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Shallow tunnel construction with irregular surface topography using cross diaphragm method

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ABSTRACT

This paper presents the analysis of site monitoring results from a high-speed railway tunnel excavated in shallowly buried soft ground with irregular surface topography using the cross diaphragm method. The surface and subsurface settlements, the normal pressures between surrounding ground and primary lining and between primary and secondary linings were systematically monitored at three tunnel cross sections. The specific surface settlement characteristics associated with tunnelling under irregular surface topography conditions in comparison to those under horizontal surface conditions are illustrated. The “rebound” phenomenon of a relative settlement curve from the intermediate anchor to the top of the access tube is observed, which can be introduced to determine the stability of a tunnel project during construction. The normal pressures measured between the soft ground and the primary lining show close agreement with the theoretical analysis results. The normal pressures measured between the primary lining and the secondary lining should be used before the influences of cell installation effects and other related factors have been considered. But the pressure measurements can still provide valuable information of a tunnel project.

1. Introduction

The use of shotcrete lining in soft ground tunnels is commonly associated with sequential excavation (Romero, 2002). To ensure an early, temporary ring closure, partial drifts such as sidewall drifts and middle drifts are world-wide used. These partial drifts are commonly supported by temporary supports, for example, temporary walls and temporary inverts. The sequential excavation can be classified into different categories according to its construction sequence, e.g., top-heading-and-bench method, center diaphragm method, cross diaphragm method (CRD method), upper half vertical subdivision method, sidewall galleries method and three-bench seven-step excavation method (Narasaki et al., 1989; Seki et al., 1989; Li et al., 2016). It is noted that the word “method” used in this paper refers to tunnelling sequence, which has been accepted by many researchers and engineers. Moreover, there are many variations of sequential excavation in the cases of subway station construction (Fang et al., 2012).

The sequential excavation method tends to be more effective than the full-face method in the stability control of soft ground tunnelling. But it requires careful tunnel support design and high quality workmanship. The determination of a tunnelling method to be used for a specific situation should consider the interaction of several factors, such as safety, cost, schedule and the experience of the contractor (Hoek, 2001). To facilitate the choice of a suitable tunnelling method, the mechanical characteristics of different sequential excavation method have been extensively studied (Karakus and Fowell, 2003; Yoo, 2009; Xue et al., 2010; Sharifzadeha et al., 2013; Li et al., 2016), most of which were carried out using numerical simulation. It is undoubted that numerical simulation can provide insights into the physical nature of sequential excavation. However, the availability of numerical prediction depends highly on the constitutive models adopted and related input parameters.

In this research, a well-documented high-speed railway tunnelling case is presented. Three tunnel cross sections, excavated using the CRD method in shallowly buried soft ground with irregular surface topography, were systematically monitored. The monitoring results associated with tunnel construction, including the surface and subsurface settlements, the normal pressures between surrounding ground and primary lining and between primary and secondary linings, are reported and illustrated. The research may server as a practical reference for similar projects.

2. Project overview

The Hejie Tunnel is part of the Guiyang-Guangzhou High-Speed Railway in southern China. This tunnel project involves building a

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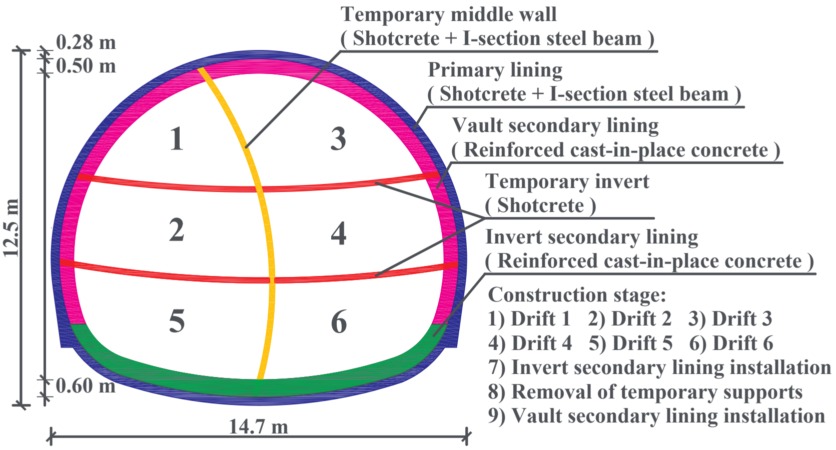


Fig. 1. Construction procedure of CRD method.

