Tunnelling and Underground Space Technology 60 (2016) 151–164

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Construction of a large-section long pedestrian underpass using pipe jacking in muddy silty clay: A case study

Dingwen Zhang [a,b], Bo Liu [a,b,*], Yujun Qin [c]

[a] School of Transportation, Southeast University, Nanjing, Jiangsu 210096, China
[b] Jiangsu Key Laboratory of Urban Underground Engineering and Environmental Safety, Southeast University, Nanjing, Jiangsu 210096, China
[c] China Railway 23rd Bureau Group 1st Engineering Co., Ltd, Rizhao, Shandong 276826, China

ARTICLE INFO

Article history:
Received 23 May 2016
Accepted 28 August 2016

Keywords:
Pedestrian underpass
Pipe jacking
Numerical simulation
Field monitoring
Roadway
Metro tunnel

ABSTRACT

This paper presents a case study of constructing a large-section long pedestrian underpass using pipe jacking method in Nanjing, China. The underpass, having a width of 7 m and a height of 4.3 m, was jacked 94.5 m in muddy silty clay under a busy roadway with 6.2 m overburden soil, meanwhile it traverses above the existed shield metro tunnels with just 4.5 m from the underpass bottom to tunnel vault. This paper introduced the design and construction schemes of this project in detail. A pre-construction three dimensional numerical simulation was conducted to investigate the responses of the roadway and metro tunnels to pipe jacking construction. Based on the simulation results, the field monitoring program was proposed, and the tunnels deformation and ground settlement were constantly monitored. The field performances of the metro tunnels and roadway were analyzed according to the monitoring data. In the jacking process, the micro-underbreak method was adopted. In order to decrease the tunnels uplift and ground settlement, the actual volume of soil conveyed out from soil chamber to ground surface was kept 95–98% of theoretical soil volume cut by cutter head. In general, this project is completed successfully without taking any additional time and money-consuming deformation control measures. The ground traffic and underneath metro runs well during the whole construction process.

1. Introduction

Pipe jacking is a trenchless technology commonly used in the installation of lined tunnel for sewers, gas and water pipelines, electricity and telecommunication cable ducts by jacking new pipe segments into the ground from starting shaft to receiving shaft (Bergeson, 2014; Chapman et al., 2007; Milligan, 1996; Sofianos et al., 2004). It can be used for a range of pipe size with internal diameter from 250 mm up to 3 m, or even for large span box culvert with size appropriate for transportation or pedestrian (McGuigan and Valsangkar, 2011; Meskele and Stuedlein, 2013; Wang et al., 2013). Compared to the traditional open-cut method, it is more widely used in urban area owing to its technical advantage of the little influence on the surface traffic and the neighboring structures. According to literatures, recent advances in pipe jacking method have mainly concentrated on the following aspects: (i) Pipe-soil interaction mechanism in the process of jacking (Barla and Camusso, 2013; Meskele and Stuedlein, 2015; Milligan and Norris, 1999); (ii) Characteristics of different injected slurry or lubricants, and their positive effects on reducing friction resistance and ground settlement (Khazaei et al., 2006; Shimada et al., 2006; Shou et al., 2010; Zhou et al., 2009); (iii) Estimation, analysis and evaluation of jacking force and its influencing factors (Barla et al., 2006; Beckmann et al., 2007; Choo and Ong, 2015; Ong and Choo, 2016; Yen and Shou, 2015); and (iv) Prediction, analysis and control of environmental deformation induced by pipe jacking (Chapman, 1999; Cheng and Lu, 2015; Cui et al., 2015; Farrell and Terry, 2015; Liao and Cheng, 1996; Senda et al., 2013; Shen et al., 2016; Sun et al., 2014; Zhen et al., 2014). However, the pipe jacking projects in the above-mentioned literatures are mainly small-medium diameter circular pipe or tunnel constructed in relatively simple environmental condition. There are few reports on the construction of large-section tunnel using pipe jacking in complex condition, such as jacking in soft clay layer with unsuitable soil properties, jacking approaching existed roadway or railway, traversing in close proximity to existed metro tunnels or facilities.

This paper presents a case study of a large-section long rectangular pedestrian underpass having a width of 7 m and a height of 4.3 m construction by pipe jacking, which passes beneath a busy roadway and traverse above the existed two metro tunnels. The underpass was jacked 94.5 m under a busy roadway with 6.2 m overburden soil, meanwhile it traverses above the existed shield

* Corresponding author at: School of Transportation, Southeast University, 2 Sipailou, Xuanwu District, Nanjing 210096, China.
E-mail address: seuliubo@seu.edu.cn (B. Liu).

http://dx.doi.org/10.1016/j.tust.2016.08.009
0886-7798/

metro tunnels with just 4.5 m from the underpass bottom to tunnel vault. The roadway and metro tunnels are sensitive to external construction disturbance. The construction site is located at the floodplain of Yangtze River on the east of China, where the ground mainly consists of soft deltaic deposit with high water content, high void ratio, high sensitivity and low strength. The large section of the underpass, the operation of ground traffic and subway train, and the unsuitable soil layer properties increase the risk of underpass construction. In order to mitigate the risk and ensure the successful completion of the project, a pre-construction three dimensional numerical simulation was conducted to investigate the road and metro tunnels responses to the pipe jacking. Then, a field monitoring program was proposed based on the numerical simulation results. The ground surface settlement and the metro tunnels deformation, including vertical displacement, horizontal displacement and diameter convergence, were comprehensively monitored during the construction. At last, the relationship between deformation and construction operations was analyzed according to the monitoring data.

