Tunnelling and Underground Space Technology 58 (2016) 159–176

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

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

Effects of above-crossing tunnelling on the existing shield tunnels

Rongzhu Liang [a,b,*], Tangdai Xia [a,b], Yi Hong [a,b], Feng Yu [c]

[a] College of Civil Engineering and Architecture, Zhejiang University, 866 Yuhangtang Road, Hangzhou 310058, China
[b] Research Center of Coastal and Urban Geotechnical Engineering, Zhejiang University, 866 Yuhangtang Road, Hangzhou 310058, China
[c] School of Civil Engineering and Architecture, Zhejiang Sci-Tech University, Hangzhou 310018, China

ARTICLE INFO

Article history:
Received 24 June 2015
Accepted 9 May 2016
Available online 28 May 2016

Keywords:
Above-crossing tunnelling
Tunnel heave
Winkler model
Simplified analytical method

ABSTRACT

Tunnelling in the dense urban areas frequently results in over-crossing or bypassing the existing tunnels. It is obvious that the over-crossing tunnelling will adversely affect and even damage the existing tunnels if the induced deformation exceeds the capacity of tunnel structures. Increasing concerns have been raised about the interactions between the over-crossing tunnelling and underlying tunnels. In order to obtain a better mechanical understanding of the effects of the over-crossing tunnelling on the existing tunnels and provide a quick but low cost assessment alternative method for evaluating the behavior of underlying tunnels prior to construction, a simplified analytical method is proposed in this study. In this simplified method, the tunnel is simply considered as a continuous Euler-Bernoulli beam with a certain equivalent bending stiffness. The unloading stress at the tunnel location caused by the over-crossing tunnelling is computed through Mindlin's solution, ignoring the presence of the existing tunnel. Then, the tunnel-soil interaction due to the relief stress is analyzed based on the commonly-accepted Winkler foundation model. The applicability of the presented method is validated by three well-documented case histories. Results of these case studies show a reasonable agreement between the predictions and observations. Finally, a parametric analysis is also preformed to investigate the influences of the different factors on the behavior of the existing tunnels, including clearance distance, advancing distance and multiple tunnels construction.

1. Introduction

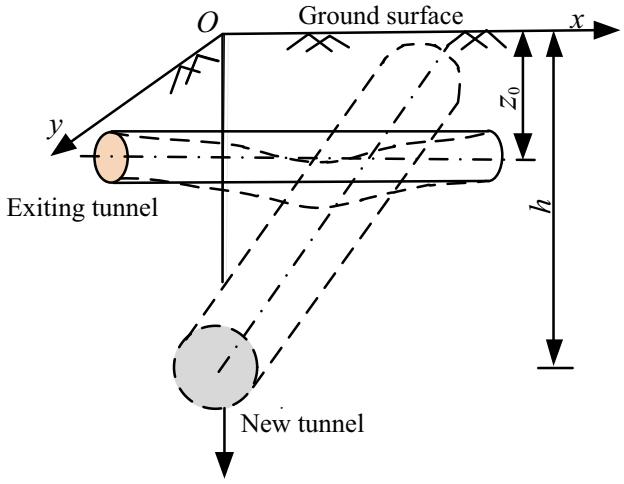
Nowadays, the urban railway transit system is one of the indispensable parts of city traffic system. Due to the rapid economic developments and urbanization of China, more urban metro lines are being planned or implemented to facilitate congested urban traffic system in many big cities, such as Shanghai, Beijing, Shenzhen and Hangzhou. For the metro tunnels in the cities, such as Hangzhou and Shanghai, in which very thick layer soft clay is distributed throughout the underground space, are mainly constructed by employing the shield tunnelling method. Shield tunnelling technology, including slurry shield and Earth Pressured balanced shield tunnelling methods, is one of the most sophisticated and popular tunnelling technologies with various advantages such as high effective, low cost and minor disturbance to surrounding environment. However, construction of a new tunnel in dense urban underground space often encounters the underground pre-existing structures and facilities, such as pile foundations, municipal pipelines and running tunnels. Therefore, serious concerns have been increasingly raised about the influence on the existing structures, especially existing tunnels which is the focus of this paper, due to adjacent tunnelling.

Fig. 1 shows the common relative locations between existing and new tunnels. According to the different relative positions between exiting and new tunnels, there are mainly five types of tunnelling conditions, namely, new tunnel down-crossing below (Fig. 1(a)), new tunnel side-by-side parallelly crossing (Fig. 1(b)), new tunnel parallelly down-crossing (Fig. 1(c)), new tunnel parallelly above-crossing (Fig. 1(d)) and new tunnel above-crossing (Fig. 1(e)).

