Iranian Journal of Engineering Geology
Summer 2019, Vol.12 , No.2

Investigation on dispersivity potential of clayey soils of Varzeghan Hajilar earth dam and its relationship with parent rocks

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Abstract

The Hajilar earth dam is under construction near the Kharvana Town of Varzaghan County. The height of this earth dam is 95 meters from foundation level. During dam studies have been identified 11 borrow material sources. As for, the evaporative formations outcrops in the project region and the presence of field evidence such as erosion of the sluice, erosion of the jars, the formation of pit and tunnel in the soil, and the flooding of the water after rainfall, it is necessary to study the potential of the dispersion of fine-grained soils in the area. In this research, the soil characteristics of five borrow sources of the clayey core of dam have been investigated, with emphasis on parent rocks, mineralogy and dispersive tests. For this purpose, field investigation and sampling and determination of parent rock related to borrow material resources, dispersive tests such as Crumb, double hydrometer, Pinhole and chemical analysis were performed on the samples. The results of this study show that clayey soils with the origin of Neogene evaporation deposits in the Leylab plain have a high dispersive potential and are classified according to the results of pinhole tests in group D1. Based on the results of double hydrometer tests, the percentage of dispersion in the Leylab plain is between 45 and 68%. The fine-grained soils around the Hajilar River, which are often the source of igneous rocks, have a low dispersive to non-dispersive.

Keywords: *Dispersive soils, Pinhole test, Hajilar dam, Leylab plain, Borrow material.*

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Extended Abstract:

1. Introduction

One of the important factors in the failure of earth dams is the internal erosion and piping by the flow of water along preferred seepage paths such as fine cracks, and particularly in their clay cores. This problem usually occurs when dispersive clay soils are used in dam construction. Dispersive soil is a particular type of soil in which soil particles lose their cohesion and are easily deflocculated in the vicinity of the water flow. Dispersive soils are among the clay soils, with a minimum clay content of 10%. The chemical difference between the dispersive and non-dispersive clays is in the type and percentage of cations in the pore water of clay.
The potential of dispersion and erodibility in a soil depends on several factors, including mineralogy, soil chemistry, amount and type of soluble salts in the soil and pore water, clay content, soil structure, Atterberg limits, soil activity number, pH of soil and water, shrinkage and swelling potential of soil, type of anions and cations, moisture content and density of soil. It is not possible to accurately determine the origin of the dispersive clays. It is obvious that the parent rocks have a very important influence on the physical and chemical properties of the soil deposits. The saline soil has a high potential of dispersion. Previous studies show that the higher the percentage of silica in the parent rock, the greater the percentage of sodium in the soil deposits. The decomposition of sodium feldspars in the silicate rocks can produce clay deposits with high percent of the sodium cations.
Despite there is a distinct relationship between the dispersive soil and its source, this issue has not been specifically considered by researchers. Generally, the soil dispersion potential is measured using laboratory tests such as Crumb, double hydrometer and pinhole. Although laboratory methods are a useful way for identifying dispersive soils, attention to the field signs and existing rock units can also be helpful in determining dispersion potential of the soils.
In this paper is investigated the dispersion potential of the borrow resources used in the clay core of Hajilar earth dam and the relationship between these sources and the existing formations in the region. The dam is located in the northern part of the East Azerbaijan province, in the Kharvana towm, on the Hajilar chai river (one of the branches of the Aras river). The dam site is close to the Qaraghayeh village at latitude 38°48'16" North and longitude 46°16'33" East. The dam is about 95 meters in height.

2. Geological setting

The north parts of the Kharvana town and the Leylab village are mostly covered by the Miocene marl facies which lie on the conglomerate. This facies consists of green, gray and pink marls with interlayers of shaley sandstones and dark gray igneous rocks. There is a strong argument that the clay deposits in the Leylab plain have been created from erosion of the Miocene evaporates and it is expected that these deposits are high in soluble salts especially sodium ones.

