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Assessment of the clay mineralogy effect on Ajabshir soils' physicochemical characteristics and swelling phenomenon

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ABSTRACT

Clayey minerals are considered as the most important factor causing soils swelling, especially fine-grained soils. This phenomenon also causes the destruction of soil structure and texture and in the water vicinity makes damage to surrounding structures. Therefore, identifying and improving the condition of such soils can be very useful. For this purpose, standard laboratory methods have been proposed to evaluate the swelling potential of clayey soils. In this study attempted to use these laboratory methods to evaluate the clayey soils' physicochemical characteristics and swelling potential form Ajabshir, East-azerbaijan province, NW of Iran. In this regard, the field survey, sampling and laboratory tests (such as physical, chemical and mechanical) conducted on 30 specimens were taken in Ajabshir. The soils samples are classified by United States Department of Agriculture (USDA) classification to identify the clay minerals classes for Ajabshir's soil. Also, the indirect swelling potential evaluation was applied for providing the swellability condition of the studied soils.

1. Introduction

Swell-able soils are one of the most costly and widespread problematic soils were causes the destruction of soil structure and texture and damage to surrounding structures. These soils present significant structural challenges and sudden behavior were contact with water. Swellability or swelling potential is occurs as clayey soils results in front of water, pore-pressure, moisture content, etc. were reflected on soil volume variations (Farrokhpay et al., 2016). Generally, swelling soils (clay minerals-based fine gradient soils) by absorbing water content providing the inflation and heave (Driscoll and Crilly, 2000). In practice, the swelling potential can be changed based on clay types were can be varied as Kandites (low swelling potential) to Smectite/Montmorillonite (high swelling potential). In the other hand, each group can be divided in low to high potential minerals (Ahadi-Ravoshti and Hashemimajd, 2017).

As mineralogical aspect, the Clay minerals are known as hydro-aluminum phyllosilicates with variable quantities of Fe, Mg, Ca, Na, K, Rb, Cs, Fr, Ba, REE, etc. which with water presence is changes and make different behaviors (Yazdandoust and Yasrobi, 2010). Structurally, clay minerals form as sheets were fundamentally built of tetrahedral silicate sheets and octahedral hydroxide sheets (Azarafza et al., 2018). Holtz and Kovacs (2010) fine-grained clayey soils (especially montmorillonite based soils) when located in surface were can be involved with atmospheric cycles can be known as high potential inflation levels. As known the clay minerals considered as weathering productions in earth surface were contain valuable materials in agricultural aspect. In the other hand, these minerals can be caused the damage buildings, facilities and infrastructure, roads, and so on were consider as geo-hazard (Mitchell and Soga, 2005). However, the swelling can cause differential lifting or settlement in clayey soil which is must be identified to improve the conditions of soils especially in urban areas. In agricultural

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aspect, the swelling can be damages on pipe lines, buildings, trees, roots, water-tanks and pounds. In this regard, the characteristics of the Swell-able clayey soils can be reducing the scale of damages (Clayton et al., 2010).

Ground deformation related to the swelling can be identified by using several direct or indirect procedures which that evaluated by in-site or laboratory standard methods. As known, the swelling potential is depends entirely on the fine-grained soil characteristics which are classified as physicochemical properties and mechanical behavior (Kariuki and der-Meer, 2004). The most important of these properties are the amount of clay, clay activity, clay type, and the percentage of fine-grains, which can be estimated by sampling and conducting the soil tests. As results of the previous researches the clay minerals swelling activities can be increase based on structures complexity in clay groups from Kaolin, Illite, Mica, Serpentine, Talc, Chlorite, and Vermiculites to Smectite (Farrokhpay et al., 2016). Smectite group (such as Montmorillonite, Beidellite, Nontronite, Hectorite and Saponite) is considered as high swelling potential in clay minerals. The presented study attempted to evaluate the swelling potential of Ajabshir soils were located in East-azerbaijan province, northwest of Iran. In this regard, comprehensive laboratory tests were conducted on studied soils.

