

# Analysis of Detection and Treatment Schemes of Highway Tunnel Lining Cracks

Yike Wei<sup>1\*</sup>, Lingfeng Yu<sup>2</sup>

<sup>1</sup>China Merchants Chongqing Testing Center for Highway Engineering CO., LTD, Chongqing 400060, China

<sup>2</sup>Chongqing Jiaotong University, Chongqing 400074, China

**Abstract:** Highway tunnels play a very important role in people's daily life. Among them, lining is an essential part of tunnel engineering, and the quality of lining greatly affects the overall quality of the tunnel. On this basis, the causes of lining cracks and the detection methods of existing highway tunnel lining cracks are analyzed, and the treatment countermeasures for highway tunnel lining cracks are proposed.

**Keywords:** Highway tunnel; Lining; Crack detection; Treatment

**Publication date:** January, 2021

**Publication online:** 31 January, 2021

**\*Corresponding author:** Yike Wei, weiyike@cmhk.com

## 1 Introduction

With the continuous development of society and economy, the transportation system plays an increasingly important role in economic development, and the construction of tunnels also plays a very important role. Tunnel cracks are the most common disease in tunnels and in turn, the cause of other tunnel diseases. Therefore, strengthening the maintenance of tunnel cracks becomes more and more important. The application of tunnel automatic detection technology in China is mainly focused on the detection of road pavement cracks, while the automatic detection of highway tunnel lining is still in its infancy<sup>[1]</sup>. The types of tunnel lining commonly used today include anchor spraying, assembly, composites and concrete. The construction company selects the appropriate lining form according to the

specific needs of the project to ensure the quality of the highway tunnel. Regardless of the type of lining, due to the influence of natural and human factors, long-term use of highway tunnels will inevitably lead to certain crack quality problems. If appropriate detection methods can be used to determine the impacts of diseases and seek for scientific solutions, the operation of road tunnels can be better secured by finding appropriate methods to eliminate defects in tunnel projects.

## 2 Treatment Principles

### 2.1 The Principle of Adaptability

When dealing with cracks in highway tunnel linings, the principle of adaptability should be adhered to. In other words, starting from the cause of cracking, the corresponding treatment plan must be formulated according to the actual detection of the lining crack. In crack treatment, we first use special tools to detect lining cracks, and comprehensively analyze the length, depth and characteristics of the cracks to provide reliable data support for future crack treatment plans<sup>[2]</sup>.

### 2.2 The Principle of Technology

When dealing with road tunnel lining cracks, relevant personnel should adopt corresponding treatment techniques so that the tunnel lining cracks will not cause new risks during the cracking process. Meanwhile, the quality of the repaired tunnel can meet relevant standards to ensure the overall quality.

### 2.3 The Principle of Research

Before dealing with cracks in the lining of road

tunnels, the crack treatment area must be checked to prevent errors and leaks and to ensure the quality of tunnel crack treatment.

## 2.4 The Principle of Preparation

After dealing with the cracks in the lining of each highway tunnel, the relevant personnel must organize and collect data, improve the corresponding tunnel files, and provide strong data support for the treatment of cracks in the highway tunnel lining.

## 3 Analysis on the Causes of Lining Cracks

Comprehensive analysis of the causes of cracks in highway tunnels. First of all, several cracks with different crack shapes appeared on the side wall of the tunnel end. Combined with the construction technology and the actual crack size, the judgment is directly related to the concrete mix ratio. The inspection of the concrete structure showed that the thickness of the upper concrete structure did not meet the original design requirements. According to statistics, most of the cracks in the tunnel section appear on the sidewall of the tunnel section and have irregular shapes. Analysis shows that the problem is mainly caused by stressless deformation caused by unreasonable concrete mix ratio. Some of the cracks appear at the top. Tests show that the safe has a lot of space, and part of the lining does not reach the thickness required by the design. It is assumed that the construction process is not standardized. At the same time, due to the small ascension span of the entire tunnel project and the relatively shallow depth of the surrounding rocks, the secondary lining will face greater environmental rock pressure in the vertical direction, and other reinforcements, leakage prevention and earthquakes measures were not considered in the design process<sup>[3]</sup>. The stressless deformation of the loaded tunnel bolts causes the lining to crack in the tunnel structure. Meanwhile, the secondary and tertiary stresses of the surrounding rocks bear greater pressure, and the technical problems of construction support and leak-proof construction are concentrated, and local stress and water pressure are too large, causing cracks in the highway tunnel lining. Meanwhile, it was found that the thicker part of the secondary lining has more cracks and the thinner part has fewer cracks. Through comparative analysis, it can be determined that the thermal stress and shrinkage stress of mass concrete

caused by the heat of hydration have a direct impact on the occurrence of cracks.

## 4 Non-destructive Testing Method for Cracks

### 4.1 Spectroscopic Analysis Technology

The principle of spectroscopy technology is similar to the traditional tapping method, which uses tapping instruments to determine whether there are cracks in the original tunnel structure in the building. However, unlike traditional percussion instrument methods, the accuracy and detection efficiency of spectroscopic analysis technology are more ideal, and the original tunnel structure will not be damaged twice during the detection process. Spectroscopic detection technology mainly uses the propagation speed of sound waves in different media and analyzes the propagation speed to deduce the actual situation of the detected object. The advantages of this technology are fast detection speed and wide application range, but in the early stage of application of this technology, construction personnel must prepare for the installation of the sensor<sup>[4]</sup>.