3. Methodology

At the first, the signs of dispersive soils were investigated in the field. Patterns of abnormal erosion (including erosional valleys, road cuts, erosion tunnels, and small valleys and erosion ditches) and the presence of mud flows during raining can be signs of presence of dispersive soils. In order to provide fine-grained borrow resources for the Hajilar dam clay core, 11 sources

including HF9, HF1, HF4, C, Z, O, N, A, L, Kalo village were investigated by Ban Aab Consulting Engineers Company. Most of these resources are located in the Leylab plain (between the new and old Leylab villages). After visiting the locations of these sources and seeking the field evidences of dispersion in them, some samples were taken from N, A, L, HF1 sources and also from in-situ soils covering the evaporative mother rock, named the Leylab hill.
Physical properties of the samples were investigated using grain size distribution and soil classification, Atterberg limits and density determination tests. To determine the percentage of soluble matter in the samples, 100 g of each soil was dried for 5 hours at 80 °C, and then soaked in 500 ml of distilled water. After mixing and keeping the specimens under these conditions for 24 hours, water and soil suspensions were passed through a filter paper. The difference in weight of the dried specimen on the filter paper with the initial sample was used as the amount of soluble matter. The mineralogy of one sample from borrow source N was determined by the XRD method. The dispersion potential of the samples was investigated using Crumb, double hydrometer, pinhole and chemical tests.

4. Results

During site visiting, erosion forms of dispersive soils such as gully and tunnel erosion were found around the dam region. Other indication for presence of dispersive soil in the region is the observation of cloudy water flows during raining. The lithological investigations show that the evaporative outcrops of Mio-Pliocene can be the main origin of fine-grained soils in the region.
Physical properties of the samples taken from L, N, A, HF1 resources, and a sample from the new Leylab hill indicate that the specimens are mainly composed of silt and clay particles and classified in ML, CL and CH groups based on USCS. The percentage of clay and soluble matter in the sample from the new Leylab hill is higher than that in the other specimens. The sample from borrow source N with 52% clay has the highest liquid limit, plasticity index and optimum moisture content and the lowest maximum dry density. Based on the plasticity index and the liquid limit amounts of the samples and position of samples in the Holtz and Kovacs (1981) chart, it can be expected that main clay minerals in the samples are Illite and Montmorillonite. The results of the XRD analysis on one sample from the N source also indicate that the main clay minerals are Montmorillonite, Kaolinite, Iliete and Chlorite.
Crumb test results indicate that almost all of the tested samples are completely dispersive. The results of the double hydrometer tests show that except samples from Kalo and HF9 sources, other samples are moderately to highly dispersive. The highest percentage of dispersion is related to the sample from the new Leylab hill. Based on the results of pinhole tests all samples are moderately to highly dispersive, i.e. lain in the D1 and D2 classes.

5. Discussion

In this study, the dispersion potential of some of the borrow resources for the Hajilar dam clay core was studied using Crumb, double hydrometer, pinhole and chemical analysis tests. The results of dispersion tests were compatible with each other. For example, samples from the Leylab hill and borrow source N are showed the highest percentage of dispersion in the double hydrometer test. In the pinhole test, the largest size of the hole and the highest flow rate were related to those specimens. The results of chemical analysis showed that the sodium ion content was high in the sample from the source N. Therefore, this sample indicated a high percent of dispersion in the double hydrometer test and was placed in the D1-grade of dispersion in pinhole

test. In contrast, the low sodium ion content in Kalo and HF9 samples led to their low percentage of dispersion in the double Hydrometer test.
Soil dispersion is directly related to mineralogy of clay. Clay minerals such as Montmoriollonite tend to have a high potential of dispersion (Barkhordari et al., 2014), but dispersion potential of Kaolinite and Halloysite is low and Illite is relatively dispersive (Mitchell, 1993). Given that the main clay minerals in the samples are Montmorillonite and Illite, the dispersion potential of the samples is high.
Based on these results, it is recommended that the clay core of dams should be constructed and compacted in densities greater than 98% of standard compaction test and in moisture between the optimum moisture content and 2 to 4% higher than that.
This study aims to determine a relationship between the parent rock and dispersion potential of its soil deposits. In the geological map (Fig. 1) the evaporative units, which have a high potential to produce dispersive soils, were differentiated from the other geological units. It can be seen that the resource HF1 is related to the E_m-Q^{t1} rock units (the old alluvial deposits, marl and sandstone). This sample showed the lowest degree of dispersion among the other samples. The lower dispersion potential of old alluvial deposits than younger alluvial deposits can be due to gradual loss of sodium ion or its replacement with calcium ion during the time. The samples from resources N and L and from the new Leylab hill are showed the highest degree of dispersion. These resources have a direct connection with the evaporative, marly and limestone units of Miocene (M_2^{mg}-M_2^{m}) and are likely productions of weathering and erosion of these units. The samples from HF9 and Kalo sources were identified to be non-dispersive in chemical and double hydrometer tests. As seen in the Fig. 1, the parent rocks of these sources are likely related to non-evaporative units of late Cretaceous-Paleocene (sandstone, conglomerate, limestone and andesite). Regarding the lithological investigations of the region, clayey soils with high dispersion potential are related to Neogene.