2. Study location

Ajabshir city is a city and capital of Ajabshir County in East-Azerbaijan Province were located in northwest of Iran. At the 2011 census, the county's population was 66,746 which are subdivided into two Central district and Qaleh-chay districts. Ajabshir city is located in Ajabshir Plain were limited by Urmia Lake in southeast and Sahand Mountain in northeast where considered as part of the Urmia Lake basin. The study location is coordinated as 45°49' E to 46°02' E and 37°23' N to 37°33' N within about 144.69 square kilometer. Fig. 1 is presented the location of the studied area. The altitude changes observed in the studied region include mountainous conditions and plains and coastline of Urmia Lake. The average annual rainfall in Ajabshir is about 300 mm which maximum rainfall often occurs in May (Kaliraj et al., 2015). The average annual temperature is 12 °C which maximum temperature has been recorded in August (Rezaei Moghaddam et al., 2018).

Geologically the studied area is located in Alborz-Azerbaijan zone based on Stoecklin’s tecto-structural-sedimentarological classification in 1968 (Stoecklin, 1968; Aghanabati, 2007; Azarafza and Mokhtari, 2013). This zone considered as high seismic activity zone in Iran which is affected risk-ability in entire platform. In terms of geology, most part of the studied region is covered by Quaternary alluvium, plain deposits, young terraces, fans, recent river sediments and clayey soils. This has also added to the ability of the region's soils to swelling potential. Fig. 2 is presented the geological map of the studied area. Due the high seismicity of the Ajabshir Plain, several active faults is located in studied area as well as illustrated in Fig. 2 (Rezaei Moghaddam et al., 2018). Due to the high groundwater level and proximity to Urmia Lake (Urmia Lake is a high saline lake), caused the Ajabshir is faced with complex hydrogeologic circumstances were provided the swellability condition (Jaafari and Eftrkhari, 2013; Mirabbasi Najafabadi et al., 2016; Shemshaki and Karami, 2017).

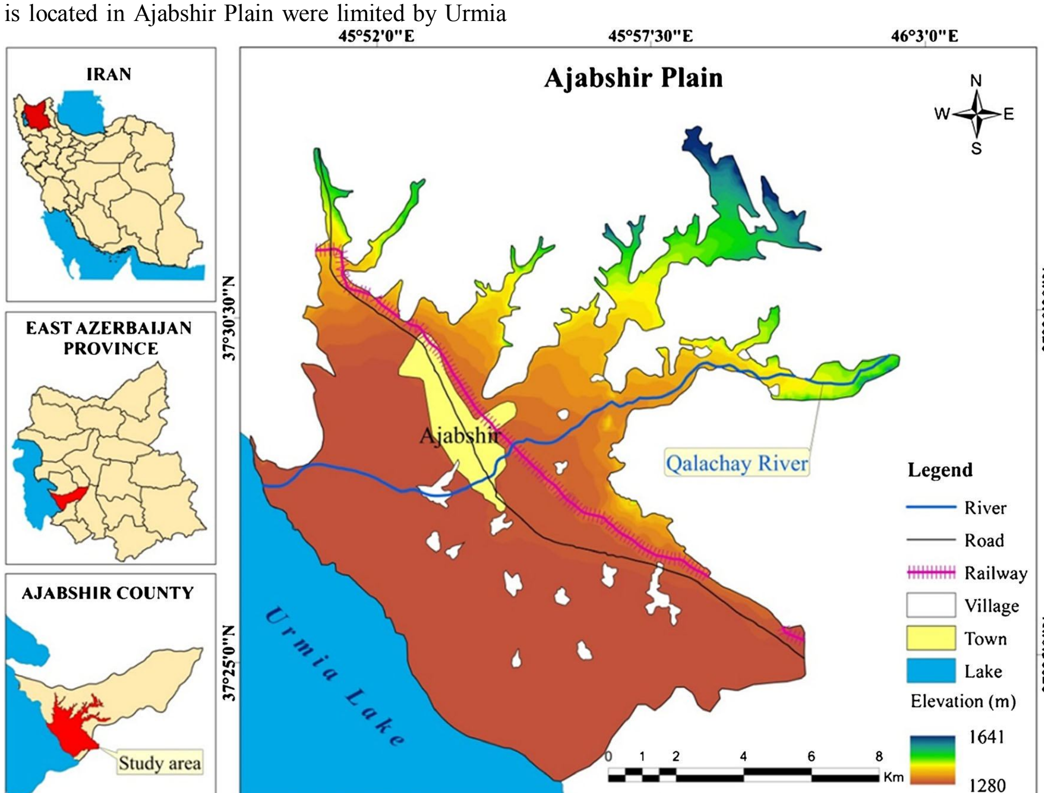

Figure 1. Location map of Ajabshir city and studied area (based on Rezaei Moghaddam et al., 2018)