### 4.2 Imaging Technology

Infrared imaging and laser holographic imaging are the most commonly used imaging techniques in the detection of tunnel lining cracks. Among them, the main principle of infrared imaging is using the corresponding heat released by molecules in the process of change. Therefore, there are certain differences in the heat emitted by substances with different structures. The construction staff can use the corresponding infrared detection equipment to analyze the temperature of the tunnel structure surface to determine whether there are cracks and damages inside the tunnel structure.

### 4.3 Ground-Penetrating Radar

Radar waves are mainly generated by the excitation of the equipment itself. Staffs use the device to transmit electromagnetic waves to the measured area, and obtain sampling signals from the road surface by reflecting and receiving electromagnetic waves. Meanwhile, the corresponding software, hardware and graphic display system conversion are performed on the collected sampling signals, and the detection results are analyzed. In this technology, the radar pulse can detect the difference of the underground medium in the detection area during the propagation process. Some radar pulses are reflected off the

detection area to receive information, while the other one is used to receive media signals from the detection area.

#### **4.4 Ultrasonic Technology**

The application of ultrasonic technology in highway engineering is mainly to transmit ultrasonic waves to structures in specific areas, and then the personnel use ultrasound receiving equipment to compare the received parameters with standard parameters to achieve the purpose of structural quality inspection of road and bridge constructions. This technology uses sound waves to detect defects and problems in the object to be tested and meets the requirements of non-destructive testing technology. However, this technology has certain professional difficulties.

### **5 Tunnel Crack Treatment Scheme**

#### **5.1 Seamless Drainage System**

Construction joints are a common part of leakage and seepage, and some cracks will also leak. Therefore, it is necessary to install Yas half-pipes for permanent drainage according to the actual conditions of the surrounding rocks before treatment. During the construction process, in order to meet the requirements for various forms of cracks on the surface of the surrounding rocks and prevent the blockage caused by the direct inflow of the surrounding rock sediments, the groundwater was sealed outside the tunnel, and then the water left in the ditches on both sides of the tunnel is used for the pipes. Drain from the outside.

#### **5.2 Concrete Mix Ratio Design Optimization**

In order to improve the impermeability of concrete, air-entraining agents are usually used to improve the pore structure of the concrete, block the infiltration channels and increase the density of concrete and self-compressive concrete. Meanwhile, the water-cement ratio of concrete should not be too high. In the construction process, the main method is to reduce the weak links of concrete pouring and ensure the quality of continuous concrete pouring.

#### **5.3 Grouting Treatment of Lining Cavity**

There should be a certain distance of PVC grouting holes on the bolts, and the grouting holes should protrude from the inner edge of the bushing to facilitate the connection with the grouting pipe. In

special areas, grouting pipes that can be held along the circumferential direction can be installed in the construction joints to fill the lining cavity when concrete is poured after lining. Meanwhile, in order to prevent the arch back cavity from protruding stress, structural cracking, damage and leakage, the arch back should be grouted in time as soon as the secondary lining strength reaches the design strength, so that the initial support is tightly combined with the waterproof board and the secondary lining.

#### **5.4 Crack Treatment**

Reinforce the exterior of the cave. As far as project cracks are concerned, lining cracks are closely related to the natural environment of the external slope of the cave. To this end, the construction company has formulated a plan to strengthen the exterior slope of the tunnel to minimize the occurrence of shallow slip at the tunnel exit, ensure the stability of the slope soil, prevent further lining cracks, and strengthen the tunnel lining. According to the project technical requirements and the actual causes of the cracks, the construction engineers adopted comprehensive reinforcement measures for the anchor piles and anchor cable frame beams to reduce the possibility of landslides.

Strengthen the tunnel lining. Use mortar bolt plum reinforcement method, and add steel plate at the end of the bolt. In the lining reinforcement treatment, the anchor rod is constructed first, and then the backfill grouting is performed immediately. After solving the crack problem, check again after half a year, and the crack will not grow. If there is no new crack problem, the corresponding processing data can be classified and saved.

### **6 Conclusions**

In conclusion, the detection and treatment of cracks in the highway tunnel lining is a necessary means to prolong the life of the highway tunnel and improve the safety and stability of the highway tunnel.

### **References**

- [1] Tang JY, Dong YZ, Yu LY, et al. Deformation Law and Crack Treatment of Lining of Super-long Span Highway Tunnel[J]. Road Machinery & Construction Mechanization, 2020, 37(7): 32-36.
- [2] Xie LG, Yang Q. Analysis on the Causes of Circular Cracks in Tunnel Lining and Suggestions for Prevention[J]. Highway,

2020, 65(5): 347-352.

[3] Chen DL. Analysis of Countermeasure on Lining Cracks of Expressway Tunnels [J]. Communications Science and

Technology Heilongjiang, 2020, 43(4): 152-153.

[4] Tang RZ. Analysis and treatment of cracks in highway tunnel lining [J]. Housing and Real Estate, 2020(6): 222-223.