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Technical Note

A case study on tail brush induced loads upon segmental lining

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ARTICLE INFORMATION

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ABSTRACT

Damage to the tunnel segmental lining induced by the construction loads has become an important issue in recent years. In this study, in-situ monitoring was carried out to measure the pressure on the lining of a large cross-river shield tunnel along Yangtze River (diameter D=11.36m) with a small overburden (0.7D) in silty sandy ground. PAD type earth pressure gauges were used to measure the tail brush pressure on the lining. The time history and the distribution of pressures on the lining during tunnel construction were obtained. It showed that the tail brush pressure had a considerable effect on the segments while the shield machine was passing through. Non-uniform tail brush pressures caused cracking and water leakages in the reinforced concrete segments.

1. Introduction

In recent years, there are increasing number of large tunnels being constructed in China (e.g., Wu et al., 2014). as the lining segments of large shield tunnels become thinner and wider, the construction loads (e.g. jack thrust force, backfill grouting pressure and tail brush pressure) on the segments have attracted the attentions of tunnelling engineers, because of loads induced damage to the segments. Prediction of the construction loads are difficult with the conventional design processes. Therefore, to identify the potential risk of construction loads and evaluate their impacts on lining is of significant importance.

Some researchers pointed out the tail brush and the tail grease may impose large pressure upon segments (Tajima et al., 2006). In-situ monitoring showed that the wire brushes pressure acting upon segments the was much larger than the earth pressure (Arimizu et al., 1999; Koyama, 2003; Mashimo & Ishimura, 2006). In most of the papers, almost all researches focused on the influence of the backfill grouting and tail brush pressures on the deep tunnels, where the axial force is the dominant factor in the lining design.

The needs for large section cross-river traffic tunnels in Yangtze River Delta, China, is increasing with the rapid development of urban traffic. Here, in some situations, the depth of overburden is very limited in order to satisfy the slope requirement of the road for a short distance. In this case, rather than the earth and water pressures, the construction loads need careful analysis.

The aim of this study is to investigate the mechanism of tail brush induced loads and its impact on segment of large tunnel with small overburden. An in-situ monitoring is done to measure the lining pressure. The measured

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Note: Discussion on this paper is open until date September 2019

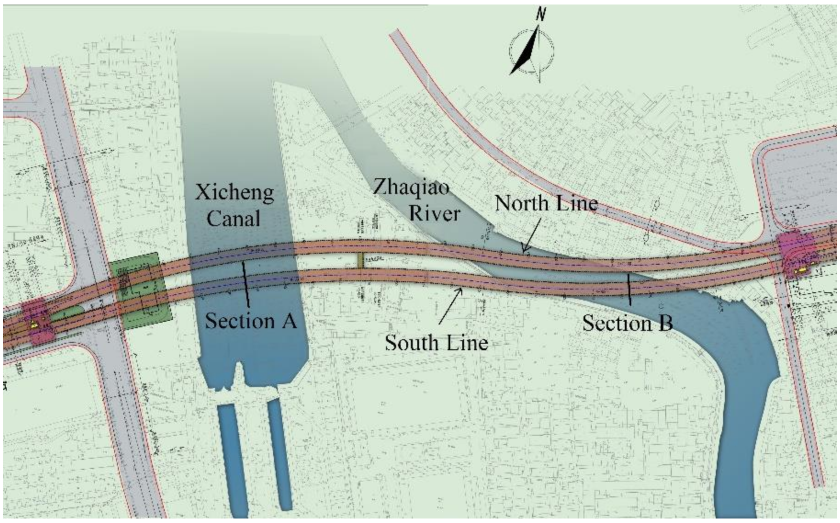


Fig. 1. Plan view of West Chengjiang Road tunnel

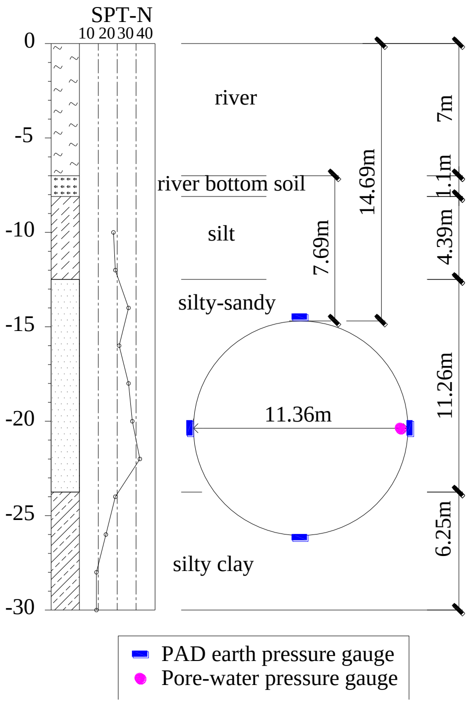


Fig. 2. Ground conditions of monitored sections and positions of pressure gauges

pressure data and the induced inner force of lining are analysed carefully.