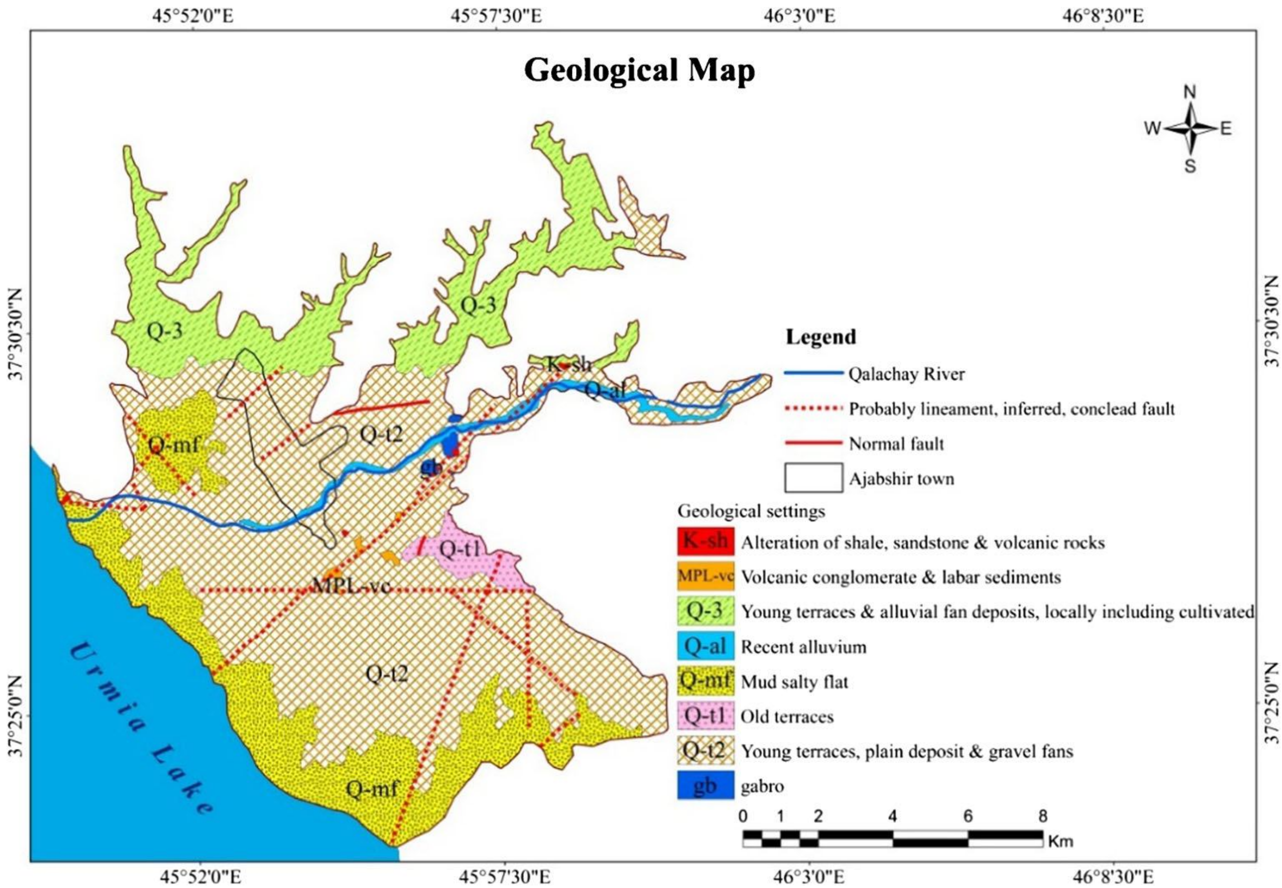

Figure 2. Geological map of the studied area (based on Rezaei Moghaddam et al., 2018)

