Kirazli-Basaksehir-Olimpiyat metro line tunneling works

Mustafa Özhan, Eralp Demir

Gulermak Heavy Industries Construction & Contracting, Konya devlet yolu 23. km, Golbasi, Ankara, Turkey.

Abstract

This work briefly describes the tunneling practices that are experienced during construction of Kirazli-Basaksehir-Olimpiyat metro line. The tunneling methods used in different sections of the line are presented. The construction stages of cross-passages and evacuation shafts are described in detail. The distance between each of the cross-passages is verified using mid-train fire assumption for the specific tunnel parameters.

1 Introduction

Currently, there is a growing demand for public transportation in Turkey especially in Istanbul to solve intense traffic problem. Metro, LRT and railway systems in Turkey are strongly under-developed. In addition, even highly developed highway and roadway network of Istanbul are incapable of answering public transportation needs. Accordingly, there is a great need for the construction of underground transporation systems in Istanbul which means tunneling.

Figure 1: Horizontal alignment of Kirazli-Basaksehir-Olimpiyat metro line, Istanbul.

We are involved in construction of Kirazli-Basaksehir-Olimpiyat metro line of Istanbul. Kirazli-Basaksehir-Olimpiyat line would connect seven lines together six of which are not yet under bidding process. Therefore, the 15.8 km long metro line that consists of 11 stations, forms the major skeleton of the metro transportation in Istanbul. The main line refers to the part of the line between Kirazli and Basaksehir stations that are shown in figure 1 and the branch line is referred as the part of the line that extends to Olimpiyat station.

In this work, the tunneling works and the challenges encountered during the construction works of Kirazli-Basaksehir-Olimpiyat metro line are desribed shortly. Main focus is on the reasoning and the construction stages of cross-passages and evacuation shafts on the line.

2 Tunneling

The line is located mainly on Trakya formation zone. The ground conditions along the line significantly varying. Generally ground consists of mainly yellow soft clay, partly silt and at some locations sand. Three different methods are used to construct the tunnels: Tunnel Boring Machines(TBM), cut & cover and New Austrian Tunnneling Method(NATM).

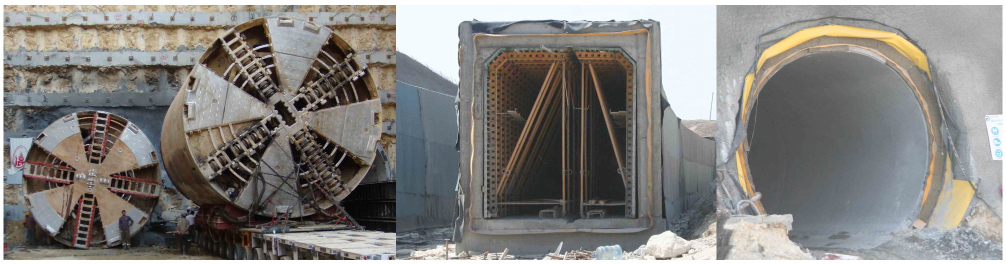

Figure 2: Tunneling works of Kirazli-Basaksehir-Olimpiyat metro line, Istanbul. From left to right; exit and transport of two TBMs in 750 m long Ikitelli Sanayi station, cut & cover tunnels near Olimpiyat station, NATM used near Ziya Gokalp station.

In total four TBMs are used during the construction of twin bored tunnels. Three TBMs were of Lovat RME 257 type and one was Herrenknecht S-325 type. In sum 26.5 kilometers of tunnel was drilled with the TBMs. A segment manufacturing facility was built to manufacture concrete tunnel segments. In the left and the right lanes of the line 4975 and 4982 number of rings with 1.4 m length were used respectively. Segments are of parallelogram type and key stone is the smallest stone of a tunnel ring.

The TBMs encountered distinctly different earth conditions. The twin TBM tunnels passed underneath a highway, an underground river and lots of poorly constructed buildings. In general ground was relatively soft hence, Earth Pressure Balance (EPB) type TBMs are used to drill the tunnels using optimum TBM parameters.

Cut & cover tunnels of 13.5 km in length were mainly constructed between Olimpiyat and Ziya Gokalp stations. The line in general extends over urban areas, hence it was not possible to construct the tunnels using cut & cover except some stations.