2. Tunnel profile

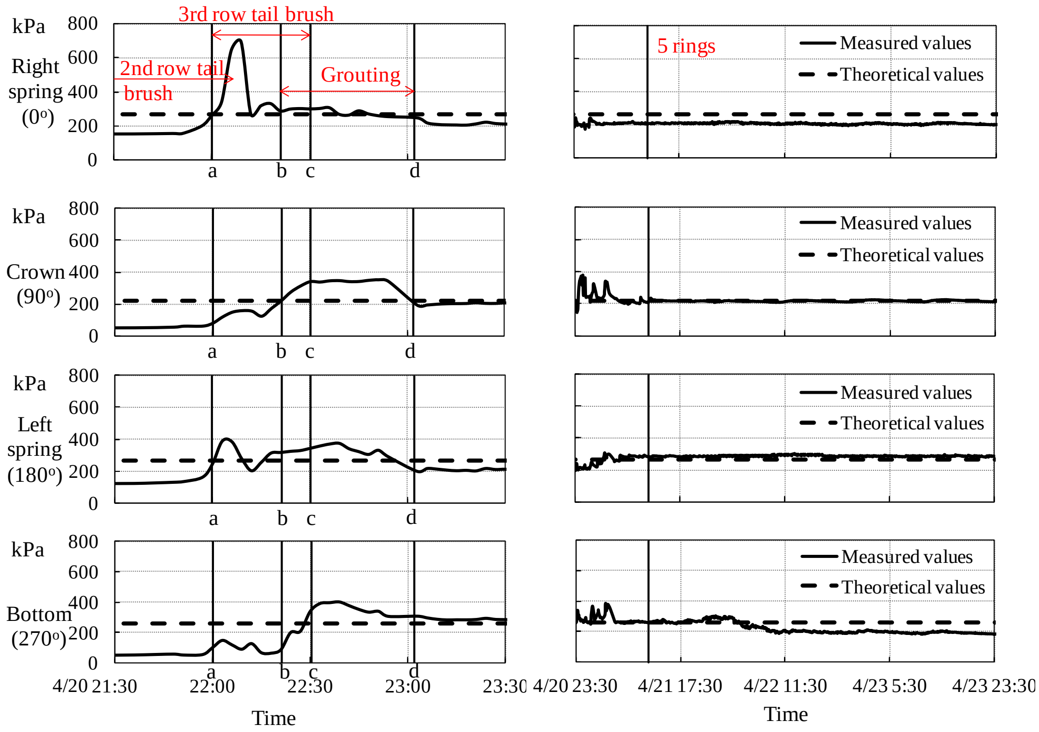
The tunnel is a twin-tube shield tunnel consisting of the north and south lines, as shown in Fig. 1. The total length is 1.27 km, of which 660 m was constructed by the shield tunnelling method.

During under-passing the rivers, silty and sandy strata was found in most of the areas with the minimum overburden of only 7 m.

In general, there are three rows of wire brushes in the shield tail, together with grease to prevent water, soil and grouting material leaking through the tail void. The replacement of the third row of wire brushes by steel plate brushes was done because of wearing out too quickly of wire brushes to maintain a sealing effect.

3. In-situ monitoring procedure of tail brush induced loads

In-situ monitoring was conducted at two sections in the south line tunnel, section A and section B in **Fig. 1.**



Note: As the data were recorded after the assembly of next ring of section A, the pressure induced by the first row of tail brushes and some of that induced by the second row of tail brushes was missed.

Fig. 3. Time history of earth pressure upon segments

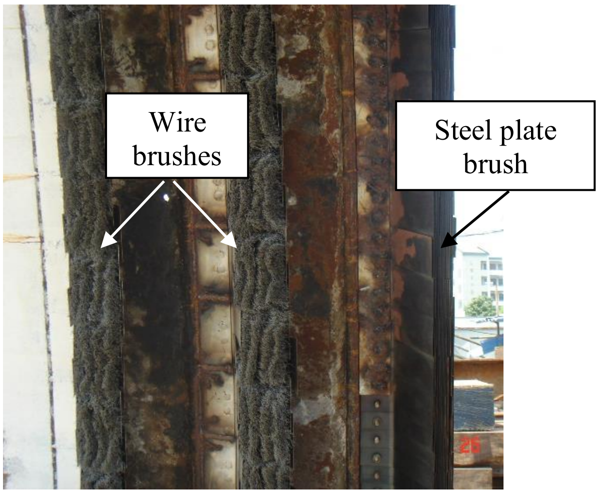


Fig. 4. Photograph of tail brushes

Section A and section B are located under two different rivers to investigate the tail brush induced loads on the segments. Since the monitoring results of two sections are similar, only the Section A is analysed in this study. The ground conditions of the section and installed positions of pressure gauges in section A are shown in **Fig. 2**.