3. Material and Methods

In order to evaluate the swelling potential of the Ajabshir soils used the comprehensive field and laboratory investigations. In this regard, the 30 location was selected for soil sampling. These samples were taken from 0 to 2 m depth in studied area. The taken specimens transferred in to the Soil Laboratory of AZAR-NIK Pey Company. In order to prevent changes in the nature of the samples during sampling, the samples are sealed. Specimens were prepared in the laboratory and three groups of physical, chemical and mechanical tests were conducted on soil samples which indicated the physicochemical characteristics. The tests were conducted in accordance with the ASTM instructions. In the other hand, the X-ray diffraction analysis (XRD) was utilizing to the detection of the clay minerals. Also, the samples were classified by United States department of agriculture (USDA) classification system to identify the clay content of studied soils. Finally, the tests results were used to classification of soil activity and estimate the swelling potential. For this purpose, the results of mechanical tests and Casagrande indexes have been used. The swelling potential assessment is build on indirect estimation which presented by Yilmaz (2006). Yilmaz in 2006 provided the activity charts for swellability condition for fine-grained soils based on engineering geological tests were present appropriate view of clayey soils condition against inflation.

4. Results and Discussions

Soil characteristics is important aspect of soil science which is lead the scholars to provide the true data about the ground status which can be used in agricultural, mining, civil, environmental, urban, construction and housing projects (Bagheri Shendi and Azarafza, 2018). In this regard, detection of any defects in the soil structures (such as swelling, collapsing, expansion, etc.) can be destructive. However, in identifying the swelling potential of soils several standard laboratory or in-site methods have been used to estimate the soils swellability. Among of these procedures, laboratory methods have a special place. The presented study attempted to use the laboratory tests for investigate the soil physicochemical properties and swelling potential of Ajabshir. In this way, 30 point of sampling specified and 30 soil sample was taken and transfer to the soil lab. The specimens prepared and have been tested by 3 groups of experiments included physical, chemical and mechanical tests.

4.1. Physical tests

The physical tests was conducted based on ASTM instructions which can classified as water absorption (ASTM C128), porosity (ASTM F1815), dry and saturated densities (ASTM D7263), and specific-gravity (ASTM D854). The result of the physical characteristics of studied soils is presented in Table 1.

Table 1 Ajabshir soil's physical tests results

Parameter	Max	Min	Ave
Water absorption (%)	17.3	7.7	12.5
Porosity (%)	68.8	45.5	57.1
Dry density (kN/m^3)	22.6	17.3	19.9
Saturated density (kN/m^3)	25.0	21.2	23.1
Specific gravity (G_s)	2.71	2.50	2.60

4.2. Chemical tests

The chemical tests were conducted to characterize the soil structure and mineralogy of soil particles. For this purpose, X-ray diffraction analysis (XRD), sulfate-chloride (ASTM C1580; ASTM D8018) and pH (ASTM D4972) tests were performing by ASTM standards. For the XRD experiment, the samples are passed form the #200 sieve (according to the standard US sieve analysis) and stirred with distilled water which is done for the collection of the clay materials base on Stoke's law, then the prepared samples is used to XRD detection of the clay minerals. Tables 2 and 3 are presented the chemical tests results were obtained from Ajabshir soil's samples.

Table 2 Ajabshir soil's chemical tests results

Specimen Number	SO_4^-	Cl^-	pH
AS-Clay-01	0.07	0.01	7.7
AS-Clay-02	0.01	0.06	7.6
AS-Clay-03	0.03	0.01	7.6
AS-Clay-04	0.06	0.11	7.3
AS-Clay-05	0.03	0.08	7.3
AS-Clay-06	0.08	0.06	7.7
AS-Clay-07	0.11	0.07	7.5
AS-Clay-08	0.15	0.11	7.7
AS-Clay-09	0.13	0.08	7.3
AS-Clay-10	0.06	0.06	7.3
AS-Clay-11	0.08	0.07	7.7
AS-Clay-12	0.11	0.06	7.3
AS-Clay-13	0.07	0.11	7.7
AS-Clay-14	0.04	0.09	7.3
AS-Clay-15	0.06	0.08	7.6
AS-Clay-16	0.06	0.11	7.5
AS-Clay-17	0.11	0.06	7.5
AS-Clay-18	0.03	0.06	7.5
AS-Clay-19	0.17	0.11	7.7
AS-Clay-20	0.07	0.09	7.3
AS-Clay-21	0.11	0.07	7.6
AS-Clay-22	0.06	0.07	7.5
AS-Clay-23	0.15	0.11	7.7
AS-Clay-24	0.17	0.11	7.6
AS-Clay-25	0.07	0.03	7.6
AS-Clay-26	0.06	0.08	7.5
AS-Clay-27	0.12	0.06	7.3
AS-Clay-28	0.08	0.06	7.7
AS-Clay-29	0.08	0.09	7.5
AS-Clay-30	0.12	0.11	7.5