6. Conclusions

- The geological formations in the Hajilar dam area are mostly composed of Neogene evaporative units. These units are the parent rock of the clayey deposits in the region which are rich in soluble salts.
- Gully and tunnel erosion forms in the slopes and plains of the region point to the high dispersion potential of the clayey soils.
- Most of the clay borrow resources are classified in the CL and CH groups according to Unified classification system, which are among the suitable soils used in clay core of earth dams.
- Of the 11 clay barrow sources specified for using in the Hajilar dam core, 5 sources were completely dispersive, 4 sources were slightly to moderately dispersive, and the others were non-dispersive.
- Among the studied samples, the sample from the new Leylab hill, which is originated from the evaporative units, showed the highest degree of dispersion.
- Based on the results of pinhole tests, the dispersive soils are slightly eroded by the water flow when they are compacted in the optimum moisture content and the maximum dry density. In this condition, the flow rate through the specimen and the hole size after test are smaller and the outlet water color is more clearer.

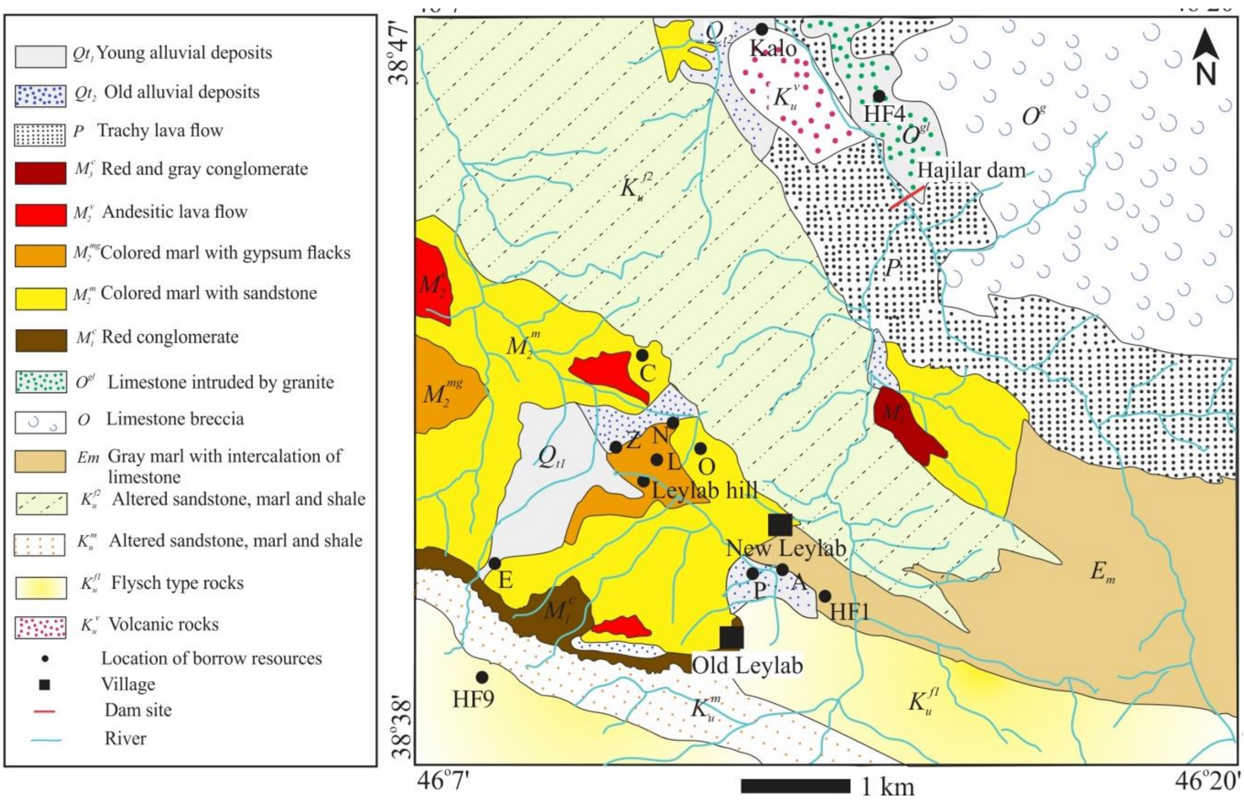

Fig. 1. Geological map of the study area prepared on the basis of Siahroud map 1:100000 (Geological Survey of Iran, 1997). The locations of clay resources for the dam core are specified on the map

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