The platform tunnels of Ziya Gokalp station and the tunnels near Ziya Gokalp station were constructed by NATM. This corresponds roughly 3.5 km of NATM tunnelling. This method is not preferred in general for this line since ground was relativly soft. However, Ziya Gokalp station is located rocky location which made it feasible to construct twin tunnels using NATM.

3 Tunnel Connection Elements

According to NFPA 130 [1] twin tunnels must be connected via cross-passages that have a spacing of 244 m from the nearest exit or another cross-passage. NFPA 130 also suggests the use of evacuation shafts instead of cross passages with a spacing of 732 m from the nearest exit.

3.1 Cross-passages

Cross-passages are constructed to allow passengers to pass from one tunnel section to another. It is important to minimize the effect of smoke on the passengers for safe evacuation. The smoke shall be extracted from the tunnel in fire in a direction opposite to the expected passenger evacuation direction. The direction of ventilation should be the same for the two tunnels.

The distance between cross-passages of 244 m is verified using the tunnel parameters based on the calculation using mid-train fire [2]. Table 1 shows the evacuation time in one direction for the tunnel parameters in the case of mid-train fire that is calculated using parameters from NFPA 130. According to the calculation, 15.45 minutes of time required to evacuate the tunnel which is close to 15 min[1]. Therefore,

[1]The half of the flashover time is assumed as 15 minutes and flashover time is the duration from the beginning of fire to the time at which fire reaches its peak heat generation rate called flashover.

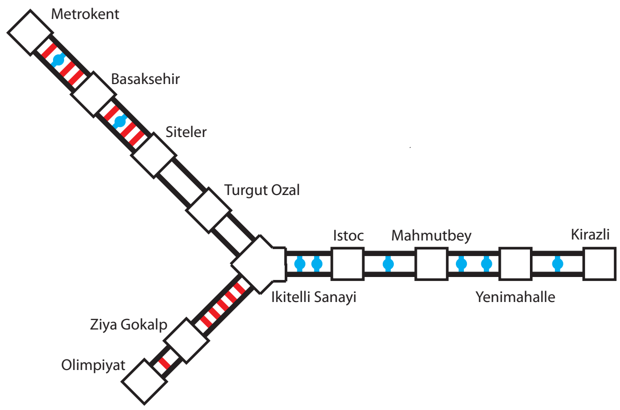

Figure 3: Location of cross passages (red) and evacuation shafts (blue) of Kirazli-Basaksehir-Olimpiyat metro line, Istanbul.

15.47 min evacuation time that is obtained using the tunnel properties of Kirazli-Basaksehir-Olimpiyat line which is a reasonable value for the evacuation of passengers.

$$t_{evac} = \frac{yD - \frac{L}{2y}}{V} + \frac{P}{2Qw} + \frac{d}{V} + t_{discovery} + t_{fansactive} \tag{1}$$

Table 1: The calculation of evacuation time using tunnel parameters.

variable	description	unit	value
$t_{flashover}$	flashover time	min	30
$t_{discovery}$	time to discover the fire	min	0.75
t_{comms}	time to comminication and decision making	min	0.5
$t_{fansactive}$	time to make start the fans	min	1.5
V	passenger evacuation time	m/min	61
d	distance to narrowest location along the evacuation path	m	1.5
P	number of passengers in a train	m	1250
Q	evacuation capacity at the narrowest location	person/mm/min	0.0819
w	width at the narrowest location	mm	750
L	length of train	m	180
y	number of cross-passages	-	1
D	distance between cross-passages	m	244
t_{evac}	latter evacuation time (calculated)	min	**15.47**

Figure 4 shows the construction stages of a cross-passage. Initially samples were collected at different depths to characterize the ground conditions. The location of the cross-passage was marked inside both tunnels and wedges were inserted to suppor the segments by allowing uniform distribution of the loading to the tunnel segments. A foldable steel frame was inserted in order to support the inner tunnel lining. Similar method for the tunnel lining support can be found in reference [3]. The segments that correspond to the opening were removed. To secure the region that is to be drilled from the tunnels, steel pipes were inserted that are filled with groute. Injection was performed from the face of the cross-passage. The earth was excavated using a mini rock breaker/excavator. Cross-passage enterance was constructed first to avoid falling of tunnel segments. 15 cm thick first lining that consists of jet grout and reinforcement layer was constructed. Similarly bottom half of the cross-passage was excavated and first lining of the cross-passage tunnel was completed. Second lining consists of reinforcement and water insulation layers by using a mold. The length of the cross-passage between the two tunnels was approximately 9 m.

