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Influence of the fault zone in shallow tunneling: A case study of Izmir Metro Tunnel

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ABSTRACT

Today, there is a great need for larger underground spaces for various purposes and hence, construction of new metro tunnels has become a necessity to meet the demand in urban life in spite of certain ground related difficulties such as fault zones, altered and fractured rock mass and ground water. This study has aimed at investigating the risky areas around a shallow metro tunnel in weak, faulted rocks and determining the effects of tunnel behavior on the structures on ground surface. Therefore, an attempt has been made to determine the risky areas on the line of the tunnel by field observations, laboratory work and computer modeling. Later, the data obtained from computer models have been compared to which obtained from in situ measurements. The results from modeling and in situ measurements were interpreted considering the current status of superstructure and the differences between pre- and post-excavation states in the ground. Finally the data obtained from the modeling analysis and measurements provided the necessity of strengthening the already used support system for the safety of the buildings on surface. Shortening the application ranges of the rock bolts, use of face nails with application of umbrella arc and jetgrout methods are among the precautions to be taken.

1. Introduction

Growing populations, increasing oil prices and new developments in urban areas have increased the demand for rapid underground metro railway networks for mass transportation. Metro tunnels are usually opened at shallow depth in weak rock or soft soil conditions. Hence, faulting and frequent fractures in rock, low bearing capacities of soil, large deformations and underground water dynamics can induce difficulties during the construction of metro tunnels.

Basic parameters studied by Whittaker and Frith (1990), which influence the stability of tunnels in soft soil and weak rocks can be listed as the strength of intact rock and the rock mass and other geomechanical properties, excavation induced stresses, method of excavation, applied support systems and dynamics of underground water. Therefore, detailed geological and geotechnical investigations must be conducted along the route of tunnel in order to propose the most appropriate excavation and support method and to minimize the possible risks due to tunneling activities (excavation, support and drainage, etc.). Excavation process must be initiated and sustained under control, following evaluations and verifications of the computer modeling of proposed methods. Tunnel excavation must be maintained under control by continuous deformation measurements, exploratory boreholes and the experiences gained from previous tunneling works in the region (Onargan et al., 2009).

Bell (1994) has defined an order for tunnel advancing and processing to minimize the risks during the opening of tunnels. In his definition, a structure which takes into account the field investigations, experiences and estimations, results of the models used, regular in situ measurements has been formed to maintain controllable advancement of the tunnel. Certain techniques relying on analytical, empirical or numerical solutions can be found in the literature. Each technique may possess certain advantages and disadvantages. Hence, the use of at least two of them simultaneously may yield more reliable results and enable comparisons of the solutions for justification (Ulusay, 2001).

Also, the geology forms the basis for all rock engineering works, such as field investigations and the following rock engineering evaluations. Wrong geological interpretation will affect all engineering analyses and calculations based on the geological model. An important feature in geology is the occurrence of possible faults and weakness zones, as well as rocks and/or minerals with special properties and/or behavior (Stille and Palmstrom, 2008).

In this study, the fault zone and surroundings, defined as risky area, on the route of the 2nd Stage of Izmir Metro Tunnel Project were investigated in detail based on the principles of New Austrian Tunneling Method (NATM) at a shallow depth (18–25 m). The data in hand, results of laboratory tests (conducted in compliance with ISRM (1981)) and the results of numerical modeling were compared with in situ measurement values obtained during the excavation of tunnel in order to examine the potential risks in

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tunnel itself and on surface structures, due to the existence of fault zone.

2. Location and geological structure of study area

Study was conducted in the frame of 5640 m long Izmir 2nd Stage Metro Tunnel Project in the south of Izmir Province located in western Turkey (Fig. 1). Geological units crossing the tunnel route can be listed as: Vulcanites, alluviums, sandstones, claystone, pebblestones (Altindag formation), clayey limestone sequence and flysch. These lithological units are overlaid by an artificial filling material on the surface. Vulcanites of Miocene age, extensively spreaded on the route of tunnel, have been formed of andesites of gray colored medium size grains, low-to-medium alteration and medium-to-dense spaced, clay filled joints.

The agglomerate contains andesite pebbles and blocks of 0.5–30 cm in size and has reddish brown color, moderately altered, open and planar joints with clay-filling and low-to-medium strength. Miocene aged Altindag formation consists of sequences of claystone, siltstone, sandstone and conglomerate. This formation is covered with alluvium and artificial fill. It outcrops the Bornova flysch beneath it. The units of Altindag formation are medium-to-high altered, medium-to-densely jointed and possess low-to-medium strength. Also, they display vertical–lateral transition with local vulcanites owing to their common geological ages. Study area and its surrounding geology are shown in Fig. 2.

2.1. Tectonics and local geology of near fault zone

When tectonics of the region along the tunnel route was investigated one can notice the existence of active faults in Izmir and its surroundings. Active faults in Izmir and nearby have been mapped by Saroglu et al. (1992). Later, Barka et al. (1996) and Emre and Barka (2000) have reported that number of active faults in this region was more than anticipated.

