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Application Strategy of NDT Technology in Tunnel Engineering Quality Inspection

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Abstract: Nondestructive testing (NDT) is an advanced and commonly used technique in tunnel engineering quality inspection. To achieve good application of nondestructive testing technology, its main application in tunnel engineering quality inspection strategy is analyzed, including the significance of applying nondestructive testing technology in tunnel engineering quality inspection, the main nondestructive testing technology applied in tunnel engineering quality test analysis, and the analysis of nondestructive testing technology of tunnel engineering quality inspection strategy. The analyses in this paper are done in hopes of providing scientific reference for the utilization of NDT technology and the improvement of tunnel engineering quality.

Keywords: Tunnel engineering; Nondestructive testing technology; Significance of application

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1. Introduction

To maximize the advantages of nondestructive testing technology (NDT) in the tunnel engineering quality inspection process, relevant units and technical personnel must be fully clear about this technology and the significance of applying it. At the same time, the main operation techniques should be sufficiently understood, and then reasonably apply the technology depending on the actual situation and type of project. In this way, NDT can be utilized appropriately, so as to lay a solid technical foundation for tunnel engineering quality testing.

2. NDT and its application in tunnel engineering quality testing

2.1. Overview of damage detection techniques

The purpose of NDT is to allow quality testing to be performed without changing the original state and properties of the sample [1]. In recent years, this detection technology has been widely used in many detection fields, such as aerospace, shipbuilding, customs, mechanical engineering, pressure vessels, tunnel engineering, and so on. Especially in tunnel engineering quality testing, NDT has received much attention due to its remarkable advantages [2].

2.2. The main application significance of NDT in tunnel engineering quality testing

The construction of tunnels can be affected by many factors, thus it is easy to have some problems in its structural quality. If these problems cannot be detected and resolved in time, they will not only affect the construction quality and safety of tunnel engineering, but will also pose many threats to the quality and safety of subsequent applications [3]. However, the process of quality inspection through traditional detection technology will inevitably cause structural damage. The damages can be prevented by using NDT, and a scientific, comprehensive, and accurate testing of the engineering quality can be achieved without damaging the tunnel structure, so as to ensure the quality and safety of the tunnel engineering [4].

3. Analysis of main NDT techniques in tunnel engineering quality inspection

3.1. Ultrasonic springback detection technology

Ultrasonic springback testing is the most typical NDT in tunnel engineering quality testing. This technology can scientifically detect the strength of tunnel lining. Its working principle is to first use a rebound hammer to measure the strength of the concrete to obtain a rebound value R. The ultrasonic propagation time t is measured to calculate the ultrasonic velocity v in concrete. The rebound value R and the ultrasonic velocity value v are then used as the basis to convert the concrete strength value through the national unified strength curve or regional unified strength curve. The strength of the tunnel is then estimated with further mechanical tests.

3.2. Geological radar detection technology

Geological radar detection technology is also a very advanced NDT. Through this technology, the thickness of tunnel lining can be effectively determined. It works by transmitting electromagnetic waves through the transmitting antenna R, the waves will then be reflected into the receiving antenna R. With the help of geological radar reflection image, the reflection layer can be fully defined, and the double travel time t of its reflected wave can be measured. The detection formula is as follows:

$$z = \frac{\sqrt{t^2 v^2 - x^2}}{2}$$

where z stands for lining thickness, with the unit m; t represents the two-way travel time of the reflected wave, with the unit s; v represents the propagation speed of electromagnetic wave in the medium, with the unit m/s; and x represents the distance between the transmitting and receiving antennas, which is measured in m.

At the same time, the geological radar detection technology can also detect the tunnel lining structure. In axial detection, the right wall, left soffit, left wall, vault and right soffit measurement lines should first be arranged along the axial direction of the tunnel, and the measurements are then taken [5]. In transverse detection, it is necessary to lay a section line along the tunnel at intervals and then perform the detection. In the detection process, it is necessary to ensure that the transmitting antenna and receiving antenna are close to the tunnel lining surface so that readings can be obtained. The detection results can then be obtained after noise reduction, filtering, and equalization [6].

3.3. Infrared high temperature detection technology

Infrared high temperature detection technology is a common commonly used technology in tunnel engineering quality inspection. In this method, an infrared camera or scanner is mounted on a mobile carrier to measure lining defects, voids, and geological conditions in the tunnel. However, this technology requires a high temperature gradient, so it is best to use it under the condition of large temperature difference to ensure its detection accuracy [7].

4. Analysis on the application strategy of NDT technology in tunnel engineering quality inspection

Through the analysis above, it is clear that NDT has a very significant advantage in tunnel engineering quality inspection. In order to realize the utilization of NDT, this paper takes an actual construction quality testing of a tunnel project as an example, and analyzes the application strategy of NDT in it. The following is the specific application of NDT in the tunnel project and.

