Tunnelling and Underground Space Technology 25 (2010) 63–69

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

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

Study on the effect of a new construction method for a large span metro underground station in Tabriz-Iran

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ARTICLE INFO

Article history:
Received 4 October 2008
Received in revised form 21 July 2009
Accepted 18 August 2009
Available online 25 September 2009

Keywords:
Underground station
Construction method
Pre-supporting system
CAPS
Numerical modeling
Ground settlement

ABSTRACT

A method for construction of large underground spaces based on a new pre-supporting system is introduced. In this paper *Mansour Station*, in Line 1 of Tabriz Metro (Tabriz Urban Railway Organization, TURO); Iran has been studied using this method. *Mansour Station* have some special characteristics such as shallow depth, soft surrounding soil, wide span and heavy street traffic, thus requires a method of underground construction that can control the stability of the underground space and the ground settlement. This method includes a pre-supporting system that is called *Concrete Arch Pre-supporting System* (CAPS). Construction of CAPS is mainly based on construction method of old Iranian small water tunnels, *Quanat,* which is generally fast and more economical than usual methods such as forepoling. CAPS is a rib like underground structure consists of concrete piles and arch beams constructed around a proposed underground space prior to its constructions. This method has been utilized in several underground stations in Tehran Metro since 2002 and can be used for any large span underground spaces in similar ground conditions. Numerical modeling is used to simulate all the construction stages and analyze the ground behavior. The results of the modeling show that CAPS reduces the ground surface settlement and enhances the ground stability. Dimension of arch beams and their spacing has also notable effect on the ground deformation.

1. Introduction

The stress redistribution caused by tunnel excavations induces movements in the earth mass and ultimately at the ground surface. The need to control ground surface settlements in urban area is widely recognized and new construction methods are continuously developed. Settlements induced by underground excavation may cause serious damages to nearby structures and subsurface underground utilities, (Sozio, 1998; Sekimoto et al., 2001). Several methods of predicting ground surface settlement are presented by Peck (1969), Chow (1994), Wang and Sampaco (2000) and ITA (2007). Various ground treatment techniques to improve stability of underground excavation and reduce settlements are described and studied in recent literature. Carrieri et al. (2002), Kontolhanassis et al. (2005), Lignola et al. (2008) and Ocak (2008) described different forepoling and grouting methods and pre-supporting the main tunnel by concreted small horizontal tunnels was explained by Johnson et al. (1983).

A new pre-supporting method, *Concrete Arch Pre-supporting System* (CAPS) is described and studied in this paper that can be very effective for stabilizing large span underground spaces in shallow and soft ground. In this technique underground reinforced concrete elements, including piles and curved beams (arches), are constructed around the proposed underground space prior to main excavation in order to support the ground during the excavation of the underground section. Subsequent to pre-supporting, excavation can be executed in variety of methods. In this case multi-stage excavation and supporting is used to construct the desired section.

In last decades, numerical simulation has quickly become the dominant method for solving engineering problems including the stability analysis and predicting the system behavior. Numerical modeling, such as finite element method is a useful tool for analysis of the stability of underground space in sequential construction and determination of the influence of effective parameters (Delezalova, 2002; Galli et al., 2004; Ercelebi et al., 2005). In this research CAPS method and construction sequences along with the influence of some parameters are analyzed using numerical methods for one of Tabriz metro stations.

2. Site specifications and geology

Tabriz is a large city in northwest of Iran with over two million populations. The construction of metro in Tabriz began in 2003. The Line 1 is from east to west and consists of two phases. The first phase has a length of about 6 km and connects *Elgoli Park* in east to

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doi:10.1016/j.tust.2009.08.004

Daneshgah Station. This phase was constructed by cut-and-cover method and consists of 6 stations. The second phase has a length of about 12 km and connects *Daneshgah Station* to *Laleh Station* in the west and includes 14 stations. Main part of this phase is located in city downtown with heavy traffic and congested subsurface utility lines; therefore, the cut-and-cover method is not suitable method in this phase and main tunnels and most of the stations must be constructed using underground methods. Two separate tunnels (i.e., twin tunnels) are being bored by two earth pressure balanced tunnel boring machines (EPB-TBM) and ten stations will be constructed by underground methods. According to the construction plan, twin tunnels are bored first and stations will be constructed subsequently. The station under consideration, *Mansour Station* (station number 10), is an underground island station and has 110 m length. The general cross section of this station is shown in Fig. 1.

Geologically, Tabriz is located in a tectonized area in northwest Iran. It is along *Alp-Himalaya* active belt. The location of *Mansour Station* is in *Bamesheh Formation*. This formation is consisted of marl and marlstones with upper alluvial sediments of silty sand to gravelly sand. The groundwater level is variable during year. The station is located in the alluvial layer at shallow depth. The geotechnical investigation was conducted to determine the geotechnical properties and groundwater condition along the Line 1 (TURO, 2004). Three 40 m deep boreholes were bored in the vicinity of the station and various tests carried out on the samples acquired from these boreholes. The soil around the station is mainly silty sand with gravel and the water level is at the depth of about 11 m, Fig. 2.