3.2 Evacuation Shafts

Instead of cross-passages, construction of evacuation shafts with a spacing of 732 m are foreseen according to NFPA 130. The evacuation shafts provide safe evacuation of passengers to outside.

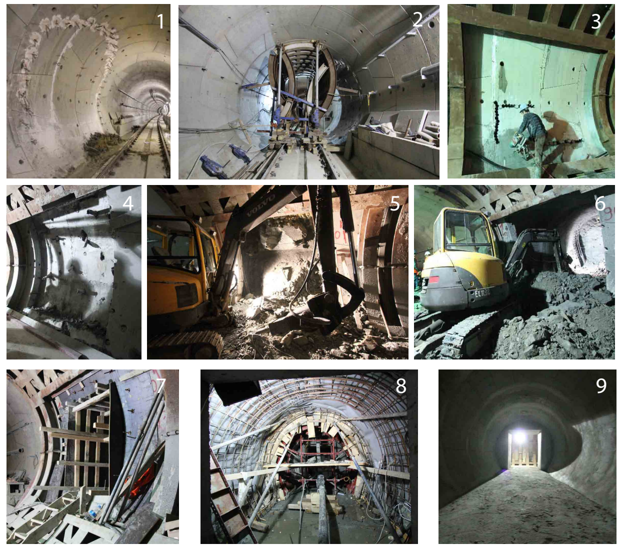

Figure 4: Manufacturing stages of a cross-passage. 1- wedge insertion, 2- foldable tunnel support, 3- removal of tunnel segments, 4- groute injection from face of the cross-passage, 5- use of breaker, 6- excavation of cross-passage, 7- contruction of cross-passage entrance by molds, 8- contruction of second lining with molds, 9- the final structure.

The processes to construct evacuation shafts was as follows. Again samples were collected at different depth levels from outside to characterize the ground since length of the pile, its number and its diameter can be determined accordingly. For example at locations where water level was high, intersecting piles were used to avoid water leakage from outside to the shafts. At deeper locations bored piles were used in conjunction with mini piles. After pile insertion, initially the head beam was constructed. At certain depths belt beams were constructed by reinforcing the steel part of the beams to the steel pary of the columns. The depth of the tunnel was reached, the tunnel segments were broken and the opening was cut. Finally the stairwell was constructed. The depths of the evacuation shafts vary between 18 and 35 m.

Figure 5: Important manufacturing stages of a evacuation shaft. 1- pile insertion and excavation, 2- construction of shaft lining, 3- stairwell construction.

4 Conclusion

In this study, tunneling works of Kirazli-Basaksehir-Olimpiyat metro line in Istanbul are described. There were issues with the ground condition which conssits of clay and some regions that have high levels of water content. In addition there were poorly constructed apartments along the path of the metro line. Under these circumstances, it was one of the most difficult metro construction jobs compared to other projects in Turkey.

Construction techniques for cross-passages and emergency exit shafts are explained in detail. Special steel supports were used to avoid collapse of tunnel rings. The use of steel segments instead of concrete segments was suggested in order to be able to excavate the cross-tunnels safely.

The distance between the cross-passages was calculated using a mid-train fire scenario for the specific tunnel parameters. 244 m spacing between cross-passages allows reasonable evacuation time for passengers for Kirazli-Basaksehir-Olimpiyat metro line.

References

[1] NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems, 2010 Ed.

[2] Tunnel emergency egress and the mid-train fire, M.P. Colino, Rosenstein E.B., ASHRAE Transactions, July 2006.

[3] Design of cross-passages, C. Lawrence, J. Taylor, Rapid Excavation and Tunneling Conference Proceedings, 2011.