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Performance of constructing a double-deck subway station by combining the shield method and cavern–pile method

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ABSTRACT

A method of constructing a double-deck subway station by combining two parallel shield tunnels and the cavern–pile method is presented. Taking the practical engineering of the Beijing subway as the background, numerical simulations were carried out to study enlarging construction. Mechanical and deformed performances for opening segments, important nodes, and main components of the station structure were investigated. Subsequently, a comparative analysis was performed to investigate the effects of side piles. Finally, an economic investigation was conducted to validate the practicability of the present method. This paper systematically demonstrates the applicability of the proposed method through a three-dimensional numerical simulation. The results show that it is safe and feasible to create a double-deck subway station by enlarging two parallel shield tunnels using the cavern–pile method.

1. Introduction

The shield method has been extensively used in subway construction for its advantages of safety, quickness and slight negative effect on the surrounding environment. Under current construction conditions, however, when the shield machine arrives at the location of a station, it is affected by non-promoting operations of the shield machine, such as excavation of the receiving shaft, excavation of the originating shaft, and dragging shield machine.

These non-promoting operations reduce the continuous driving distance of the shield machine, reduce the service efficiency of the shield machine, and increase the construction period and cost. These problems have been intensively studied. New methods have been developed for the construction of a subway station, such as the use of two connected shields, the use of multiple small shields, and the shallow tunneling method (Edwards, 1990; Fang et al., 2011, 2012, 2016; Yu et al., 2016; Bobet and Yu, 2016).

In addition, creating a subway station by combining the shield method with other methods has been investigated by many researchers (Barski and Hong, 2000; Nakamura et al., 2003; Shirai et al., 2005; Kunihiko and Kenichi, 2006; Liu et al., 2009, 2012, 2015; Zhang et al., 2008; Ding et al., 2011). Barski and Hong (2000) put forward a method of constructing a metro station with three arches by enlarging a large-diameter shield tunnel. Nakamura et al. (2003) later provided a method to excavate a rectangular cross-section for the Kyoto Municipal Subway. Shirai et al. (2005) described a construction method of large underground spaces combined with the large-diameter curved pipe roof. Kunihiko and Kenichi (2006) presented a construction method for subway combined with a large diameter shield tunnel. Liu et al. (2015) later presented an approach for building a subway station by combining large-diameter shield tunnels and the pile–beam–arch method. Beyond that, construction schemes of a metro station based on two parallel shield tunnels have also been studied. For example, Zhang et al. (2008) provided a construction method of metro station by enlarging shield tunnels combined with open cut method. Liu et al. (2009) later put forward a method of constructing a pylon shaft station by enlarging shield tunnels and using a shallow burial method. Liu et al. (2012) introduced a construction method for metro stations by enlarging twin tunnels and remodeling the shield shaft.

Overall, most studies on subway station construction schemes that combine enlarging the shield tunnel with other methods were based on large-diameter shield tunneling and a single-layer station built as the main structure. However, a special shield is needed when constructing a station by enlarging a large-diameter shield tunnel and the economic benefits will be small when applying this special shield in the construction of tunnels. There have been few studies on the construction of a double-deck subway station structure based on two parallel shield tunnels. Obviously, the double-deck subway station can organize the dispersion and transfer of passengers more efficiently, arrange function zones more reasonably, and be managed more easily. Given this reality, the present paper puts forward a construction method of a double-deck subway station involving two parallel shield tunnels and

