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Research on Highway Bridge Inspection

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Abstract: Highway bridges are important transportation infrastructures in our country, and their quality is related to the people's lives. Highway bridge inspection, identification and test are measures to evaluate the quality of highway bridges. Through the comprehensive application of various technologies, quality problems of highway bridges can be found early, thereby ensuring traffic safety. This paper first summarizes the role and the types of highway bridge inspection and test. Then the problems and solutions in highway bridge inspection and test are analyzed and studied, and some examples are given, in hopes of providing reference for future testing.

Keywords: Highway bridge; inspection and identification

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1. Introduction

The construction of highways and local roads in our country has been developing rapidly. In recent years, and the number of highway bridge projects has increased significantly. At the same time, due to the large stock base of bridges, insufficient maintenance funds, and the increase of overloaded vehicles, accidents such as road bridge collapses occur from time to time. Such accidents not only endanger people's lives, but also cause huge economic losses. To this end, it is necessary to carry out systematic inspection, identification, and test before and during the use of highway bridges. The tests should include aspects like the appearance, material degradation, and bearing capacity of highway bridges. Problems that are identified through these tests should be addressed promptly, so as to ensure that the quality of highway bridges meets national standards, thereby ensuring traffic safety.

2. The role of highway bridge inspection, identification, and tests

Highway bridge projects are large-scale, and requires a variety of construction materials and construction technologies. Besides, various tests are carried out to determine whether the material quality, bearing capacity, and structural stability of highway bridges meet the national standards. Quality problems in highway bridges can also be detected through these tests. When the problems are resolved, accidents such as collapses can be prevented, thereby ensuring traffic safety[1].

3. Main contents of inspection, identification and test of highway bridge

3.1. Appearance inspection of highway bridges

In the process of appearance inspection to the highway bridge, technicians need to determine the items for

inspection according to the type of bridge. When performing appearance inspections on highway bridges, the selection of items for inspection is determined by technicians based on the bridge type. The appearance inspection typically comprises three main components: superstructure, substructure, and bridge deck[2]. Inspection of the superstructure primarily focuses on composite elements like hollow slabs and small box girders. In the case of arch bridges, the inspection targets arch ribs. Inspection of the substructure concentrates on elements such as abutments, foundation caps, and piers.

3. 2. Material condition inspection

The quality of construction materials of highway bridges has a great influence on the overall quality of highway bridges. During the operation process, problems such as material weathering will also occur with the passage of time. Therefore, it is necessary to adopt effective methods to detect the condition and aging of existing materials[4]. It is necessary to focus on the quality inspection of steel bars and concrete. Ideally. under non-humid and dry environmental conditions, the mechanical performance indicators of steel bars should be consistent with the design drawings and inspection reports during construction. If quality problems are suspected of steel bars or there is no clear reference data, samples of the steel bar needs to be taken for inspections. To test the strength of the concrete, the ultrasonic rebound or core drilling method can be used.

3. 3. Bearing capacity inspection and identification

3. 3. 1. Static load test

Bearing capacity inspection and identification is an important aspect of highway bridge inspection. Relevant parameters of the bridge should be measured and calculated to determine whether the bearing capacity is sufficient. Taking the static load test as an example, a suitable test hole should first be selected. The hole should be of the most unfavorable condition, quality, with serious issues or defect. Besides, it should be easy to set up scaffolding or observation points, and easy to load during the test. After selecting the test hole, it is necessary to determine the loading scheme according to the actual position of the loading vehicle in order to obtain certain representative test data[5-6].

3. 3. 2. Dynamic test

The dynamic testing process of highway bridges involves acquiring data such as dynamic strain, dynamic displacement or velocity, and acceleration from various components. This data is used to determine the structural dynamic characteristics and how the bridge responds to dynamic loads. The instruments used in the dynamic test of highway bridges mainly include signal amplifiers, test sensors, digital signal processors, etc. During the test process, it is necessary to select vibration methods such as pulsation, resonance, and natural vibration according to the structural characteristics of the highway bridge to accurately measure the natural frequency, damping, mode shape, impact coefficient, and other parameters of the highway bridge, and then evaluate the overall quality of the highway bridge[7].

4. Problems existing in inspection, identification and test of highway bridges

The problems in highway bridges inspection, identification, and test are summarized below.

Firstly, certain regions lack adequate attention to the inspection, identification, and testing of highway bridges, coupled with the absence of a well-established management system. Secondly, several highway and bridge inspection units lack a comprehensive management system, leading to deficiencies in the inspection and testing processes. This has also resulted in instances of irregular staff operations, compromising result accuracy. Thirdly, issues with technicians further compound the problem, as the

specialized nature of highway and bridge inspection demands proficiency in utilizing various testing equipment and technologies. Some technicians lack the necessary professional skills, leading to ineffective use of test equipment and techniques, or an incomplete understanding of testing and identification aspects. This ultimately leads to inaccurate test results[10].

5. Highway bridge inspection strategy

5. 1. Developing a sound management system

In order to ensure the quality of highway bridge inspection relevant departments need to formulate a sound management system, clarify the highway bridge inspection and test items and standards, and frequency of tests, etc. Moreover, it is essential to establish clear guidelines for penalties related to violations, conduct regular assessments of testing agency operations, and promptly address identified issues. This ensures that inspection and testing efforts yield desired outcomes. Concurrently, testing institutions must develop management systems aligned with their specific circumstances, define operational protocols for inspection, identification, and testing, allocate personnel responsibilities, enhance equipment oversight, and rigorously enforce systems. This ensures that personnel can consistently employ diverse instruments, equipment, and technologies to execute testing tasks in a standardized manner[11].

