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Response of a double-decked metro tunnel to shield driving of twin closely under-crossing tunnels

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ABSTRACT

Twin tunnels on Shenzhen metro Shekou Line were driven by EPB shields through weathered granite gneiss closely under-crossing a double-decked tunnel embedded in strongly weathered granite gneiss on Luobao Line. The performance of the existing tunnel as affected by under-crossing tunnels was continuously monitored by means of an automatic high-performance total station measuring system. Displacements of the existing tunnel caused by under-crossing tunnels in different under-crossing stages were measured. The measured data were timely processed and fed-back to related operators to realize an information-oriented project. Based on the measured data discussions and analyses were carried out in terms of the impact of the under-crossing shield tunnelling on the existing tunnel, effect of rainfall infiltration on the performance of the existing tunnel, allowable deformations of the existing tunnel, possibility of reducing the number of measuring points in a monitoring cross section and the influence on the existing tunnel caused by twin tunnels. Thanks to the staggered single tunnel under-crossing and other favorable factors, the measured deformations of the existing tunnel were well below the predefined allowable values. Under the guidance of monitoring, the under-crossing project was smoothly completed without interruption of metro traffic. This is a valuable example for evaluating the shield tunnelling induced effects on adjacent existing tunnels and establishing criteria to guide shield tunnelling under similar conditions.

1. Introduction

As population of Shenzhen city is growing, metro system becomes compulsory for solving traffic problems while its benefits are widely appreciated. First line of Shenzhen metro opened on 28 December 2004, making it the seventh city in mainland China to have a metro after Beijing, Tianjin, Shanghai, Guangzhou, Dalian, and Wuhan. Now the city is still extending the existing networks of its metro system. The four existing lines are undergoing expansion and new lines are under construction. The network will reach a total length of 177 km by June 2011 before the 2011 Summer Universiade. As a versatile tunnelling method in urban areas, the Earth Pressure Balanced (EPB) shield tunnelling has been widely adopted in the construction of Shenzhen metro tunnels (Maidl et al., 1996; Guo and Chen, 2006). In urban areas of the city, it is sometimes unavoidable that new shield tunnels close to or directly below the existing metro tunnels are built, and in these cases the response of the existing tunnel to the under-crossing shield tunnelling will be of great concern.

Response of existing tunnels to adjacent construction theoretically belongs to the problem of the interaction between adjacent ground structures and the bearing capacity of the existing tunnel, and has been studied in recent years using a variety of approaches: field observation, physical model testing and finite element simulation.

Yamaguchi et al. (1998) analyzed the deformations of the tunnels and compared the solutions with monitoring data obtained during the construction of four metro tunnels that run close to each other in the Kyoto City. Standing and Selman (2001) presented precise levelling data along the tunnels of the Northern and Bakerloo Line (London Underground) which were subjected to movement caused by the construction of the Jubilee Line Extension (JLE) and investigated the applicability of using the principle of superposition within the region between the adjacent excavated tunnels for the Northern and Bakerloo Line tunnels. Chang et al. (2001) presented the response of a Taipei Rapid Transit System (TRTS) tunnel to adjacent excavation. Chen et al. (2006) reported the longitudinal settlements of an existing tunnel on line No. 2 caused by over-crossing shield tunnelling on line No. 8 in Shanghai. Byun et al. (2006) carried out several large-scale model tests to measure the ground behavior around tunnel-crossing zone and the existing tunnel behavior located above the newly excavated tunnel. He et al. (2008) studied the longitudinal displacements,

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circumferential deformations, axial forces and moments of an existing tunnel induced by shield tunnel construction directly underneath using analogous material model test. Hefny et al. (2004) investigated the effect of a new bored tunnel on the stresses induced in the lining of an existing adjacent tunnel using two-dimensional finite element program PLAXIS and typical lining and soil parameters of the North-East line MRT Tunnel in Singapore. Hage Chehade and Shahrour (2008) presented analysis of the interaction between twin-tunnels with a particular interest for the optimization of both the relative position of the twin-tunnels and the construction procedure using the finite element program PLAXIS. Liu et al. (2008, 2009) investigated the response

