and the initial readings of different measurement points were read using the hanging gauge method. A preload was applied at 1/2 of the span of the test bridge based on the calculated maximum load of 0.2 times. Relevant personnel comprehensively inspected instrumentation, loading safety, and strain gauge preparation during the test phase. Following preloading, four loading vehicles with a mass of 40 tons each were utilized under working conditions, including eccentric loading and mid-span symmetrical loading. After each loading, the bridge

structure's relative displacement was tested, with stabilization time for loading and unloading exceeding half an hour. Once structural displacement became stable after loading, the next level of load was applied, and readings were taken, particularly when the displacement of the main beam structure of the bridge was stable, enabling expansion to the next load level. Post-inspection, strain, deflection, and other coefficients of the test section were compared to analyze any instability problems in strain and structural displacement, providing data support for formulating subsequent maintenance plans.

(2) Dynamic load test

The dynamic load test process included ground pulsation, vehicle jumping, vehicle driving, vehicle braking, and other items. There was no traffic load from pedestrians or vehicles on the test bridge deck and no irregular vibration sources around the bridge during the fluctuation test. The dynamic inspection system of the bridge structure was used to analyze the pulsation process data, including water flow load, wind load, and surface pulsation, and the bridge's natural frequency was measured^[9]. Second, when carrying out the bump test, it was necessary to prepare a test vehicle in advance with a mass of 30t. The vehicle's rear wheels were kept in the middle of the span of the test bridge, and wooden blocks were placed under the wheels with a thickness of 0.15m. According to the impact of the wheels on the bridge deck after the test, the instantaneous impact force and the up and down vibration amplitude of the bridge body were used to obtain the excitation force frequency and maximum dynamic deflection value of the bridge 1/2 section. Third, a test vehicle with a mass of 30 t was prepared before the driving vehicle test. The vehicle passed the test bridge section at a constant speed of 15km/h. Then, the vehicle speed was controlled and increased by 5km/h for each test until it increased to 35km/h. A total of 5 speed tests were conducted to determine that at different vehicle speeds when the excitation force generated by the vehicle driving was similar to the natural frequency value of the bridge, the vibration response value was the highest. Fourth, the braking test also required a 30-t test vehicle, which drove at a constant speed of 20 km/h and braked urgently when it reached 1/2 of the bridge deck. According to the impact of the braking condition of the test vehicle on the bridge, the dynamic inspection system and sensors were used to obtain the motion time course and deflection signals of the bridge test points, and the signals were digitally processed to obtain the dynamic test results of the bridge structure and obtain the impact coefficient. The above nuclear tests were used to clarify the bearing capacity of the bridge structure and provided direct materials for maintenance theory, technology, and other applications^[10].

7. Conclusion

With the development of the transportation industry, the demands for the transportation infrastructure are increasing. Roads and bridges play a crucial role in this regard. Ensuring the safety and functionality of bridges necessitates the formulation of scientific and practical maintenance plans, which are based on the results of load tests. These tests help identify potential safety risks associated with the use of roads and bridges. During load tests, technicians should precisely specify the test objectives, strategically apply both static and dynamic load test methods, and integrate the actual maintenance requirements of highway bridges.

Disclosure statement

The authors declare no conflict of interest.

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