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A Case Study on the Importance of Local Geology on Selection of Cut-off Wall Construction Procedure

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ABSTRACT: A cut-off wall was implemented for a shopping mall to be constructed in Eskisehir/Turkey. The subject site is located near Porsuk River on an alluvial plain. Local geologly of the subject site consists of Quarternary aged alluvial deposits overlying Eosen and Neogene aged marls and limestones. In the soil investigation results, it was reported that the alluvial deposits consists of sandy gravelly layers with occasional boulders. The groundwater level was around 4.0 m below ground surface. An excavation of 9.5 m depth for foundations and basements of the mall was deemed necessary. Considering the available soil investigation data, a retaining structure composed of diaphragm wall socketed into the marl layers and supported with one level of prestressed anchors was designed. The method of construction was selected therefore to implement the diaphragm wall by means of hydraulic grab equipment based on the reported subsoil conditions. According to construction schedule imposed, the site had to be divided into two pieces in order to proceed partial superstructure construction. For this purpose, a cut-off wall to be formed by jetgrouting in the mid of the site was also envisaged. During the implementation of the diaphragm wall, the encountered local subsoil conditions indicated that there exists very hard conglomeratic levels below alluvial layers in variuous thickness and elevation which was not identified during soil investigations. Therefore, the penetration of diaphragm wall through this hard conglomeratic layers was very difficult and therefore, since the diaphragm wall could not be closed on foresen schedule the designed jetgrouting cut-off became absolute and as a result unesired delay in completion of excavation work was inevitable.

1 Introduction

The construction of a shopping mall in the city centre of Eskisehir/Turkey was planned to be completed on October 2007. The construction site of the planned shopping mall formerly was used as a brick factory in which three different high-rise chimneys exists. In addition to construction of new shopping mall relocation of two chimneys was planned. The subject site is composed of old and recent alluvial soil deposits of Porsuk River nearby with a high groundwater table.

Considering that an excavation for foundations and basements of the mall structure was deemed necessary reaching down to 9.50 m depth, based on the available soil invesigation information and the gorundwater levels, a retaining structure composed of diaphragm wall was designed. In this paper, the selected method of construction is evaluated considering the unforeseen presence of conglomerate layers and relevant consequences of dewatering and excavation are discussed.

2 Description of the site

2.1 Location and morphology

The subject site covers an area of approximately 16,000 m^2 and is located in south part of Eskisehir near Porsuk River on an alluvial plain. Topography of the site is almost flat with very little variations of elevations within the site resulting from the removal of former brick factory buildings and foundations. Local geogoly of the subject site consists of Quarternary aged alluvial deposits overlying Eosen and Neogene aged marls and limestones. Based on the soil investigation results performed for the mall construction, it was reported that the alluvial deposits consists of sandy gravelly layers with occasional boulders. Subject site being close to Porsuk river, the groundwater level was around 4.0 m below ground surface.

2.2 Local geology

Eskisehir is found in a valley of about 123,12 km^2. The Porsuk River runs from west to east in the valley. The area is consisting of Quaternary aged alluvial deposits having mostly gravel, sand, silt, clay, silty and clayey sands. Eskisehir Graben is related with the Eskisehir Fault Zone (EFZ), a regional tectonic element extending for 400 km from Bursa to the west of Tuzgolu as seen in Figure 1 (Kocyigit, 2000a).

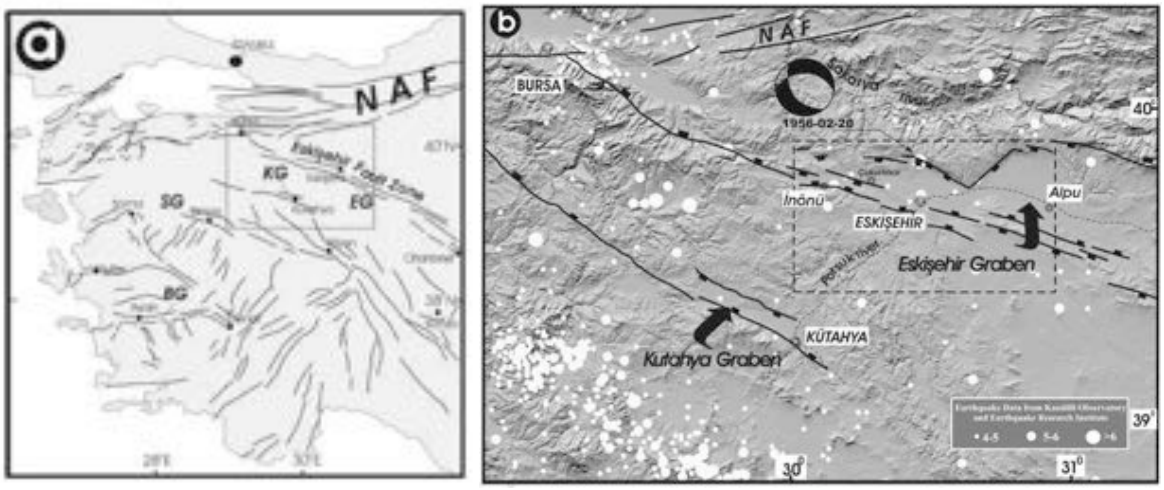

Figure 1 – Active Faults in Western Anatolia (Ocakoglu, 2007)

