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Discussion on the Status Quo of Non-Destructive Testing Technology in Highway Engineering and Strategies of Improving the Quality of Testing

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Abstract: Highway test and detection technology play a very important role in controlling the quality of road and bridge engineering and improving the maintenance of roads and bridges. The study of highway bridge test detection technology is both theoretically and practically useful. Road and bridge test and detection is a complicated task. With the development of science and technology, highway and bridge engineering test and detection technology has also made great progress. The continuous improvement of test and detection technology has brought good social benefits to road and bridge construction. This article discusses the problems in test and detection technology of highway bridges and how to improve the quality of test and detection.
Keywords: Highway engineering; Non-destructive testing; Testing technology; Quality improvement

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1. Introduction

Highway and bridges are important structures that should be tested by unique test and detection technology. Highway bridge test and detection technology is key ensure the quality of the road and bridge. Therefore, the study of road and bridge test and detection technology is not only theoretically useful, but also practically useful. The development of automation technology, computer technology, and high-precision micro-measurement has greatly advanced the test and detection techniques in highway bridge engineering. This progress is particularly evident in the direction of non-destructive, intelligent, automated, and precise methods. In this paper, we will analyze the test and detection technology of highway bridge engineering.

Non-destructive testing refers to the use of changes in thermal, sound, light, electricity, magnetization, and other reactions caused by abnormalities in the structure or defects of materials without damaging or affecting the performance and the internal organization of the tested object of the tested object[1]. It is crucial for the development of the road inspection industry, including radiographic inspection, ultrasonic inspection, magnetic particle inspection, and image inspection.

Non-destructive testing technology is a testing technology for engineering structures. It is an intuitive, fast, and effective testing method that can display the internal conditions of structural components. This testing technology can avoid damaging the structure of the tested object. Therefore, it is of great significance to establish a scientific inspection system to improve the quality of roads and bridges. Several common non-destructive inspection techniques are introduced below.

2. Common non-destructive detection technology in highway engineering

2. 1. Ultrasonic testing

Ultrasonic testing involves high-frequency sound waves and utilizes the medium' s ability to emit ultrasonic waves. It analyzes the reflected waves received from roads and bridges, thereby providing insights into the condition of the road or bridge[2]. Its working principle involves studying how ultrasonic waves interact with a test piece through reflected, transmitted, and scattered waves. This is used to detect macroscopic defects, measure geometric characteristics, assess changes in structural organization and mechanical properties of the test piece. For highway and bridges, ultrasonic testing technology is mainly used in the detection of internal defects of structural components, such as the integrity of foundation piles, the rebound strength of concrete structures, cracks in concrete structures, and cracks in welds.

In flawless concrete, ultrasonic waves propagate through a continuous medium. However, if structural defects like voids or honeycomb areas exist, the concrete´s continuity is disrupted. The interface between the defective region and the concrete (air and concrete) is shown in Figure 1. At this interface, the propagation of ultrasonic waves changes. The defects of the foundation pile body can be detected.

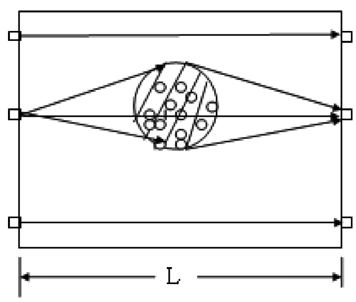

Figure 1 Schematic diagram of foundation pile integrity detection

2. 2. Magnetic particle testing

Magnetic particle testing operates on the principle of magnetizing ferromagnetic materials and the workpiece. Discontinuities cause localized distortion of magnetic field lines on and near the surface of the workpiece, resulting in a leakage magnetic field. This field attracts magnetic powder applied on the surface, forming visible indications under appropriate lighting conditions. These indications reveal the location, shape, and size of the discontinuity. Hence, magnetic particle testing promptly and visually pinpoints component issues and failures, detecting cracks, gaps, incomplete penetration, central inclusions, incomplete fusion, and surface pores. This identifies defect shapes and sizes, streamlining subsequent processing tasks[3].

Magnetic particle testing is a simple, quick and low-cost method. This method is also highly sensitive, and it can detect very small defects, up to a nanoscale degree.

2. 3. Image detection technology

Image detection technology uses infrared imaging and laser holographic imaging. Infrared imaging involves using materials with different thermal conductivity. High-precision sensors can detect the heat transfer and temperature inside the road and bridge. This allows a good analysis and inspection of the surface of the structure[4]. Laser holographic detection technology detects and analyzes the pictures that are taken by a camera, and then uses the images for mechanical analysis. Therefore, this intuitive and high-precision detection technology clearly display the defects on the surface of roads and bridges. At present, image detection technologies commonly used in highway engineering are used in inspection vehicles for tunnels and roads[5] (detection of road surface cracks, potholes, etc., recognition of landscape along roads, concrete structure crack width detectors, etc. [Figure 2]).

