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Research paper

Assessment of the effect of mineralogy on the geotechnical parameters of clayey soils: A case study for the Orta County, Çankırı, Turkey

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ABSTRACT

The purpose of this study is to investigate and relate the geotechnical parameters with the mineralogical properties of the Miocene and Plio-Quaternary (Pliocene to Quaternary) lacustrine and fluvial sediments, particularly clayey soils in the Orta County, Çankırı. The study area is located about 110 km northeast of Ankara which is the capital city of the Republic of Turkey and Orta is a small county of Çankırı. The study area is a structural depression in the northern part of the Orta plain which is filled by fault-controlled continental sedimentation. In order to correlate the geotechnical and mineralogical characteristics and to establish a relation between these properties, comprehensive geotechnical laboratory studies have been performed. For correlation purposes, disturbed and undisturbed soil samples were collected from twenty-two locations of the study area. On these samples, mineralogical (i.e., methylene blue absorption, specific surface area determination, X-ray powder diffraction (XRD) and scanning electron microscope (SEM-EDAX)) analysis and geotechnical (i.e., sieve analysis, hydrometer, Atterberg (consistency) limits, oedometer and swelling) tests were implemented. By the aid of the statistical analysis, cross-correlation of the soil properties was established by the regression analyses performed. In particular, the plasticity index was correlated with cation exchange capacity, specific surface area, clay content, percent of fines, smectite and smectite/kaolinite ratio (SKR). There was a direct relationship between PI and smectite percentage as well as between PI and SKR. Additionally, the liquid limit was correlated with the clay content and the effect of the specific surface area on the swelling characteristics was studied. The effects of the mineralogical properties of the Orta clays together with the geological history on geotechnical parameters were investigated by considering the relationships mentioned. The results of the study revealed that the mineralogical characteristics had a significant effect on the geotechnical behavior of clayey soils of the Orta County which was demonstrated by regression analyses. Finally it was identified that the geotechnical properties of clayey soils can be approximated and more reliably determined if the mineralogical character and composition of clay is accurately investigated and well developed.

1. Introduction

In engineering, the relation between different parameters is used either for the determination of the required parameters or to just compare the results. Generally, these relations are defined by a statistical evaluation of empirical results. There are quite a few studies reported in the literature that relate different engineering parameters. For instance, parameters such as clay content, liquid limit (LL), plasticity index (PI), water content could be used to estimate the swelling percent (Yılmaz, 2006) or it is possible to relate the mineralogical and geotechnical characteristics (Met et al., 2005; Schmitz et al., 2004). There are studies in the literature which correlate smectite percent and consistency limits (Ohtsubo et al., 2002) and relate the liquid limit values with the clay mineral characteristics (Means and Parcher, 1963). The total smectite percent gives a useful measure of the swelling potential according to Olsen et al. (2000). In addition, the strength parameters affected by mineralogy as reported by Myint et al. (2015) demonstrate that clay mineralogy is the key point in understanding the behavior of fine grained soils (Prakash and Sridharan, 2004; Yitagesu et al., 2012). In the literature, this subject has generally concentrated on the effect of the crystalline structure of the clay minerals on the geotechnical properties of soils (e.g., Mesri and Cepeda-Diaz, 1986). The aim of these

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relationships is to demonstrate that the structure of a crystalline clay particle has a potential to specify its shape, size and surface energy, which in turn determine its interaction with water and its mechanical response to the applied stresses (Mitchell and Soga, 2005; Terzaghi et al., 1997).

The present study defines the geotechnical and mineralogical characteristics of Miocene and Plio-Quaternary aged clayey soils in order to better understand the effects of their clay mineral compositions on the engineering behavior of these natural materials. For this purpose, field studies have been conducted and geotechnical (natural water content, sieve analysis, hydrometer, Atterberg limits, swelling, oedometer test) and mineralogical (X-ray powder diffraction (XRD), Scanning electron microscopy coupled with energy dispersive X-ray spectrometer (SEM-EDAX), Cation exchange capacity (CEC) and specific surface area (SSA)) characteristics were determined. Bilinear regression was implemented on the test results in order to statistically evaluate the collected data. The results of the study displayed that the mineralogical characteristics of clays had an influence on the geotechnical behavior of clayey soils of the Orta County.

1.1. Location and general setting of the study area

The study area lies within the Orta County which is a district of the Çankırı Province. It is located 70 km from Çankırı and 110 km north of Ankara, the capital city of Turkey. It mainly encompasses the northern part of the Orta District along with the Kanlıca and Salur villages, and is located within an approximately SW-NE-trending, 7–8 km long and 4–5 km wide structural depression (or basin) that is drained in the direction through the present-day course of the Devrez River and its tributaries. Towards the southeast of the study area, the Yaylakent River that flows towards the south is the other major river that is important for considering the erosional and depositional activities of the sediments within the structural depression (Fig. 1a).