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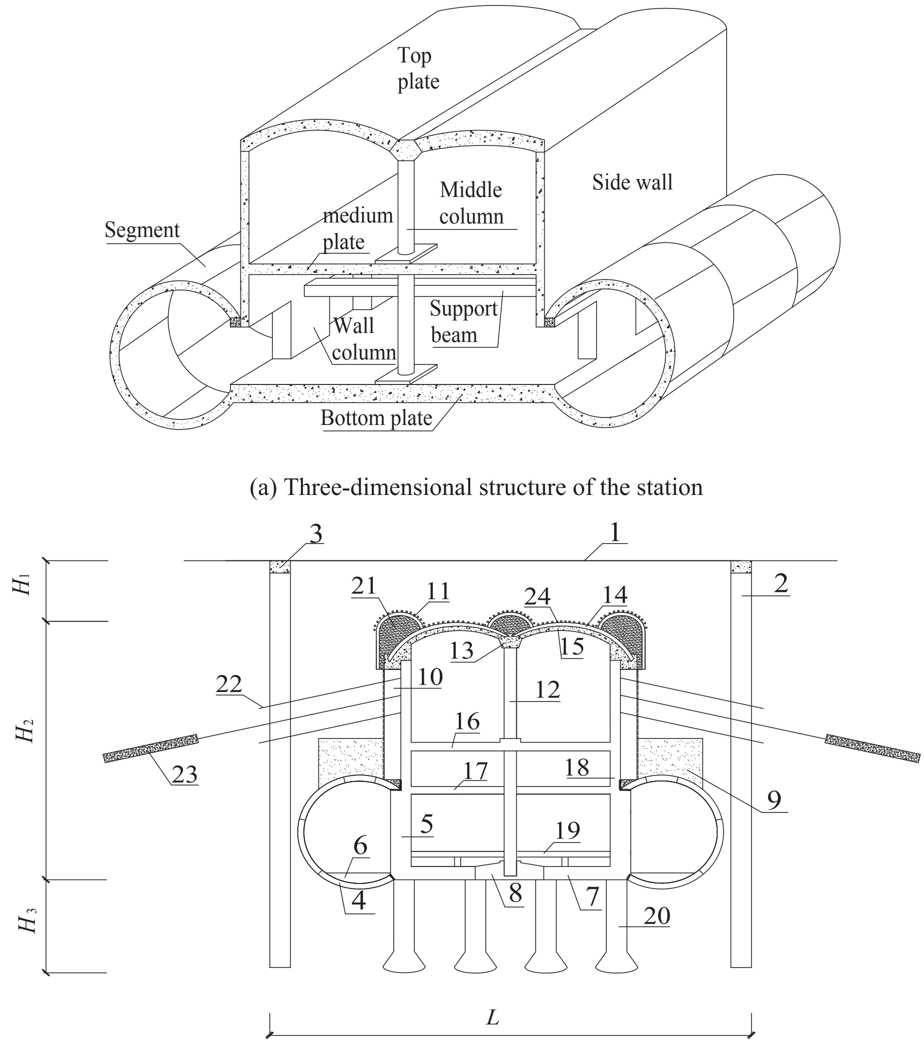

Note: 1-Street, 2-Side pile, 3-Crown beam, 4-Shield segment, 5-Wall column, 6-Inverted arch, 7-Bottom plates, 8-Foundation of the middle column, 9-Grouting reinforcement of soil layer, 10-Fender pile, 11-Pilot tunnel, 12-Middle column, 13-Top beam, 14-Advanced small pipe grouting, 15-Secondary lining, 16-Medium plate, 17-Support beam, 18-Side wall, 19-Platform slab, 20-Uplift pile, 21-Backfill material, 22-Anchor, 23-Cable, 24-Primary lining, H_1-Soil stratum thickness above the structure, H_2-Height of the station, H_3-Height of the uplift pile, L-Width of the whole station

(b) Cross section of the station

Fig. 1. Double-deck station cross section.

the cavern–pile method. The performance of the double-deck subway station construction is investigated in a series of numerical simulations.

2. Proposed construction method

The cavern–pile method has been widely employed because it can be used for small construction sites and it interferes less with surface traffic (Liu et al., 2015). The proposed construction method for the subway station structure, which combines the shield method and cavern–pile method, has been developed as a study. For the construction method, two parallel tunnels over a long distance was constructed by a shield machine with a diameter of 6.0 m, the station was built on the basis of the tunnels subsequently. Fig. 1(a) shows the three-dimensional structure of the station, which is a frame supporting structure as a island platform with double spans. The typical cross section of the station is shown in Fig. 1(b).

The construction steps of the proposed scheme are shown in Fig. 2. Side piles are constructed outside the tunnels before the shield machine passes through the station location (Fig. 2(a)).

First of all, an internal supporting system inside the segments is erected and segments are removed at regular intervals (Fig. 2(b)). Then the cross tunnels are excavated and uplift piles are constructed (Fig. 2(c)). Next, the bottom plates, wall columns, and nodes between the wall columns and segments are constructed. At the same time, the foundation of the middle columns and support beams are constructed at regular intervals, and temporary steel supports are erected between wall columns (Fig. 2(d)). After that, the soil above the cross tunnels is reinforced by grouting. The upper pilot tunnels, the foundation fender piles and middle columns of the main structure are constructed (Fig. 2(e)). And then, the lining of the pilot tunnels are dismantled at regular intervals. The upper soil of the subway hall floor, the arch primary lining and permanent lining are constructed (Fig. 2(f)). Subsequently, the soil of the subway hall floor and the anchors are constructed. The masonry wall cling to the fender pile is constructed and the anchor head is laid in the wall. The medium plate and the side wall of the subway hall floor are constructed later (Fig. 2(g)). Then, the