Kocyigit (2005) recognized the Inonu-Eskisehir Fault as a mega shear zone forms a boundary between continental extension in the south and strike-slip faulting in the north. Eskisehir region consist of a relatively thin Neocene to Quaternary cover on a mostly metamorphic and ultramafic basement as seen in Figure 2 (Ocakoglu, 2007). The most widespread basement rocks, the blueschist metamorphics and tectonically overlying serpentinized ultramafics, are thought to have occurred in the course of closure of Neo-Tethys in Late Cretaceous (Goncuoglu et al., 2000a), yet a Triassic age and a Paleo-Tethyan connection fort he same rocks were substantiated by Okay et al. (2002) as well. The regional trend and vengeance of the structures on metamorphic and ultramafic rocks are east-west and to the north respectively, suggesting a general southward tectonic transport (Gozler et al., 1997). The crystalline basement rocks are unconformably overlain by Paleocene to Eocene terrestrial coarse siliciclastics in small patchy outcrops (Figure 2).
In the axial zone of the Graben, Quaternary deposits are composed of gray-colored channel gravels, levee sands and interleaving flood-plain mud. Towards the Graben margins (particularly east of Inonu and north of Eskisehir) debris flow-dominated alluvial fans are presently under construction. Several fluvial terraces have also been discovered in the course of Porsuk River between Kizilinler and Eskisehir (Ocakoglu and Akan, 2004; Ocakoglu, 2007).

2.3 Seismicity of the region

Eskisehir city is placed on the south side of the North Anatolian Fault Zone (NAFZ) has the EFZ within the Anatolian plate. The fault zone is characterized by fault segments which trend between E-W and NW-SE around Eskisehir. Syndepositional and postdepositional faults cutting Pleistocene and Holocene units indicate that the Eskisehir fault zone has been active since at least Pleistocene. At least 14 earthquakes ($M \geq 4$) occurred on the Eskisehir fault zone in the 20th century and the 20th February 1956 Eskisehir earthquake ($Mw = 6.4$) was the largest event in this century. The isoseismal map of the 1956 earthquake shows that this earthquake occurred on about km long WNW-ESE trending Oklubal-Turgutlar segment. There is no major earthquake record, in the historical earthquake catalogues before the 20th century.