Figure 2 Image detection technology

The road surface imaging software of the multi-function inspection vehicle can identify, quantify, and classify the cracks (transverse cracks, longitudinal cracks, cracks, block cracks), potholes, and other problems of the road surface. The road surface shape data is processed by a software to obtain information on deformation of the surface such as rutting, wrapping and local subsidence. The front image stereo measurement software can measure the facilities along the road, check the road and its surrounding environment, and provide historical records for road condition monitoring, property cataloging, accident cataloging, etc.

The multi-functional inspection vehicle utilizes a high-performance onboard computer and a variety of sensors to automate data collection, thereby reducing the potential for human errors and enhancing precision. It achieves speeds of up to 80 km/h, ensuring efficient and rapid detection. Moreover, it operates without causing disruptions to normal traffic flow, which helps to minimize economic losses due to road closures or traffic congestion. Additionally, this vehicle decreases the labor intensity associated with manual measurements and reduces the potential risks of such operations.

3. Problems in non-destructive testing technology

Each type of non-destructive testing technology comes with their own advantages. These technologies can efficiently and quickly detect the performance and defects of structural components of highway bridges, which provides convenience for highway bridge testing. however, there are still some limitations to these technologies.

3.1. The quality of the tests performs depends on the experience of the personnel

The amount of knowledge or experience of testing personnel significantly affect the analysis and processing of test data. For example, possible defects can be identified according to the subtle differences of waves in the image, and the types and causes of defects can be analyzed.

3.2. Some non-destructive testing techniques have limited detection range

Ultrasonic testing utilizes the reflection of elastic sound waves in solids to determine the presence and location of defects in the workpiece. The size and nature of defects can be determined according to the reflected sound waves which include the following aspects: (i) the propagation time of the elastic pulse, (ii) the energy of the echo, (iii) the degree of attenuation of the oscillation after passing a certain distance. The limitation of this method is the instrument can only measure three physical quantities: propagation time, equivalent, and relative values. Besides, this method cannot detect the parameters of the defect such as size, shape, depth, inclination angle, surface roughness, internal filling, etc.

Furthermore, current research on the propagation theory of ultrasonic testing primarily focuses on a limited range of typical defects in solids. Additionally, defects of various shapes, sizes, inclinations, and surface roughness at the same depth can result in echoes at identical heights, making it impossible to differentiate these defects based solely on echo height. Therefore, this method is not 100% reliable with these shortcomings.

Magnetic particle testing also has its limitations. While it can accurately detect defects, it is not applicable to non-magnetic materials. Moreover, this method cannot determine the depth of defects, and it may not effectively identify extremely small defects hidden deep in the corners of the section' s surface.

3.3. The technology of non-destructive testing equipment is not mature enough, and its performance is unstable

While the equipment are highly sensitive, the accuracy of the equipment will decrease as it ages, and the inaccuracies are difficult to detect, resulting in inaccurate data, thus affecting the quality of testing.

4. Measures to improve the quality of testing

In order to reduce the limitations of non-destructive testing technology and increase their reliability, the following measures are proposed:

(i) The research and development new nondestructive testing technologies should be improved. New non-destructive testing instruments should be designed and developed, such as transducers and auxiliary equipment, based on new discoveries and new laws in mechanics, sonics, and magnetism. Building on the foundation of existing non-destructive testing techniques, efforts are being made to expand and enhance these methods, including refining the design of testing equipment to improve defect detection capabilities.

(ii) The training and assessment of technicians should be improved, more discussions regarding nondestructive testing technologies among experts should be carried more frequently. A national non-destructive testing technology practice information database can then be established based on previous experiences and failures, and various software can be created to aid road and bridge testing.

(iii) The standards and specifications of non-destructive testing technologies should be constantly updated so that they are in line the current situation and development of the industry, especially in terms of reliability.

(iv) Old equipment should be replaced, and the equipment should be well-maintained so that they can operate normally.

5. Conclusion

In conclusion, as science and technology advance, road and bridge inspection methods must continually evolve, adapting their approaches to keep pace with global progress. This includes innovative thinking and expanding the use of detection technology, integrating it with other advanced methods, and enhancing non-destructive techniques to elevate the overall quality of inspection and maintenance practices.

Disclosure statement

The authors declare no conflict of interest.

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