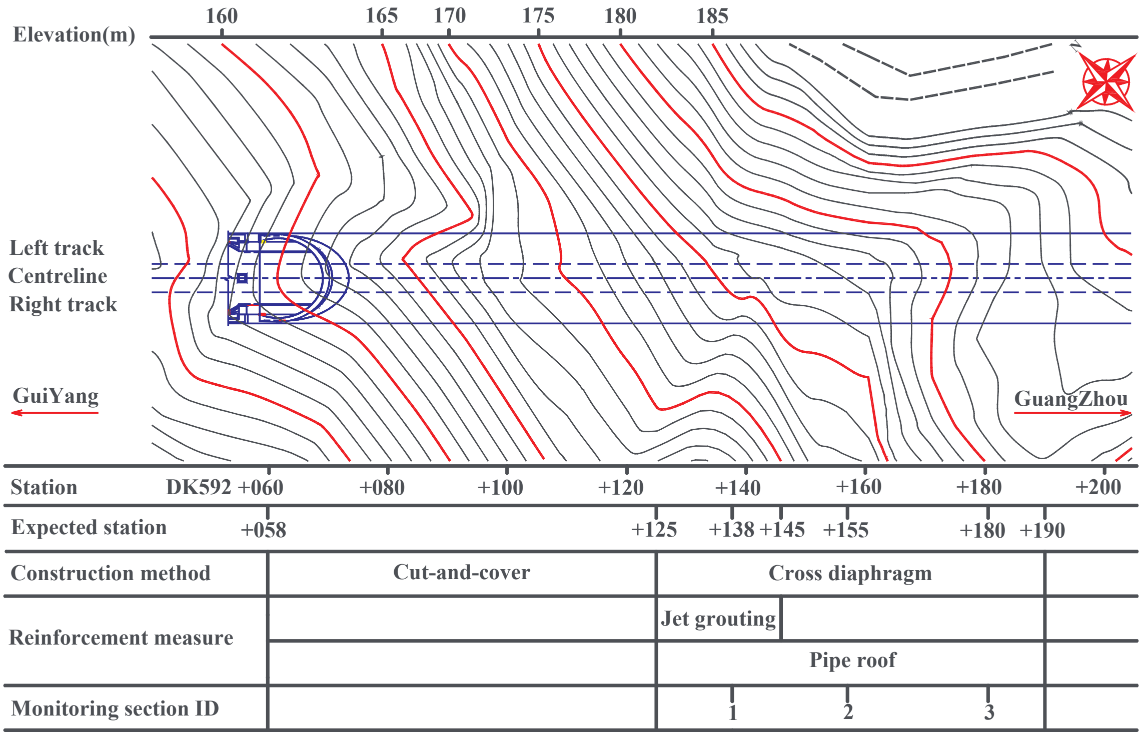
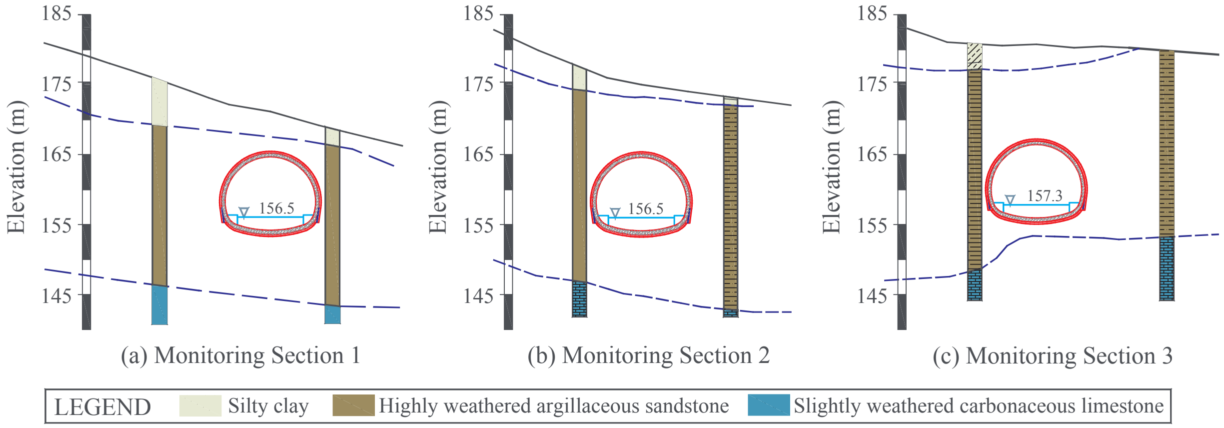


Fig. 2. Topographic map of Hejie Tunnel (from DK 592 + 50 to DK 592 + 200).



(a) Monitoring Section 1
(b) Monitoring Section 2
(c) Monitoring Section 3

Fig. 3. Surface topographies and borehole information of three monitoring sections.