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Evaluating Erodibility of gupsiferous soils of Masjed Soleyman petrochemical plant site with emphasiss on dispersive and solubility

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Abstract

Dispersivity is a physico-chemical phenomenon whereby clay soil particles lose their cohesion in the presence of water and repel each other, so that the particles become suspended in water and easily washed with very little energy from the environment. Potential dispersivity in a given soil depends on several factors, including: type of clay minerals, pH, organic matters, temperature, moisture percentage, type and concentration of ions existing in the soil pore water and the characteristics of eroding fluid and usually there are high amounts of sodium cation. Soil dispersivity evidence can be alluded to the development of erosional shapes on steep and flat areas; since these erosional shapes were observed upon the Gachsaran formation in Masjed Soleyman petrochemical site, so sampling was carried out from different parts of the site in order to assess the causes of erosion. Then, by performing physical and chemical tests as well as the tests to characterize soil dispersivity, it was observed that the amount of sodium cation is low and soil itself is non-dispersive. By observing the gypsum mineral, voids and free spaces available in manual and microscopic samples, their gypsum content was determined. Again, by its relation with field observations, it was revealed that erosion shapes induced by leaching, dissolution and ultimately the soil to be hollowed in the result of gypsum mineral presence that has been contributed in developing a kind of mechanical erosion in the region.

Keywords: *Dispersive, Masjed Soleyman petrochemical plant, Content gypsum, leaching, Mechanical erosion*

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Extended Abstract:

1. Introduction

Dispersive soils are defined as fine-grained soils which lose their cohesion and disperse in water when subjected to relatively pure water, and which own a lot of sodium ions in their absorptive cations (Askari and Fakher, 1993). It is very simple to identify dispersive soils in areas with steep slopes; in which very deep and seeable rills emerge on the ground due to rainfall and rapid erosion, as a major characteristic of dispersive soils (Sherard and Decker, 1977). The tests so far conducted to detect dispersive soils include Crumb, Double hydrometer, Pinhole and chemical tests (to determine soluble salts in the soil).

2.1. Chemical criteria to assess dispersive soils

Chemical tests (to determine the sodium adsorption ratio, sodium percent and the total dissolve solids in soil, etc.) have been used to assess soil dispersion, based on which various criteria have been presented by different researchers (like Sherard et al., 1976; Rahimi and Delfi, 1993; Bell et al., 1994; Bazargan and Ismaeili 2010; and Fan and Kong, 2013) to determine soil dispersion.

3.1. Soluble and gypsum soil

Gypsum soils are considered the most challenging soils in the problematic soil group so that carrying out any project about such soils without predicting deformations can lead to a catastrophe (Al-Sauodi et al., 2013). As gypsum functions like cement in the dry state, thereby improving the engineering properties of soil; but soil’s salt and minerals are leached and dissolved when hydraulic structures are constructed upon gypsum soil or moisturized due to rainfall or groundwater level changes (Fauziah et al., 2012). This problem becomes more intense when the flowing water inside the soil causes the loss of mass due to leaching. Leaching is a process whereby fluids penetrate into the soil naturally and artificially, leading to the dissolution and leaching of the soil’s soluble compounds (Al-Zgry, 1993).

2. Materials and methods

Considering rills, gullies and other erosional forms at the Masjed Soleyman Petrochemical Site, the researcher did the sampling from 10 different points of the site including erosional forms (with letter S) and holes excavated for the conduction of the plate loading test (with letter P) in order to examine the causes of erosion. Then, in order to identify the causes of erosion, the researcher conducted diverse microscopic (n = 9), chemical (n = 90), physical (n = 50), mechanical (n = 10) and soil dispersion-determining tests (n = 30) in accordance with the ASTM standards and finally evaluated the consistency of the results.

3. Tests results

1.3. Physical and mechanical test

After field sampling from 10 locations, the physical and mechanical characteristics (LL%, PL%, W (%), CMW (kN/m3), MDW (kN/m3), OMC (%)) of the samples were determined. Most of the samples were in the CL group based on the unified soil classification and the percentage of silt in the sampled soils was between 51.8 - 64.6% based on the classification by the US Department of Agriculture.

2.3. Tests to determine Dispersive soil

To examine dispersive soil, the researcher performed Crumb, Double Hydrometer and Pinhole tests on the samples, according to which most of the samples were non-dispersive.

3.3. Chemical tests

In order to specify the dispersion, nature and chemistry of soil, the researcher prepared saturation extracts of the specimens. Initially, their amounts of pH, EC were measured and then Inductively Coupled Plasma (ICP) analysis was exerted over the specimens after making standard salt solution and dilution in order to determine the percentage of the cations of sodium, potassium, calcium and magnesium. Also for the mineralogy of the samples, Clay - XRD analysis was performed on the three samples in all three samples of clay, chlorite and illite - mica minerals with regard to the sameness of mica and illite spectrum. On the other hand, the results of the X -Ray test indicated the lower amount of sodium oxide and showed that the content of the samples comprising silica and carbonate ranged from 20% to 35%.

