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Research Paper

Twin tunnel configuration for Greater Cairo metro line No. 4

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ABSTRACT

Construction of twin tunnels in crowded urban cities compels the designer to select a suitable configuration and the associated railway alignment. Therefore, the estimation of optimum clear distance between tunnels, then vertical and horizontal curves of rails is significant for twin tunnel projects to obtain the optimum design of tunnels, safety and passenger comfort. A case study is the Greater Cairo metro line No. 4, Phase 1. The configuration of twin tunnels includes vertical, horizontal and diagonal alignment. Two cases for diagonal alignment, one of them tunnels pass under the River Nile. Also, two cases for horizontal alignment, one of them tunnels running above bottom clayey soil. Proper clear distance between twin tunnels has been identified according to internal forces and displacement in tunnels. Vertical and horizontal displacements have been presented for twin tunnels and for the surrounding soil. Moreover, induced internal forces in tunnel lining have been computed. Two-dimensional numerical models are employed by using PLAXIS program to perform the analysis. Also, the procedures of construction of the twin tunnels have been discussed. Based on the calculated result, the clear distance between tunnels has a major effect on soil movement and internal forces in tunnel lining. It shows that the construction procedure affects the soil displacement and internal forces. Construction of the bottom tunnel at first reduces bending moment in top tunnel lining and results in small changes in bending moment in the bottom tunnel lining after the construction of top tunnel. On the other hand, the results have also shown the influence of twin tunnel configuration on railway track alignment.

1. Introduction

Twin tunnels are constructed because of their many advantages, including control of the soil movement and internal forces of lining. Procedures of construction of twin tunnels lead to decrease internal forces in one of them as a result of construction of one of them before the other. The clear distance between twin tunnels is one of the most important factors that control soil movement and internal forces in the lining. Greater Cairo metro line No. 4 passes under the River Nile in Egypt, whereas Phase No. 1 of the line will extend from El-Malek El-Saleh station on line No. 1 to Hadaek AlAshgar station as shown in (Fig. 1). It will meet the route of line No. 2 in Giza station. The study area for Greater Cairo metro line No. 4 starts from station No. 1 (El-Malek El-Saleh) and extends up to station No. 6 (Madkor Station) (Fig. 1).

Do et al. [1] concluded that due to the interaction of twin tunnels, an increase in the surface settlement can be expected compared to that induced above a single tunnel. Chehade and Shahrour [2] concluded that construction of tunnels causes movement of soil and straining action in the lining of the tunnel. Also the procedure of construction impacts on soil settlement and lining forces. Moller [3] studied the internal forces in tunnel lining and displacement of soil and found that tunnel design needs an honest idea of surface settlements and lining internal forces. Garner and Coffman [4] found that the design of the tunnel depends on the induced settlement in the tunnel. Therefore, they proposed method giving acceptable ground surface settlement profile to generate a tunnel system configuration. As well as the proposed characterization method can be used to help designers to eliminate potential configurations that would cause excessive surface settlements. Chen et al. [5] concluded that a good estimation of surface settlement is very important to the construction of tunnels in very crowded cities because failure of neighboring structures due to extra surface settlement above the tunnels. They examined the interaction of multi-tube tunnels on ground surface settlement and the methods of prediction of the transverse ground surface settlement profile.

Zhechao Wang et al. [6] found that for shallow tunnels constructed in clay soil, a surface settlement above tunnels depends on the creep of soil. They concluded that behavior of clay creep

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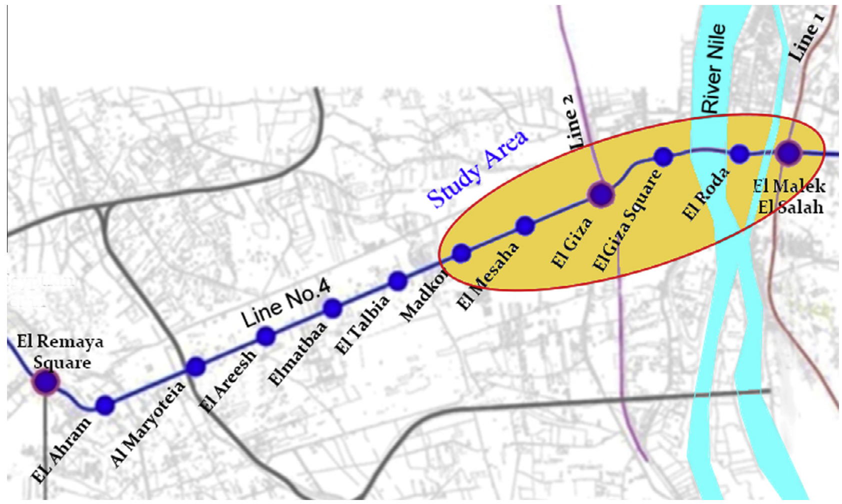

Fig. 1. General layout of Greater Cairo metro line No. 4 (Phase No. 1).