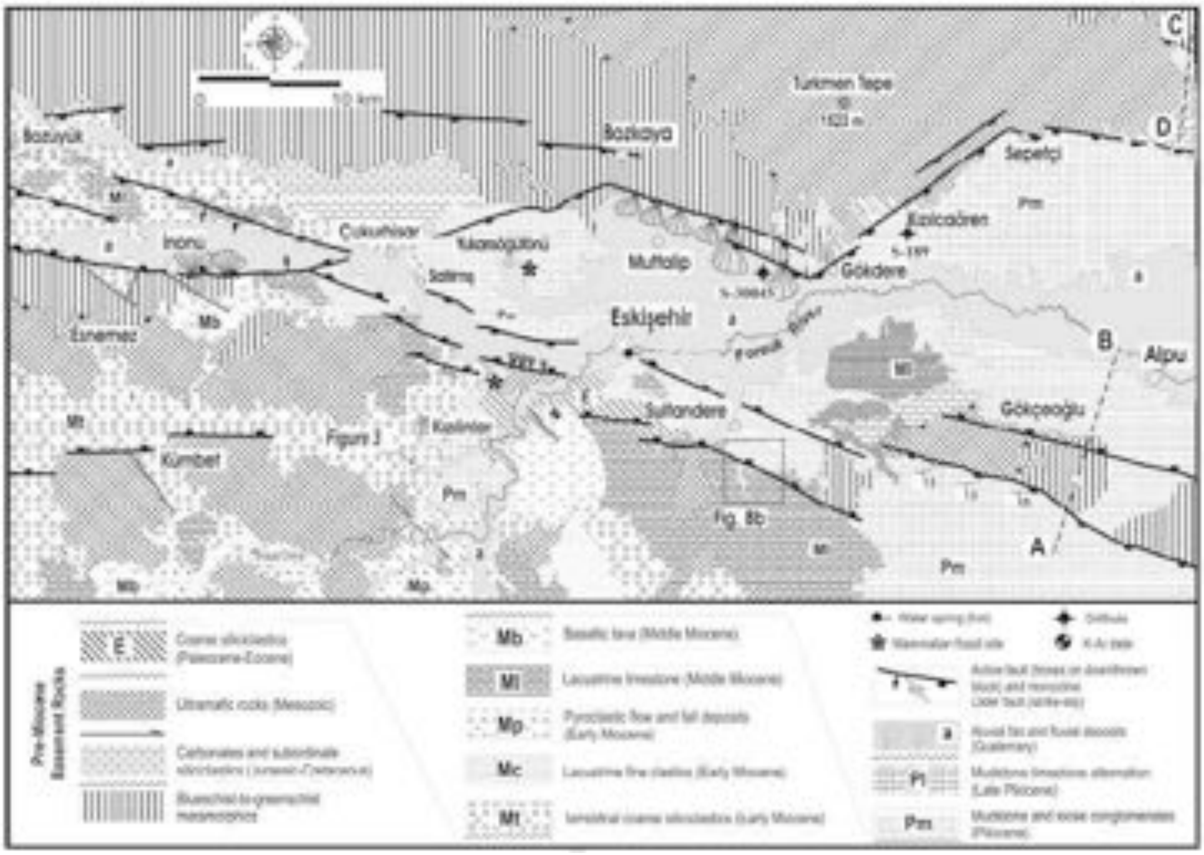

Figure 2 – Geology of Eskisehir region (Ocakoglu, 2007)

3 Soil Investigations and local soil conditions

For the purpose of foundation engineering evaluations of the local subsoil conditions, soil investigations composed of rotary boreholes, undisturbed and representative sampling, permeability and pressuremeter testing during drilling and geophysical surveys were performed. The soil investigations were carried out by a local drilling subcontractor on behalf of the Owner.

3.1 Boreholes

A total of 331.20 m boring at 16 different locations had been performed within the subject site with average borehole depths being around 20.0 m and reaching a maximum depth of 34.5 m. According to the borings performed within the site, a fill layer at the top of variable thickness of 0.5 m – 2.4 m were encountered throughout the site. Underneath the fill layer, fine grained soils were encountered down to 5.1 m to 8.1 m depths. Below this layer coarse grained alluvial subsoil was reported to be encountered down the borehole depth. In two of the boreholes, coarse grained alluvial soil between 8.1 m – 23.5 m and 7.5 m – 20.9 m depths contained boulders and cobbles. Furthermore, in two of the boreholes Neogen aged clayey marl bedrock formation was encountered at approximately at 21.0 m and 24.0 m depth, respectively.
Groundwater tables measured in 16 boreholes were determined to be located between 4.0 m to 4.5 m depth from present ground surface elevations. Systematic permeability tests were conducted in these boreholes and the coefficient of permeability, k was reported to be between 1.2×10^{-3} cm/sec to 7.5×10^{-4} cm/sec.

3.2 Laboratory Test Results

On the retrieved undisturbed and representative samples from the boreholes laboratory tests are conducted to deteremine index properties, shear strength and compressibility. Based on USCS, encountered subsoils are identified as CL and CH on upper fine grained soil zones, and as SW-SC, GW-GC at deeper levels. Based on shear strength tests performed by means of unconfined compression tests, shear box and triaxial compresions test, the shear strength parameters are determined in the range of cu= 16 kPa to 213 kPa, c'=11 kPa to 76 kPa and ϕ'=2° to 34°.

3.3 Geophysical Surveys

Geophysical surveys composed of seismic refraction surveys were performed in order to determine the shear wave velocities of the subsoils at six different locations. The surveys were performed by means of a 12 chanel instrument (ABEM-TERRALOC MK6) and the shear wave velocities are measured in the range of 89 m/sec to 151 m/sec within the upper 3.5 m to 7.5 m depth and 288 m/sec to 419 m/sec within the lower layers.

3.4 Pressuremeter Tests

A Menard type pressuremeter instrument was used during the pressuremeter tests. Measured modulus, Ep (Mpa) and limit presssure P_l*values are summarized in Table 1.

4 Selected retaining system and cut-off with diaphgram wall

Considering that the groundwater level was around 4.0 m below ground surface and an excavation of 9.5 m depth for foundations and basements of the mall was deemed necessary, a retaining system was necessary to retain the surrounding soil for the excavation depth as well as to form a cut-off wall for groundwater infiltration into excavation. For this purpose, considering the available soil investigation data, a retaining structure composed of diaphragm wall with t=60 cm in thickness and socketed into the marl layers and supported with one level of prestressed anchors was foreseen for a feasible solution by the foundation subcontractor. The prestressed anchors was designed at -3.5 m depth, being slightly above the groundwater level with an inclination of 10° with the horizontal, each with a capacity of 40 tons and composed of 3 x 6" steel strands. Based on the soil profile, the geotechnical parameters utilized in the design of retaining structure are given in Table 2.