5. 2. Standardizing operating procedures

Test institutions need to standardize the operating procedures for different tests and inspection, which include the workflow of sampling, equipment operation, and result analysis. Besides, the use specifications of various equipment should also be determined, and the error range of test results[12]. Test agencies should actively bring in new testing equipment, keep updating their testing methods, and learn from practical experiences. By identifying issues in highway bridge inspection, they can adjust and improve their strategies, leading to better quality inspection overall.

5. 3. Strengthen personnel management

The quality of highway bridge inspection, identification, and testing work is closely linked to the competence of the personnel involved. Thus, inspection organizations should enhance personnel management by establishing a comprehensive system, clarifying responsibilities and operational guidelines, and defining reward and penalty criteria. Vigilant supervision of inspection, identification, and testing procedures is essential, including the imposition of penalties for any violations to ensure high-quality work[13]. Additionally, testing agencies should regularly arrange training for staff, enlist experts to explain technical operational methods, and provide guidelines and precautions for different equipment. Moreover, the recruitment of skilled technical staff should be a priority to continually bolster the testing team´s capabilities and ensure compliance with relevant standards.

6. Case analysis

6. 1. Case overview

The highway bridge features a reinforced concrete rigid frame arch superstructure (2×50 m) with a sagittal height of L/8 = 6. 25 m and a total length of 128. 50 m. The substructure employs a gravity pier design, constructed using prefabricated component suspension hoisting technology. The bridge has been operational since 2005, and due to its functional changes in 2020, it underwent structure reliability, bearing capacity detection, identification, and testing to ensure traffic safety. This process was conducted in accordance with relevant national regulations[14].

6. 2. General inspection and force analysis

The inspection results indicated that the highway bridge had undergone repairs and strengthening, as the traffic volume showed a consistent year-by-year increase. The component composition and force analysis yielded the following findings: Firstly, the main components of the rigid frame arch bridge. The highway bridge belonged to the arch system, with the force system along the bridge direction comprising the arch structure and the main arch circle. In the transverse direction, the structure was composed of the cast-in-place bridge deck and the girder slab. The rigid frame arch superstructure included structures such as arch leg supports, chord supports, and inclined leg supports. These design features ensured that the dead load thrust of the bridge remained significantly lower than that of conventional arch bridges. To maintain a reasonable bridge height, the rise-span ratio was set at L/8, usually falling within the range of 1/7 to 1/10. Secondly, the mechanical analysis of the rigid frame arch bridge. This type of arch bridge mainly experienced compression, leading to minimal internal bending moments within the arch ring. Under overloading conditions, the rate of tensile stress growth in the arch ring section was considerably lower than in the bridge deck. Simultaneously, the arch bridge exhibited a considerable load-bearing potential due to the combined effects of the arch structure and the main arch ring. Thirdly, the lateral stability and lateral force reinforcement scheme. Addressing the bridge´s unique characteristics and identified issues necessitated lateral rigid reinforcement to enhance overall structural stiffness and reinforce the rigidity of the consolidated beams between the arch ribs beneath the bridge deck.

6. 3. Inspection of rigid frame arch bridge

The results of the inspection and identification of the rigid frame arch bridge were as follows: Firstly, the concrete strength of the stressed parts in the main structures were tested according to the "Standards for Experimental Methods of Concrete Structures." The results indicated that the concrete strength met the design requirements. Secondly, a bridge deck inspection and identification were carried out. The assessment of the bridge deck pavement and flatness revealed that the flatness of the bridge deck pavement was generally normal with some bumps. Additionally, the height difference of the stretched area of the bridge deck was measured at 40 mm. Among these, the height difference between Piers No. 0 and No. 1 was particularly noticeable, potentially leading to issues like vehicle jolting. Therefore, this area should be flattened. The drainage test results for the bridge deck indicated that the drainage facilities were essentially normal, with minor water accumulation. Moreover, some parts of the sidewalk railings were damaged, requiring timely repairs.

6. 4. Structural test of the rigid frame arch bridge

Loading tests, section stress tests, deflection deformation tests, and support displacement tests were performed in accordance with the relevant standards. For the loading test, four vehicles with weights ranging between 35-37 tons were selected. These four vehicles were positioned side by side on the arch foot area of the rigid frame at the No. 0 abutment and the mid-span of the No. 0-1 abutment. Upon completion of this test, the four vehicles were rearranged into a square formation, and a loading test was subsequently performed on the mid-span of the No. 0 - 1 abutment. Secondly, the main section' s displacement and strain were assessed. A dial gauge was used to measure the stress, strain, and displacement of the abutment. Proper equipment operation was standardized to ensure the precision of the test outcomes.

6. 5. Result analysis

Based on the inspection and test results, it is recommended to limit the tonnage of vehicles passing the

bridge, prohibit parking on the bridge, and timely divert traffic if there is a traffic jam on the bridge. At the same time, highway bridges need to be inspected and maintained regularly, focusing on the deformation cracks of piers and abutments and arch foot cracks. Besides deteriorating components should be repaired and replaced accordingly[15].

7. Conclusion

The quality of highway bridges is related to people's vital interests. Therefore, it is necessary to standardize the inspection, identification and test, determine the quality problems of highway bridges based on the test results, and take effective measures to prevent accidents such as highway bridge collapse.

Disclosure statement

The authors declare no conflict of interest.

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