4.1. Project overview

The total length of a tunnel is 1.275 km, most of which are Grade IV and Grade V surrounding rocks. The lining of part of the tunnel is a composite structure, and there are many safety risks on the project site. Based on this, the combination of shotcrete, system bolt, steel mesh, and section steel support is adopted in the tunnel construction to create a tunnel structural support system, so that the construction safety can be ensured. Subsequently, ultrasonic rebound testing technology and combined with geological radar detection technology was used in quality inspection. In this method, some completed sections of primary support and secondary lining were selected, and ground radar scanning was conducted to determine the thickness and detect any defects in the sampling locations. Then, the second lining of a mold was extracted, and the strength was checked by ultrasonic rebound method.

4.2. Primary support quality inspection

According to the actual characteristics of the primary support of the tunnel project, the main content of quality inspection includes three aspects: the first aspect was to detect the undercutting and overcutting in the middle of the initial support and surrounding rock; Secondly the layout and quantity of steel supports was tested [8]; Thirdly, the interference of surrounding rocks within the construction range was tested. Through geological radar scanning, three vertical strong reflection rays appeared in the detection area, which indicates that there is a cavity in the detection area. The region with the most significant distribution of reflection rays is in the annular depth of 21.5-23.5 cm, and the reflection of steel support appears at the position of 2.5 cm, indicating that there is a cavity here, and the degree of influence is relatively large. However, through the detection image of each ray position information, it is found that the reflection is relatively uniform, and the continuity of the same axis is relatively good. After further detection, it is found that the thickness of concrete injection in the initial support and the spacing of steel support are consistent with the design requirements [9].

The geological radar detection shows that there is a specific dividing line between the thickness of the initial support and the surrounding rock, but it is unclear. The reason for this situation is that each structure is complicated, and it is affected by many physical factors, thus causing irregular reflection of radar electromagnetic wave [10].

When calculating the thickness of concrete, it is necessary to define the radar electromagnetic wave transmission characteristics in the lining structure, and then calculate the thickness according to the following formula:

$$h = vt / 2$$

where, h represents the thickness of concrete, with the unit m; v represents the radar electromagnetic wave transmission speed in the lining structure, with the unit m/s. t represents the time difference between the reflected wave and the incident wave, and the unit is s.

Through testing and calculation, it is found that the primary support structure of the tunnel has under–digging phenomenon, and is partially jagged, and some areas showed sagging. All these problems will cause adverse effects on the strength and stability of the tunnel. In view of these problems, it is necessary deal with them using appropriate measures depending on their situations and locations. In this way, accidents during the tunnel construction and use can be effectively prevented, so as to achieve good control of tunnel engineering quality and safety [11].

4.3. Secondary lining quality inspection

The main contents of quality inspection of the secondary lining in this tunnel project includes the following aspects. Firstly, any defects on the secondary lining was detected; secondly, the thickness of the secondary lining was determined. Next, the degree of water seepage in the secondary lining was determined. It was found by NDT that there is a relatively obvious wedge space in the baffles of the secondary lining area [12].

The secondary lining structure of the tunnel can be calculated according to the concrete injection thickness. However, a unique method is to analyze the electromagnetic wave velocity in the secondary lining [13]. Electromagnetic wave velocity analysis can be carried out through the hole-drilling measurement method. Therefore, in the actual operation, the open hole position can be further measured, and then the dual travel time of radar image can be comprehensively considered, so as to achieve the accurate measurement of electromagnetic wave velocity [14].

In the concrete inspection, the ultrasonic rebound NDT was mainly used to detect the lining strength. In order to ensure the convenience of detection, the molding lining was regarded as a component in the detection, and ten areas was selected within each component to conduct orderly detection of each area. After the completion of springback detection, ultrasonic test was carried out, and the data was recorded in detail, which was then summarized [15]. **Table 1** is the summary of ultrasonic springback detection results of the secondary lining of a mold in a tunnel project.

Table 1. Summary of ultrasonic springback test results of secondary lining in this tunnel project

No	Item	Test result
1	Detection range	12-24m
2	Concrete design strength	C25
3	Rock type	Grade V
4	Minimum concrete strength	22.5MPa
5	Standard deviation of concrete strength	2.35MPa
6	Average concrete strength	29.4MPa
7	Concrete specified strength	25.5MPa

Based on geological radar and ultrasonic rebound testing data acquired, it was found that there are voids in the primary support and secondary lining, but the strength of the sampling position meet the design requirements, and no water seepage was found. This shows that the construction quality control of the sampling section of the tunnel project is relatively good, and there was no obvious structural safety hazard [16]. Therefore, the grouting method was used to treat the existing cavity, so as to ensure the stability and overall strength of the tunnel project to ensure its construction quality and safety while in use.

5. Conclusion

In short, NDT is significant in tunnel engineering quality testing. In the process of tunnel engineering quality testing by NDT technology, relevant units and technicians must fully understand the main types of NDT technology and their applicable conditions and apply it depending on the actual situation and type of project. In this way, the quality problems existing in the tunnel project can be found accurately in time, and the scale and severity of the problems can be determined. Reasonable measures can then be taken to deal with them, so that the construction quality and safety of the tunnel project can be well guaranteed. Besides, the quality of use can also be improved, and accidents can be prevented. Therefore, the application of NDT and the selection of optimal strategies can play a very positive role in improving the safety assurance and management of tunnel engineering during the construction and operation period.

Disclosure statement

The authors declare no conflict of interest.

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