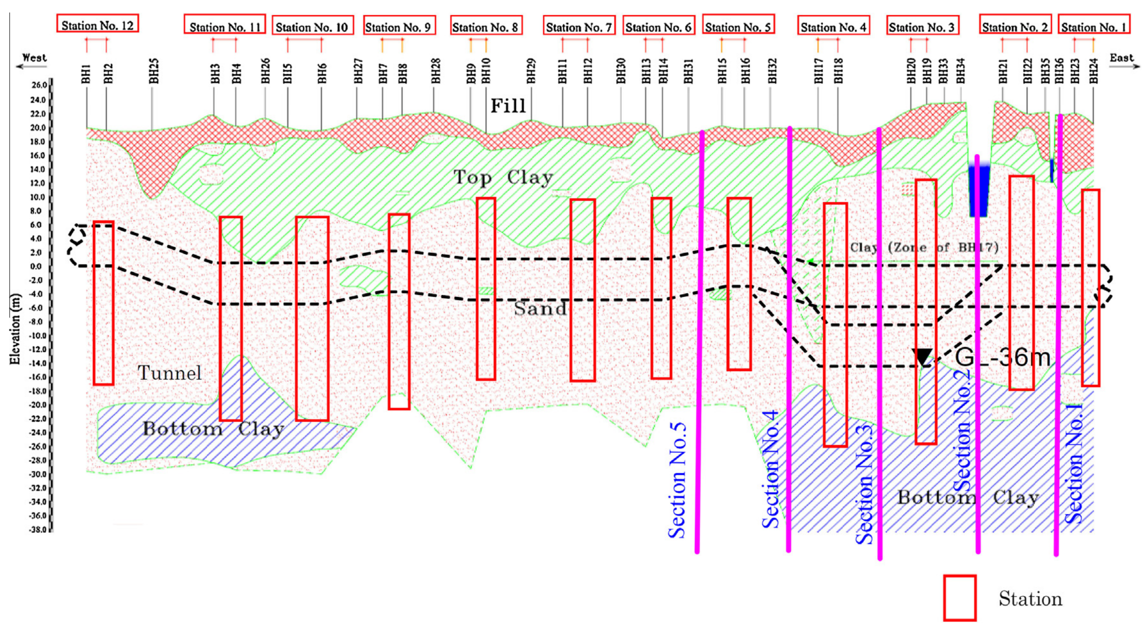

Fig. 2. Generalized geological profile with station and rail levels.

is very important for long term settlement above tunnels. Mazek and Almannaei [7] used finite element analysis to determine a model dimension of cross section for line No. 3 at Cairo metro and they found that minimum width equals to ten times of the diameter of the tunnel. Migliazza et al. [8] computed vertical settlement of ground surface during excavation and using empirical method and finite element analysis where they found numerical data are similar to experimental data. Mazek [9] has forecasted the performance of EL-Azhar tunnel systems, hence he used a finite element model to analyze twin tunnel construction, and concluded that the computed surface settlement is different from measurement data in the field by 10%. As tunnels will be used as underground routes for metro railway tracks; the designer should select the proper tunnels configuration. Proper configuration should fit the track alignment as well as the interaction with surrounding soils. Also, the designer should select the route which minimizes values of longitudinal gradients and number of curves especially sharp ones as they increase the rate of track deterioration; thus the cost of maintenance will be increased too.

2. Materials and data

2.1. Railway track alignment

Configuration of twin tunnels between stations affects directly the railway alignment which includes vertical and horizontal curves. In the vertical plane, vertical curve allows smooth and safe transition from one grade to another. Also, horizontal curve is applied to allow a smooth and safe transition between two directions in the horizontal plane. Specifications of parameters of track alignment are given in Table 1.

2.2. Geological profile

Fig. 2 shows the geological sections based on the data obtained from the National Authority for Tunnels (NAT) in Cairo [10,11]. In this figure, there are five main soil layers, namely, fill soil, top clay, dense sand, very dense sand and bottom Clay. The physical and mechanical properties of these layers are documented in Tables 2