The major part of the study area at the north of the Orta Plain constitutes Pliocene lacustrine and fluvial sediments, and Quaternary alluvium deposits which have filled the fault-bounded depression as a result of fault-controlled continental sedimentation. The pyroclastic and volcanic products of the Pliocene volcanic activity and some lignitic sedimentary layers of varying thicknesses are also observed to be interbedded with the clayey sedimentary deposits (Türkmenoğlu et al., 1991). These sediments which were deposited in the Pliocene lacustrine environment are important due to their clay rich mineral potential. The geological setting and the major geological formations within the study area are shown in Fig. 1b.

1.2. Geology of the study area

There are several different lithological units in the Orta Plain and its surroundings. The rock units outcropping in the region range from Middle Miocene to Quaternary in age. The basement rock group having volcanic origin consists of lava flows and pyroclastic units having Middle to Lower Miocene ages. These volcanic units crop out at the northwestern (Tha) and eastern (Tmkb1) side of the study area. They are composed mostly of andesite, basalt, dacite, tuff, and agglomerate (Fig. 1; Akyürek et al., 1980). During Late Pliocene, the last products of the volcanic activity (Tpo) have spreaded over the northwestern part of the study area. They have basaltic origin, and cut through the underlying older volcanics (Türkecan et al., 1991). During the Pliocene period, the volcanic activity ceased and the sedimentation was initiated by a fluvial depositional system in the Orta Plain (Türkmenoğlu et al., 1991). These fluvial sediments have a large areal extent along the study area and a high groundwater level was encountered at some localities in this unit. This unit unconformably overlies the basement rocks while it is disconformably overlain by the alluvial sediments of the Devrez River (Fig. 1). At the uppermost part of this unit, a red colored soil and silt are observed. Varying thicknesses of the light brown to white colored clay

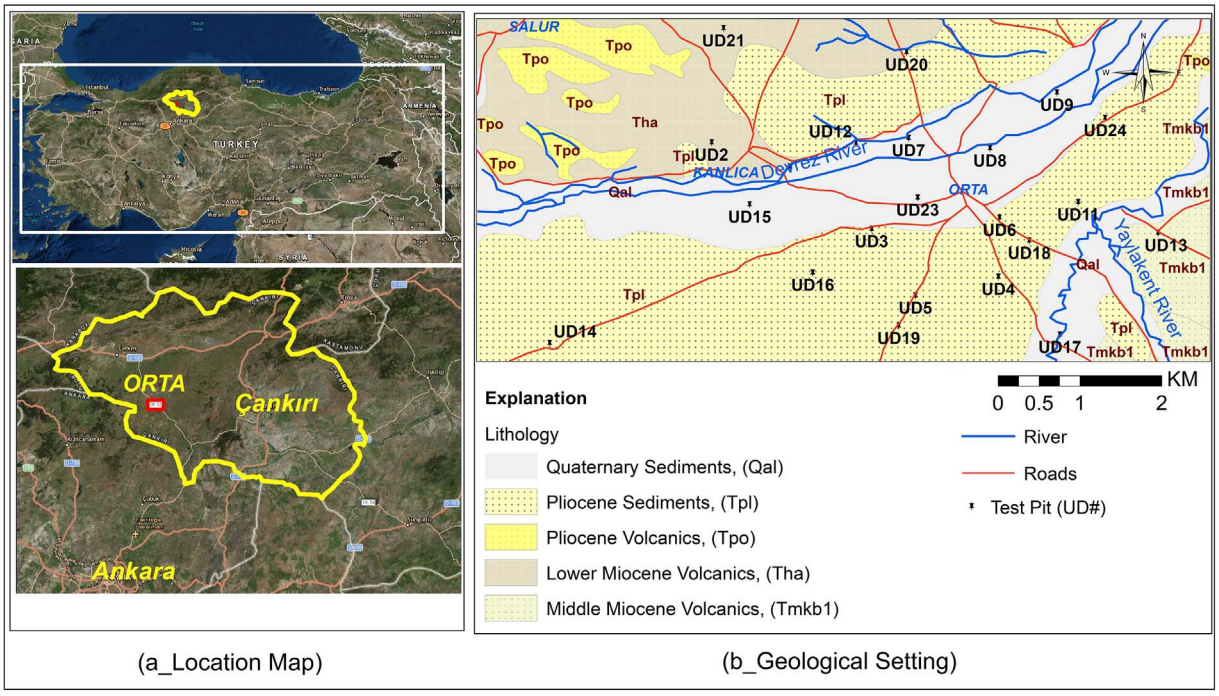

Fig. 1. a) Location map and b) geological setting (Akyürek et al., 1980) of the study area.