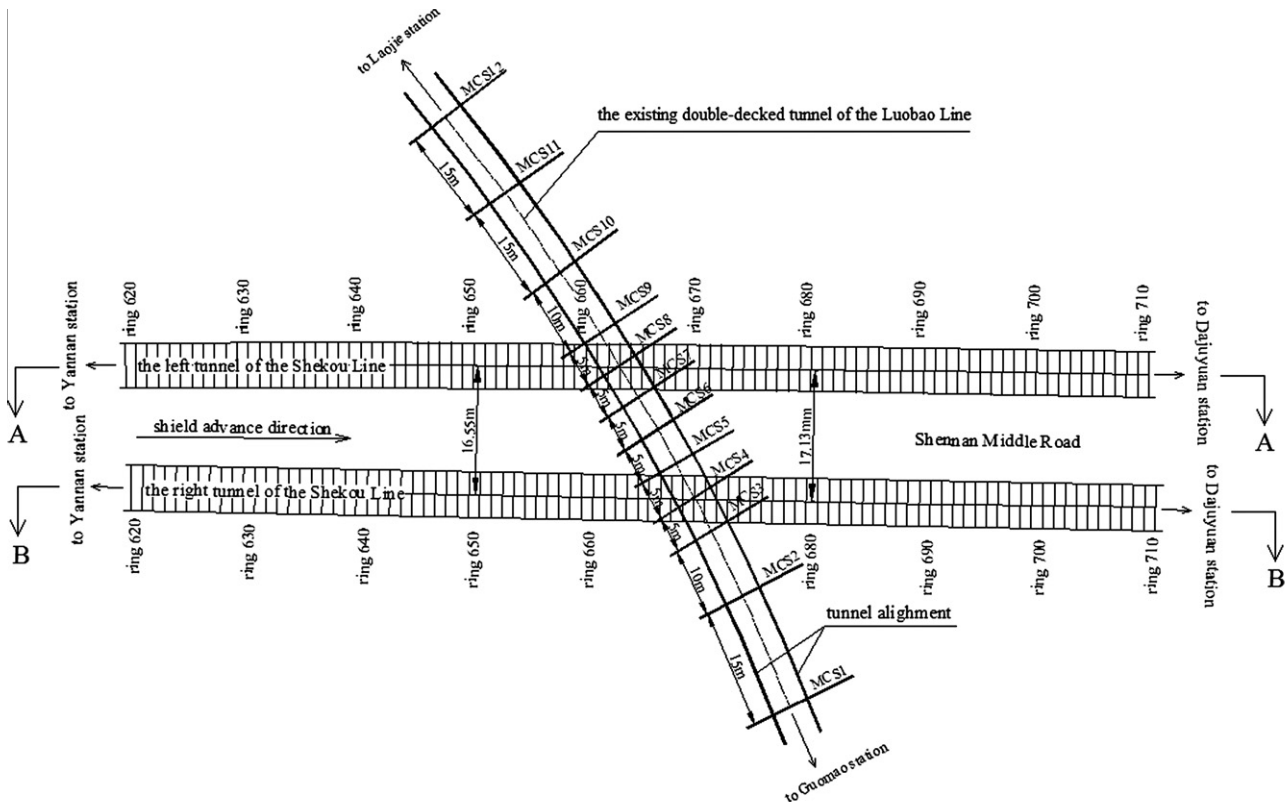

Fig. 1. Plan of construction site.

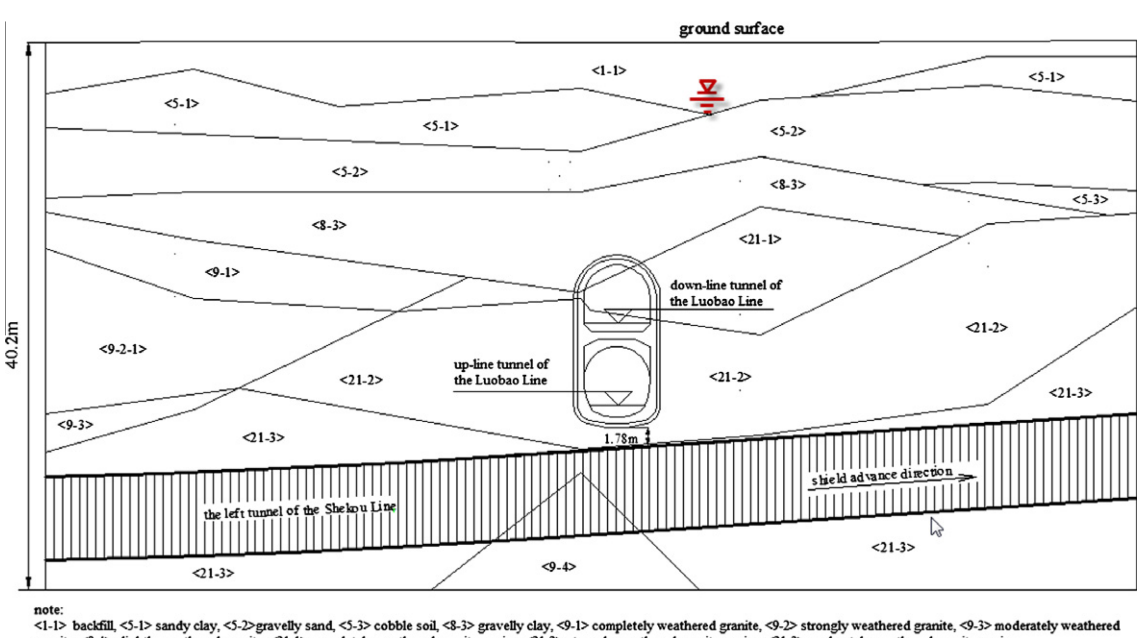

Fig. 2. Section A–A.