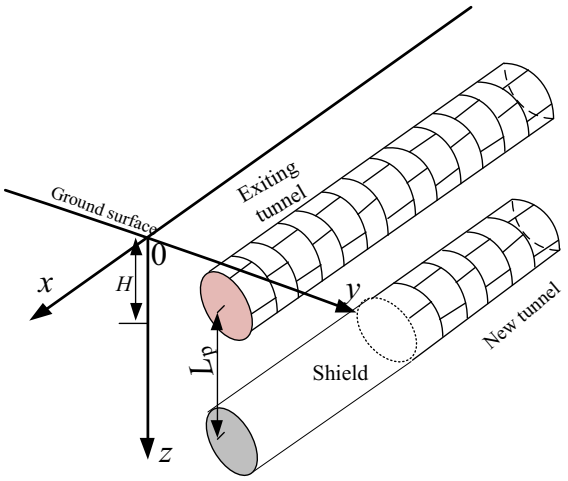
To ensure the safety and serviceability of the existing tunnels is extremely critical, as the nearby new tunnel construction will alter the already balanced ground stress field and cause free soil movements, which will inevitably induce adverse effects, such as additional loads and bending moments, on the existing tunnels. Theoretically, the responses of existing tunnel structures result from the interaction between the disturbed soil movements induced by tunnel excavation and the bearing capacity of existing tunnel.

* Corresponding author at: College of Civil Engineering and Architecture, Zhejiang University, 866 Yuhangtang Road, Hangzhou 310058, China.
E-mail addresses: liangcug@163.com (R. Liang), xtd@zju.edu.cn (T. Xia), chrishyi@ust.hk (Y. Hong), pokfulam@163.com (F. Yu).

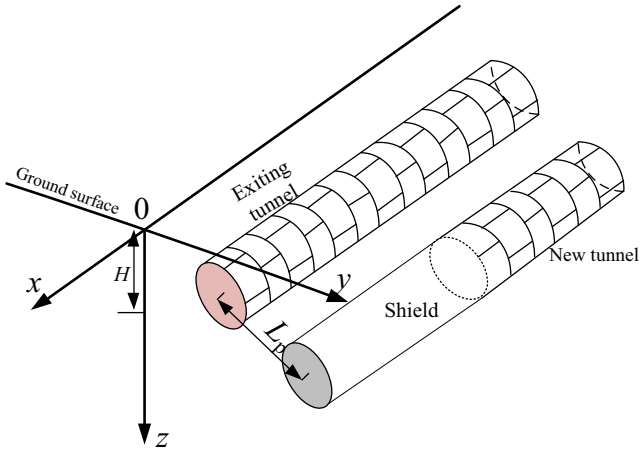
http://dx.doi.org/10.1016/j.tust.2016.05.002
0886-7798/



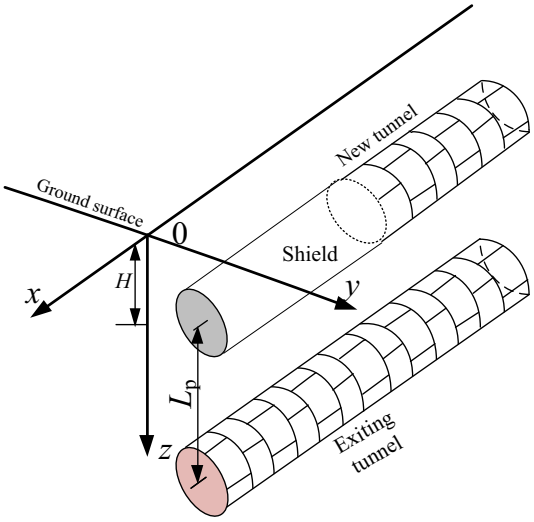
(a) New tunnel down-crossing



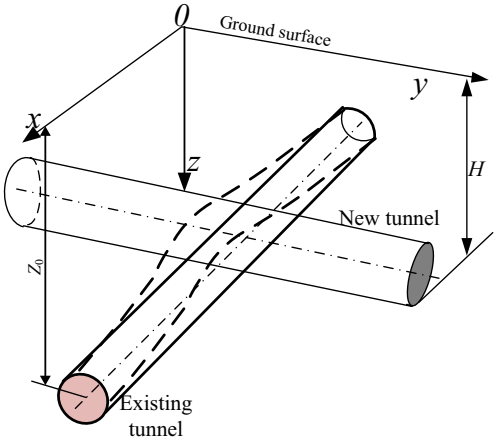
(c) New tunnel parallelly down-crossing



(b) New tunnel side-by-side parallelly crossing



(d) New tunnel parallelly above-crossing



(e) New tunnel above-crossing

Fig. 1. Relative position between new tunnel and existing tunnel.

However, the interaction mechanisms between the existing tunnel and the adjacent tunnelling are highly complex and severe construction risks and damage of integrity of tunnel structures may occur, unless effective geotechnical protective measures are undertaken during the adjacent tunnelling. In order to provide effective geotechnical protective measures for the exiting tunnel,