A PAD type earth pressure gauge with a very thin pressure cell invented by Hashimoto et al. (1993) is used for the measurement of the pressure on tunnel segments. The output signal of the PAD type earth pressure gauge is measured with a vibrating wire data logger. The real-time data recording commenced only after the assembly of the next ring, due to the construction conditions. At that time, the first row of tail brushes had already passed beyond the earth pressure gauges and the second row of tail brushes was acting upon the earth pressure gauges.

4. Monitoring results and discussion

4.1 Overall monitoring results

The time histories of the pressure measured on the segments of the two monitored sections are shown in Fig. 3. In Section A, the real-time data recording started after the assembly of the next ring. At that moment, the pressure gauges had already been passed by the first row of tail brushes and had touched the second row of tail brushes. Therefore, the pressure induced by the first row and a part of that induced by the second row of tail brushes is found missing in Fig. 3. By crosschecking with the shield advancing records, four pivotal moments are identified in **Fig. 3**. Time "a" indicates when the third row of tail brushes begins acting upon the earth pressure gauges. Time "b" indicates when the third row of tail brushes begins passing away from the earth pressure gauges. Time "c" indicates when the third row of tail brushes completely passes away from the earth pressure gauges. Time "d" indicates the completion of the shield advancing through the current ring.

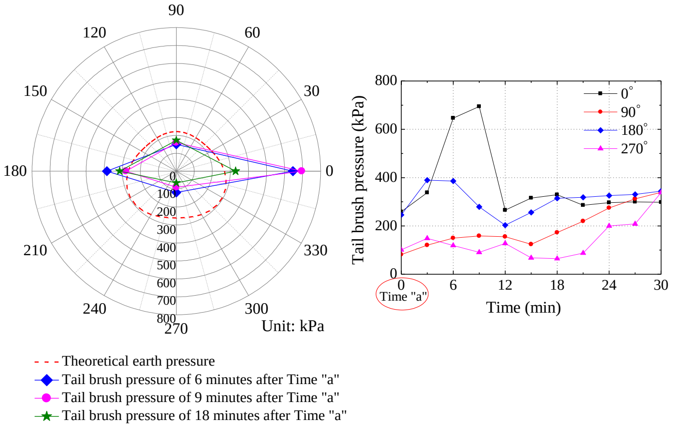


Fig. 5. Pressure distribution induced by 3rd-row steel plate tail brush of section A

4.2 Discussion on the influence of tail brush

When passing through the third row of the tail brush, most of the measured pressures increased and became larger than the theoretical values. The large discrepancy between the pressures induced by the first~second rows and those by the third row of tail brush was obviously due to the different materials used in the three rows of tail brush. As mentioned in session 2, the first and second rows were conventional wire brushes, while the third row was steel plate brush as shown in **Fig.4**. The outmost steel plate brush is much stiffer than the wire brush. It can provide better sealing effect than the wire type. On the other hand, it imposes unexpected pressure upon segments.

The distribution of tail brush indueced lining pressure of Section A during passing through the third row of tail brush is shown in **Fig. 5**. Such a non-uniform pressure distribution is prone to produce excessive bending moment in the tunnel lining. In the case of a shallow tunnel like this project, since the design maximum moment is relative small, a small amount of excessive bending moment can easily lead to cracking in the RC segments.

In the tunnel, water leakage from cracks in segments were observed right after passing of the tail brushes, creating voids.

This phenomenon in turn proved that the non-uniform pressures distribution induced by the steel plate brush is one of the main factors for cracking which reduces the durability and service performance of RC segments.

5. Conclusions

An in-situ monitoring of the tail brush induced pressure upon large section shield tunnel with small overburden, the time history and the distribution of lining pressures were obtained, and the inner force of lining were analysed. The in-situ monitoring showed that steel plate type has induced unexpected large loads upon segment. Therefore, in the case of shallow tunnel, where the axial forces are relatively small, the large bending moment caused by the non-uniform distribution of tail brush pressure may damage the segments.

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