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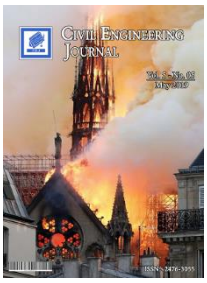

Analysis and Study on Crack Characteristics of Highway Tunnel Lining

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Abstract

Lining cracks are one of the most common diseases in highway tunnels, and the existence of lining cracks directly affects the overall stability and durability of tunnels, which has an important impact on the safe operation of tunnels, and it is necessary to analyze and study the characteristics of tunnel lining cracks. Combining with the detection data of multiple highway tunnels in the field, the different types of tunnel cracks are divided, and the classification numerical statistics method is used to obtain that the number and length of annular cracks in highway tunnel cracks are significantly higher than those of the other two kinds of cracks, and the longitudinal cracks in tunnel crack cracking degree are greater than the circumferential cracks and the inclinded cracks. The influence degree of cracks on the safety of tunnel structure longitudinal cracks are relatively the largest, the inclinded cracks are second only to longitudinal cracks, and the influence of cyclic cracks is relatively small. It provides reference for tunnel engineering design, construction, operation management and comprehensive improvement work.

Keywords: Highway Tunnel; Lining Crack; Crack Cause; Crack Law.

1. Introduction

With the rapid development of expressway and more and more highway tunnel construction, tunnel diseases have become an important problem in tunnel engineering at present, and tunnel lining cracks, as a common disease phenomenon, will have adverse effects on the stress, waterproofing, appearance and so on of tunnel structures. In order to ensure the durability of the tunnel in operation and the safety and comfort during the driving process, it is an important problem to be solved to study the tunnel crack characteristics.

Guoquan Li, et al. (2015) The safety analysis of the tunnel with cracking of lining is carried out by using Shuguang Analysis Software, and the different cracking depth of two-storey lining cracks is put forward to have a great influence on the safety coefficient of the structure [1]. Sulei Zhang, et al. (2015) based on the equilibrium strip resin model of the sharp point mutation model, the stability criterion of lining crack is established, and a model of lining crack diagnosis based on field monitoring data is constructed [2]. Haiqiang Wang, et al. (2016) put forward the comprehensive judgment method, the integration of each single index evaluation system, so that the safety evaluation results of belt fracture lining more comprehensive, objective and accurate [3]. Zhijie Wang, et al. (2017) the regulation effect is verified by numerical simulation method, and the distribution law and difference of disease in different position and longitudinal mileage of cross section are obtained [4]. Jie Huang, et al. (2017) combined with geological reports, using the method of finite

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element numerical simulation, it is concluded that the structure is easy to produce longitudinal structural stress cracks under the action of deformation pressure [5]. Xujuan Wu, et al. (2017) Design Image Acquisition System image acquisition of Common Highway tunnel lining part, practice proves that this method is feasible, not only improves the capacity of highway tunnel during detection, but also solves the problem of tunnel crack lining detection [6]. Jin Feng, et al. (2017) using the K-s test method, the characteristic distribution law of highway tunnel lining cracks is analyzed statistically from the aspect of crack length and width two, and the crack length and width are in accordance with the logarithmic normal distribution characteristics [7]. Jianchao Li, et al (2018) a tunnel lining crack detection system based on image recognition technology is proposed [8].

Tunnel lining is the main building of the project which bears the formation pressure and the deformation and collapse of the upper surrounding rock, and the fracture tunnel lining fracture caused by the tunnel lining structure destroys the stability of the tunnel structure, reduces the safety and reliability of the lining structure, affects the normal use of the tunnel, and even endangers the driving safety [9]. The analysis and study of the characteristics of tunnel cracks play an important role in the normal use and maintenance of tunnels. Taking the highway tunnel detection of lining cracks in 13 provinces of Hangzhou city as the research object, the general law of Highway Tunnel cracks is analyzed by using the method of classification numerical statistics. The research focuses on the law of fracture distribution of different kinds of lining and its influence on the safety of tunnel structure.

2. Causes of Lining Cracks in Highway Tunnel

There are many forms of tunnel lining cracks, and the causes of the cracks are also varied. However, the most direct reason for the cracks in tunnel lining is that the tunnel lining structure is subjected to uneven force or excessive force [10]. Tunnel lining is the main building of engineering which bears formation pressure and prevents the deformation and collapse of surrounding rock. The magnitude of formation pressure mainly depends on the engineering geology and hydrogeological conditions and the physical and mechanical characteristics of the surrounding rock, and at the same time, it also depends on the construction method. Whether the lining is timely or not is related to the quality of the project. Due to deformation pressure, loosening pressure, uneven distribution of strata along tunnel longitudinal and mechanical behavior, temperature and shrinkage stress, swelling or frost heaving pressure of surrounding rock, corrosive medium, artificial factors in construction, The cyclic load of the running vehicle will cause cracks in the lining structure. To sum up, the main reasons [11-13] leading to cracks in highway tunnel lining are plastic ground pressure, partial pressure, expansive ground pressure, cavity behind the lining, insufficient lining thickness, and construction of "first arch after wall" method. Improper handling of surrounding rock (including fault break zone, construction collapse, etc.), formation disturbance (proximity) Construction, mining surrounding mining), no inverted arch and other reasons.