Table 1. Summary of pressuremeter tests (ELC Group Ltd, 2005).

Borehole no	*Depth [m]*	*Modulus, E_p [Mpa]*	*Limit Pressure, Pl* [kPa]*
SK8	4.0	2.3	250
SK8	8.0	23.1	1690
SK8	12.0	23.6	207
SK9	4.0	2.4	210
SK9	7.0	11.7	1060
SK10	4.0	6.0	490
SK10	7.0	3.8	290
SK10	9.0	17.9	1290
SK15	5.0	2.6	180
SK15	9.0	10.8	1460
SK18	4.0	2.4	230
SK18	7.0	9.8	1520
SK18	9.0	18.5	1300

The method of construction was selected to implement the diaphragm wall by means of hydraulic grab equipment based on the reported subsoil conditions. In the design of diaphragm wall top layer of will with a thickness of 2.0 m was considered to be excavated and the diaphragm construction to be made from -2.0 m elevation with respect to present ground elevations reaching down to approximately -22.0 m depth, i.e. the length of the diaphragm wall was foreseen to be L=20.0 m. Furthermore, according to construction schedule imposed by the Client, the site had to be divided into two pieces in order to proceed partial superstructure construction in paralel to diaphragm wall construction. For this purpose, a cut-off wall to be formed by jetgrouting in the mid of the site was also designed, such that dividing the site into two approximate equal pieces and could be easily demolished after serving the purpose. The cut-off wall with jetgrouting was designed with one row of 80 cm diameter intersecting jetgrout columns of 20 m length.

Table 2. Geotechnical parameters for design of retaining structure (ZETAS Zemin Teknolojisi A.S., 2006).

Soil Type	Total Unit weight, γ [kN/m^3]	Angle of shearing resistance, ϕ' [°]	Cohesion, c' [kN/m^2]	Elasticity Modulus, Es [MPa]
Fill layer	17	28	0	10
Fine grained soils	17	20	0	5
Coarse grained soils	19	32	0	40
Neogene aged Clay/Marl	20	0	200	60

During the application of the diaphragm wall, the encountered local subsoil conditions indicated that there exists very hard conglomeratic levels below alluvial layers in various thickness and depth which were not identified during soil investigations. Due to presence of hard conglomeratic layers, a separate diaphragm wall equipment by means of utilization of chissels had to be mobilized to site. Inspite, the penetration of diaphragm wall through this very hard conglomeratic layers was very difficult and therefore, since the diaphragm wall could not be closed on foresen schedule the designed jetgrouting cut-off became irrelevant. Further, it was not possible to have water tight barrier by means of jetgrouts due to presence of conglomeratic layers. The view of the site during first phase excavation are shown in Figure 3.
Consequently, the excavation for the half of the site which constituted the phase one, had to wait for the closing of the outer reinforced concrete diaphragm wall. However, upon completion of peripheral diaphragm wall, excavation could proceed in paralel to one row of anchoring and the project was completed with extra effort with a marginal delay on the total time schedule for the project.

Figure 3 – Site view (ZETAS Zemin Teknolojisi A.S. 2006)

5 Results

The soil investigation results for a shopping mall project in Eskisehir, revealed that the alluvial deposits consists of sandy gravelly layers with occasional boulders. The groundwater level was around 4.0 m below ground surface. However, due to improper definition of encountered subsoil units and insufficient extent of soil investigations encountered unforeseen conglomeratic layers had a big impact on the selected method of construction for cut-off wall. An excavation of 9.5 m depth for foundations and basements of the mall was deemed necessary. Considering the available soil investigation data, a retaining structure composed of diaphragm wall socketed into the marl layers and supported with one level of prestressed anchors was designed. Althought the method of construction was selected therefore to implement the diaphragm wall by means of hydraulic grab equipment based on the reported subsoil conditions, utilization of chissel was necessary for the hard conglomeratic layers. Since the diaphragm wall could not be closed on foresen schedule, the designed jetgrouting cut-off for dividing the site into two pieces to increase construction speed became partially irrelevant. Further, due to presence of congolmeratic layers, it was not possible to construct water tight temporary cut-off by means of intersecting jetgrout columns. As a result, inspite of utilization of extra shift and equipment, the construction of the wall was constructed with marginal delay leading to undesired penalties to the subcontractor based on the applicable contract.

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6.1.1.1.1.1 The paper may be considered for

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