2. Project description

2.1. Pipe jacking project

Fig. 1 illustrates the plan layout and section view of this pipe jacking project. The construction site is located at downtown of Nanjing, China. There are several residential buildings and commercial buildings around the construction site. The pedestrian underpass, being a municipal facility connecting the residential area to neighboring business district, was designed to perpendicularly pass beneath the busy Jiangdong Road and traverse the underneath shield tunnels of Nanjing Metro Line 2 [Fig. 1(a)]. The top of underpass is 6.2 m below the ground surface and a minimum distance from underpass bottom to tunnel vault is only 4.5 m. To minimize the influence of construction on road traffic and ensure the normal operation of underneath metro, noneinvasive pipe jacking method was selected. Starting shaft and receiving shaft were constructed at the far ends of pipe jacking line. Each prefabricate reinforced concrete pipe segment is 1.5 m long, 7 m wide and 4.3 m high with thickness of 0.5 m. The whole underpass have a total length of 94.5 m and consists of 63 pipe segments [Fig. 1(b)].

2.2. Site condition

At this site, 15 boreholes, 52 standard penetration tests (SPT), 3 holes totaling 60 shear wave velocity tests were conducted before design and construction stage, and 266 undistributed samples were obtained. In the laboratory, conventional soil tests such as measurement of density, water content and void ratio, compression tests, direct shear tests, triaxial tests, unconfined compressive strength tests, and chemical composition analysis tests were performed. The geological section obtained from geological drilling is shown in Fig. 2. The results show that the ground up

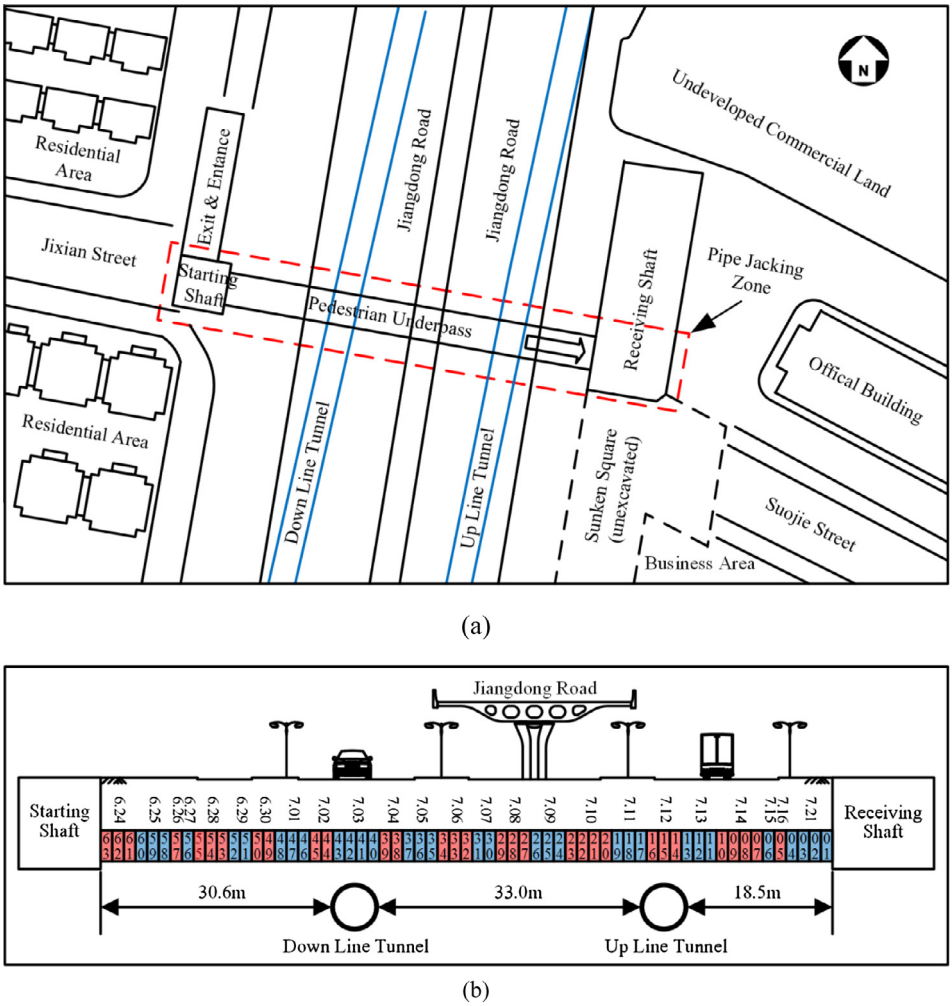

Fig. 1. (a) Plan Layout of project and (b) section view of pipe jacking zone.