3. Construction method

Cut-and-cover method was not applicable in this location due to need for disruption in street traffic and relocation of urban subsurface utility lines in application of this method. As mentioned in above section, a pre-supporting system, *Concrete Arch Pre-supporting System* (CAPS), consisted of reinforced concrete arch beams, each supported by two side piles which all are constructed by underground method prior to the excavating the main underground space. The system is first introduced in construction of *Mellat Station* in Line 2 of Tehran Metro in 2002. The ground settlement from numerical investigation was 24 mm and from field monitoring was 19 mm (Sadaghiani and Gheysar, 2003). Due to its success, CAPS has been the dominant method of construction of underground stations and some other large span spaces in Tehran Metro (Sadaghiani and Ebrahimi, 2006; Sadaghiani and Taheri, 2008).

The main advantages of CAPS in large underground spaces are that by pre-supporting the soil around the underground space prior to excavation, it reduces soil deformation and thus increases the stability of the large excavation with low overburden in soft grounds. This system restricts the ground settlement, thus enhances the general stability. Another advantage is that it reduces the construction time due to the fact that the piles and arch beams in CAPS can be constructed simultaneously from several faces in short time. After CAPS construction, the station construction is preceded by the multi-stage excavation and initial supporting of the main space. The main excavation proceeds in large sections followed by installing very light initial supporting system such as shotcrete and welded wire mesh over the excavated surface. Due to simultaneous sequential construction, the rate of construction advance increases dramatically.

3.1. Concrete Arch Pre-supporting System, CAPS

Concrete Arch Pre-supporting System, CAPS is an innovative system similar to *Rib in Roc Pre-reinforcement System* presented by Bengt and Stillborg (1979) and the method applied in construction of Mt. Baker Tunnel in Seattle, USA, in which small horizontal tunnels as pre-supporting system were constructed prior to the main tunnel excavation, (Johnson et al., 1983). Construction method of CAPS has roots in construction method of old Iranian small water tunnels, called *Quanat*. Quanat consists of wells and small semi-horizontal adit which connects wells. They are all hand excavated in alluviums to collect water, distribute and convey it to desired location in downstream. In very weak ground, to maintain stability, small perforated concrete segments are installed as the excavation proceeds. In CAPS, small adits in vertical direction as piles, in semi-horizontal and horizontal direction as arch beams and connecting galleries are hand excavated around the large underground space. The rate of hand excavation of an adit is about 3 m daily. By increasing man power, the adits can be excavated from number of faces, and several adits can be excavated simultaneously, thus generally it takes very short time to excavate the galleries, piles and arch beams. This method of hand excavation in Iran generally cost less and takes much less time compared to forepoling and grouting pre-supporting systems. The excavated pile and arch beam adits are filled with reinforced concrete to make a rib shape underground structural frames prior to main large excavation. The adits can be excavated and concreted in parallel manner. CAPS supports the surrounding ground during the main excavation and requires minimal initial supporting system.

In order to use this method in subway stations, initially either heading of main tunnel in NATM tunnelling or the TBM bored tunnel should be excavated along the station. From this opening, small access adits in both transverse directions are excavated at desired spaces. The transverse access adits are excavated to the length beyond the excavation line of main station opening. From the end of transverse access adits, side adits (galleries) in longitudinal direction are excavated with total length equal to the length of station at both side of opening. The location of longitudinal adits is beyond

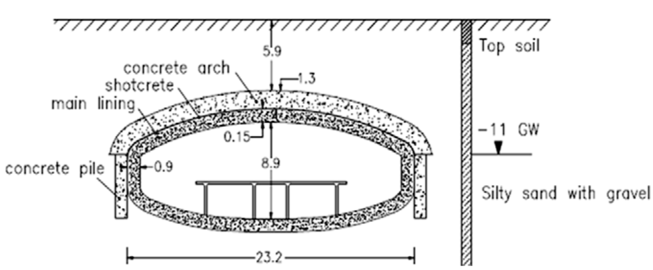

Fig. 1. Cross section of Mansour Station.

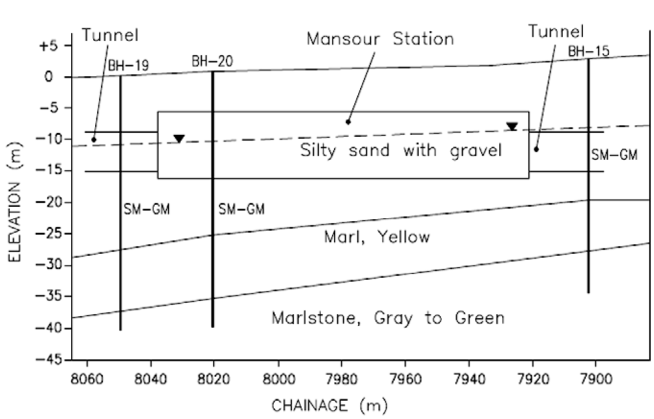

Fig. 2. Geological profile of Mansour Station area.