3. Harm of Lining Crack in Highway Tunnel

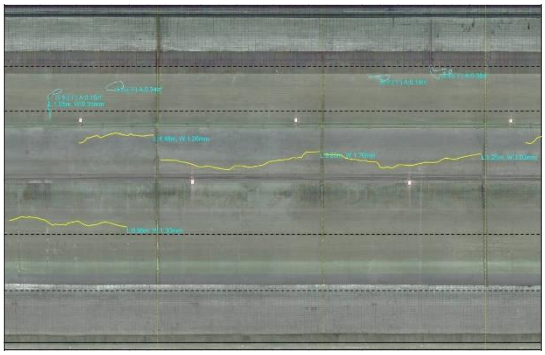
Tunnel lining cracking is the main form of tunnel disease which destroys the stability of tunnel structure reduces the reliability of tunnel structure safety affects the normal use of tunnel and even endangers pedestrian and personal safety. The main hazards of tunnel lining cracks are:

- Reducing the bearing capacity of tunnel lining structure to surrounding rock.
- The cracks of lining are easy to leak, which can easily cause corrosion of steel bars and facilities in the tunnel, mud of the pavement bed, frost damage of lining in cold area, and affect the durability of the tunnel.
- The cracks caused by excessive deformation make the tunnel clearance smaller and affect the safe passage of vehicles.
- Under the operation condition, the operation cost of the cracking lining is increased when the construction and operation interfere with each other.

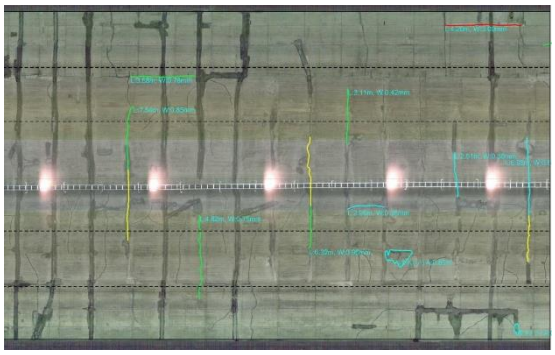
4. Classification of Lining Cracks in Highway Tunnel

Tunnel crack detector, detecting cracks picture Figure 1 Classification according to the strike relationship between cracks and tunnel axis [14]:

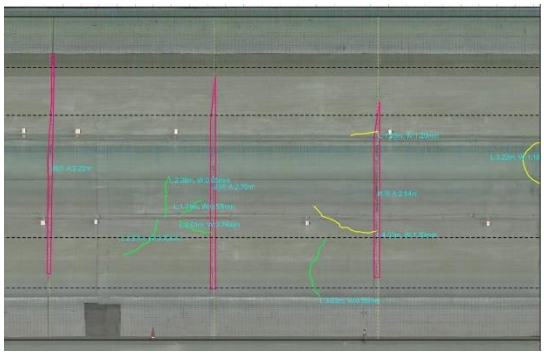
- Longitudinal cracks: tunnel lining longitudinal cracks parallel to the tunnel axis, in the arch, side wall will occur, its development may lead to the tunnel arch, side wall crack or even cause tunnel collapse.
- Circumferential cracks: tunnel lining circumferential cracks vertical tunnel axis, mostly occurred in construction joints, settlement joints, or occurred in the hole, bad geological zone and complete rock and strata junction.
- Inclined cracks: tunnel lining slant cracks and tunnel longitudinal axis of 45, around the angle, in the arch, side wall will occur.



(a) Longitudinal cracks



(b) Circumferential cracks



(c) Inclined cracks

Figure 1. Tunnel detection machine detects tunnel crack pictures

5. Research Methodology

Tunnel lining is the main building of the project which bears the formation pressure and the deformation and collapse of the upper surrounding rock, and the fracture tunnel lining fracture caused by the tunnel lining structure destroys the stability of the tunnel structure, reduces the safety and reliability of the lining structure, affects the normal use of the tunnel, and even endangers the driving safety. The analysis and study of the characteristics of tunnel cracks play an important role in the normal use and maintenance of tunnels. Taking the highway tunnel detection of lining cracks in 13 provinces of Hangzhou city as the research object, the general law of Highway Tunnel cracks is analyzed by using the method of classification numerical statistics. The research focuses on the law of fracture distribution of different kinds of lining and its influence on the safety of tunnel structure.

5.1. Statistical Analysis of Crack Characteristics

A total of 2683 tunnel lining cracks were detected in 13 highway tunnels in Hangzhou. If classified according to crack strike, there are 912 longitudinal cracks, 349 inclined cracks and 1422 circumferential cracks. The ratio of each type of cracks is shown in Figure 2 and Figure 3.