Field studies conducted on the tunnel route unveiled that tunneling operations can be affected due in part to Izmir Fault (Emre and Barka, 2000). Data on the characteristics of this fault are limited due to the intense urban settlement in the area (Fig. 3). However, geomorphological features of E–W oriented Izmir Fault were found to resemble that of normal faults (MTA, 2005).

Fault zone which is expected to influence the 5460 m long metro tunnel to be excavated was investigated in detail by geological field studies and evaluations in the area. Therefore, near Goztepe Station located at distances of 2 + 447.75 – 2 + 655.48 km, detailed information of fault zone and lithological units was collected by means of five boreholes (S15, S16, S16-A, S17, S18). Accordingly, dominating rock units in and the near fault zone were determined to be Altindag formation, andesite and alluvium (Fig. 4).

Altindag formation consists of claystone, siltstone and conglomerate units. Claystone has poor strength and displays light green and gray; light yellow to brown color, medium to well alteration, medium to dense jointing properties. It demonstrates fair plasticity owing to the possession of loose filling and high saturation degree.

Siltstone has poor to medium strength and displays green, yellow to brown color, medium to well alteration. It is well compacted and cemented with clay and carbonates. Joint surfaces are smooth and unfilled or clay filled.

Sandstone demonstrates poor to medium strength and has light gray, light yellow to brown color, medium to high alteration. It is cemented with carbonates and length of the pebbles varies between 0.4 and 4 cm. Joint surfaces are rough and partially filled with clay of 0.5 cm thickness.

Conglomerate is of poor to medium strength and has light gray to gray color and high alteration degree. It is cemented with clay, silt, sand and carbonates and the diameters of the pebbles vary between 0.5 and 5 cm. Joint surfaces are usually unfilled.

2.2. Hydrogeology

Geological units present on tunnel route depict hydro geological properties owing to their unique characteristics. Underground water is let to circulate depending on the granular structure of soil units, lithological properties and characteristics of joint sets of the rock mass. Clay unit in alluvium and impervious sand and pebble levels contain underground water. The tuff unit within vulcanites, lightly altered andesite and agglomerate units is impervious; however, well altered andesite and agglomerate enable the flow of underground water along the fractures. Sandstone and conglomerate ranges of Altindag formation allow the flow of underground water whereas the claystone unit is impervious.

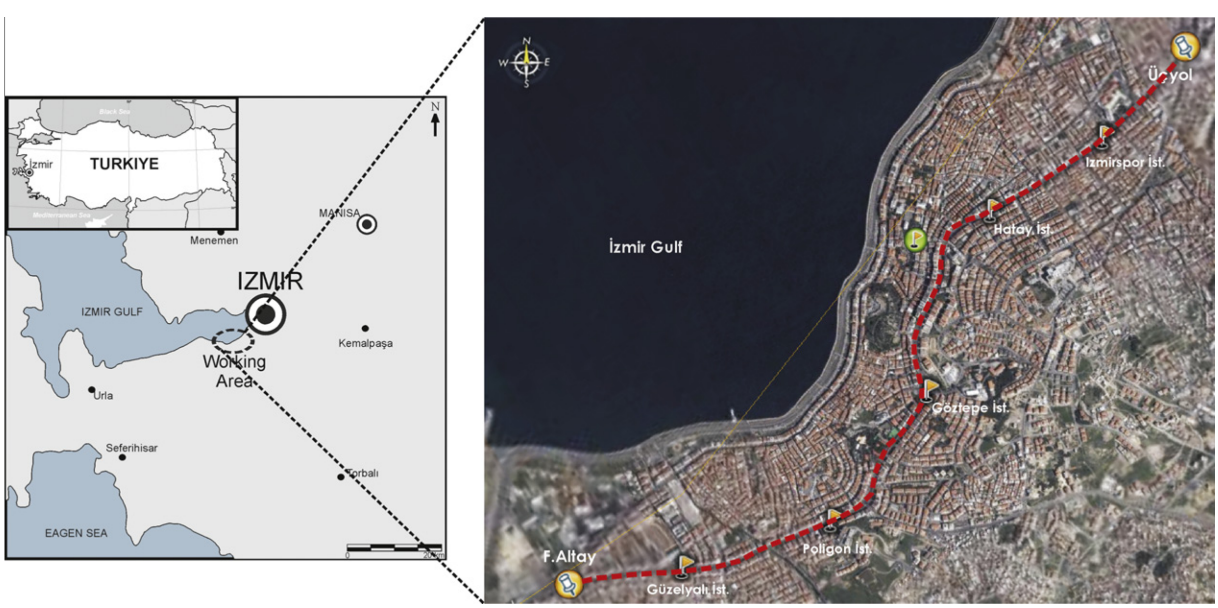

Fig. 1. Location map of the study area.