4.3. Chemical criteria evaluation of soil dispersion

Considering the chemical criteria of dispersive soil, all of the samples were non-dispersive in accordance with the Sherard criteria (1976), the S11 sample was intermediately dispersive based on Rahimi and Delfi's chemical criteria (1993), the P1 sample was intermediately dispersive in accordance with Bazargan and Ismaili's criteria (2010), all of the samples were non-dispersive in terms of the Bell and Walker's rating system (2000) and finally all of the samples were considered non-dispersive based on the Fan and Kong's criteria (2013).

5.3. Evaluation of the solubility of the samples

Considering the monitored surface solubility and increased boreholes diameter drilled in the first few meters of drilling with a diameter of 110 mm and then either scoured after a rainfall or got the diameter increase up to 170 mm (sampling location S11) and due to the existing gypsum and pores in hand samplings, thin sections of the samples were prepared for more detailed studies and the amount of carbonate was determined (by Calcimeter Bernard methods) and their gypsum content was determined (using the turbidity and Al-Mufty and Nashat (2000) methods).

6.3. Assessment of gypsum content on the samples' physical and mechanical characteristics

By plotting curves, plasticity index (PI), optimum moisture content (OMC) and maximum dry weight per unit volume (MDW) of the samples presented along with the gypsum content obtained from the two methods of Al-Mufty and Nashat (2000) (AMN) and Turbidity Meter (TM) (Fig. 1), we could observe that:

Trend related to the results of liquid and plastic limits seems uniform because of both the leaching of samples' gypsum content and having gypsum less than 5% in most of the samples. On the other hand, this trend decreases in the P2 and S3 samples because of the amount of gypsum exceeding 5%. Regarding the samples' maximum dry weight per unit and the optimum moisture content achieved from their standard density testing, no remarkable change was seen except in the case of P2 having the greatest amount of gypsum and the lowest optimum moisture content. Also, the low optimum moisture content of the P1 sample can be attributed to its high salinity as compared to the other specimens.

In the weight per unit volume of the samples being influenced by chemical composition, porosity, avoid ratio, minerals (differences in dense minerals), texture, samples' leaching and soluble minerals washed away P2 sample has the lowest weight per unit volume value due to either the high amount of gypsum or the lower specific gravity of gypsum mineral than that of the other minerals.

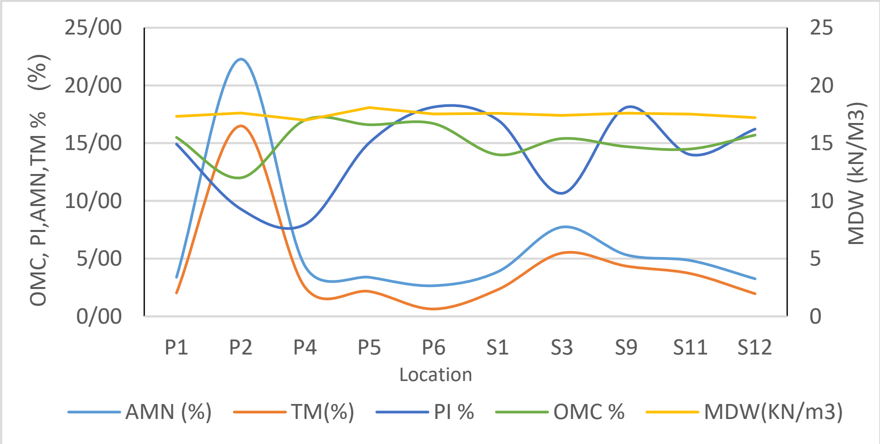

Fig. 1. The effect of gypsum content on the results of the physical and mechanical tests

7.3. Investigating the causes of forming erosional forms

The main reasons for the formation of erosion forms in the region can be the existence of formations and deposits susceptible to erosion, high groundwater levels, high evaporation due to hot and dry climate, low rainfall with high intensity in the site, lack of coverage vegetation, lack of sufficient soil strength, silty texture and gypsum mineral.

4. Conclusion

Based on soil dispersive tests (Crumb, double hydrometer, pinhole) and in accordance with the criteria (Sherard, 1976) (Rahimi and Delfi's 1993) (Bazargan and Ismaili, 2010) (Bell and Walker, 2000) (Fan and Kong's criterion, 2013)), most of the samples were evaluated to be non-dispersive.

Liquid limit, plasticity index, weight per unit volume and optimum moisture content of the samples decreased following an increase in the amount of gypsum, but the maximum dry weight per unit volume underwent little change. Not to mention, high salinity underwent optimal moisture reduction.

A low percentage of sodium oxide was observed in the XRF analysis of the samples; clay had chlorite and mica-illite minerals in the XRD analysis. In microscopic cross section, the samples containing calcite, quartz, albite, evaporate minerals and porosity were identified.

Due to having high silt percent poses, the study site was the most susceptible soil to erosion according to the USDA’s classification. On the other hand, the existence of soluble materials such as salt and gypsum helped dissolve the above-mentioned substances in water due to their contact with water, and caused a part of solid particles in the soil mass to be dissolved and removed. This phenomenon will ultimately increase soil porosity and hollowness. The existing small holes and pores within the soil as well as the relationship between the amount of gypsum and erosional forms prove this. Actually, leaching by seasonal floods caused the soil to lose a large amount of its minerals and destroyed their dispersion property.

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