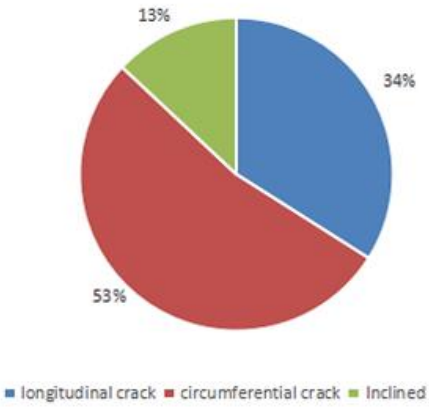


Figure 2. Distribution scale diagram of different types of cracks

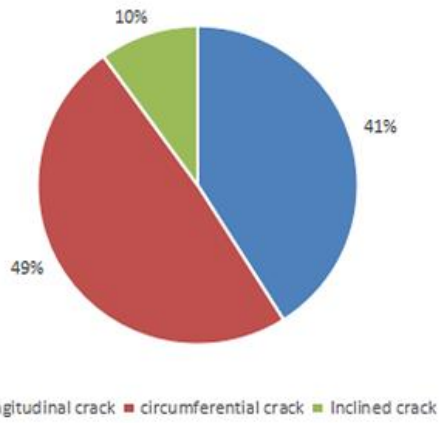


Figure 3. Proportional Chart of the total length of cracks in different types of cracks

The types of cracks (length and width of cracks) of the arch and side wall are counted, and the results are shown in Table 1.

Table 1. Results of statistical characteristics of various types of cracks

Position / Statistical characteristics	Crack length (m)			Crack width (mm)		
	Longitudinal crack	Inclined crack	Circumferential crack	Longitudinal crack	Inclined crack	Circumferential crack
Mean μ	4.36	2.62	3.27	0.28	0.26	0.31
Standard deviation σ	3.18	2.07	2.43	0.21	0.18	0.14
Maximum (Max)	34	14	12.6	2.3	1.72	1.2
Minimum (Min)	0.5	0.32	0.4	0.08	0.08	0.08

As can be seen from Figure 2, Figure 3 and Table 1:

1. In the total number of cracks in tunnel, the number of circumferential cracks is the most, accounting for 53% of the total number of cracks, the number of longitudinal cracks is the second, which accounts for 34% of the total number of cracks, the quantity of inclined crack is the least, accounting for 13% of the total number of cracks.
2. Among the three kinds of cracks, the length of circumferential crack occupies 49% of the total length of crack, and the proportion is still the largest. The length of longitudinal crack is second only to that of circumferential crack, accounting for 41% of the total length of crack, and the length of inclined crack is the least, accounting for 10% of the total length of crack.
3. Compared with the length and width of a single crack, the three kinds of cracks have a general law of longitudinal crack > circumferential crack > inclined crack.

5.2. Influence of Different Types of Cracks on Tunnel Structure Safety

Combined with engineering experience and analysis of the causes of crack formation, although the number and total length of circumferential cracks are more than those of the other two kinds of cracks, the circumferential cracks are generally caused by longitudinal uneven confining pressure and improper treatment of construction joints. It has little effect on the safety of tunnel structure. Although the number and total length of longitudinal cracks are slightly less than those of annular cracks, the degree of cracking of single longitudinal cracks is greater than that of circumferential cracks, inclined cracks, and longitudinal cracks are generally formed by bias, swelling ground pressure, and cavities behind the lining. The displacement and stress of surrounding rock caused by the change of stress, found in the actual engineering, the longitudinal cracks mostly occurred in the arch line and the arch roof. The development of longitudinal cracks may cause the tunnel to fall off arch, break the side wall and even cause the tunnel collapse, which has the greatest influence on the safety of tunnel structure. Although the inclined cracks are the least in number, the shortest in length and the lightest in the degree of cracking, the inclined cracks are generally caused by landslide, strike of rock strata, joints, etc., and the causes are relatively complex. Its influence on tunnel structure safety is second only to longitudinal crack.

6. Conclusions

This paper introduces the main causes of highway tunnel cracks and the classification of highway tunnel cracks. Combined with the data of detecting lining cracks in 13 tunnels in Hangzhou, different types of cracks are displayed directly by chart by using the method of classified numerical statistics, and the following general laws of cracks in highway tunnels are analyzed:

- In the total number of cracks in tunnel, the number of circumferential cracks is the most, accounting for 53% of the total number of cracks, the number of longitudinal cracks is the second, which accounts for 34% of the total number of cracks, the quantity of inclined cracks is the least, accounting for 13% of the total number of cracks.
- Among the three kinds of cracks, the length of circumferential crack occupies 49% of the total length of crack, and the proportion is still the largest. The length of longitudinal crack is second only to that of circumferential crack, accounting for 41% of the total length of crack, and the length of online crack is the least, accounting for 10% of the total length of crack.
- Compared with the length and width of the single crack, the three kinds of cracks have the general law of longitudinal crack > circumferential crack > inclined crack.
- The longitudinal crack has the biggest influence on the tunnel structure safety, the inclined crack is second only to the longitudinal crack, and the circumferential crack has little effect on the tunnel structure safety.

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8. Conflict of Interest

The authors declare no conflict of interest.

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