Table 3 Ajabshir soil's XRD results for mineral detection

Specimen Number	XRD results (%)		
	Smectite	Kaolinite	Illite
XRD-Clay-01	44	11	22
XRD-Clay-02	47	21	17
XRD-Clay-03	52	17	25
XRD-Clay-04	33	13	14
XRD-Clay-05	71	15	14
XRD-Clay-06	48	19	6
XRD-Clay-07	45	22	18
XRD-Clay-08	52	21	11
XRD-Clay-09	52	25	18
XRD-Clay-10	36	11	21
XRD-Clay-11	49	13	25
XRD-Clay-12	21	17	25
XRD-Clay-13	21	16	17
XRD-Clay-14	66	15	11
XRD-Clay-15	71	15	7
XRD-Clay-16	55	15	25
XRD-Clay-17	48	25	19
XRD-Clay-18	48	21	7
XRD-Clay-19	46	21	22
XRD-Clay-20	43	17	19
XRD-Clay-21	33	19	17
XRD-Clay-22	21	13	11
XRD-Clay-23	25	13	16
XRD-Clay-24	49	11	16
XRD-Clay-25	66	7	18
XRD-Clay-26	63	21	21
XRD-Clay-27	48	19	26
XRD-Clay-28	57	7	18
XRD-Clay-29	57	7	21
XRD-Clay-30	52	12	21

4.3. Mechanical tests

Soil mechanical test was conducted on studied samples to identify the activity of clayey soil as well as providing the appropriate classification for specification of soil characteristics. In this regard, the sieve analysis, hydrometer, and Casagrande tests (ASTM C136; ASTM D4318) were utilized on specimens and USDA system was used for clustering of fine-grained soil materials. Fig. 3 and Table 4 are presented the results of the soil mechanical experiments on Ajabshir soil.

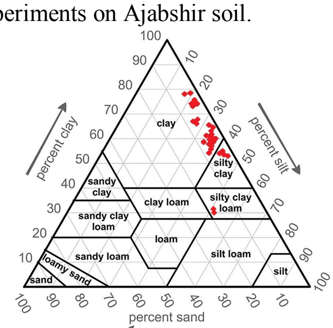

Figure 3. USDA classification of the Ajabshir soil

Table 4 Ajabshir soil's soil mechanical tests results

Sample No.	USDA Classification	Sieve-hydrometer experiments			Casagrande index		
		Passing #200	Clay (%)	Silt (%)	LL (%)	PL (%)	PI (%)
AS-Clay-01	Clay	73	79	21	65	32	33
AS-Clay-02	Clay	70	67	33	45	35	10
AS-Clay-03	Silty clay	65	55	45	50	27	23
AS-Clay-04	Silty clay loam	52	32	68	57	33	24
AS-Clay-05	Clay	63	68	32	69	35	34
AS-Clay-06	Clay	63	66	34	66	37	29
AS-Clay-07	Clay	67	57	43	49	20	29
AS-Clay-08	Silty clay	69	55	45	45	26	19
AS-Clay-09	Clay	71	57	43	86	29	57
AS-Clay-10	Clay	75	64	36	51	41	10
AS-Clay-11	Clay	73	75	25	77	39	38
AS-Clay-12	Clay	73	74	26	73	25	48
AS-Clay-13	Clay	63	65	35	71	21	50
AS-Clay-14	Clay	65	56	44	51	30	21
AS-Clay-15	Clay	60	59	41	59	27	32
AS-Clay-16	Clay	57	61	39	65	35	30
AS-Clay-17	Clay	59	60	40	60	34	26
AS-Clay-18	Clay	52	60	40	66	31	35
AS-Clay-19	Clay	57	77	23	67	30	37
AS-Clay-20	Clay	45	61	39	59	29	30
AS-Clay-21	Clay	63	60	40	71	27	44
AS-Clay-22	Clay	67	71	29	77	33	44
AS-Clay-23	Clay	69	63	37	80	35	45
AS-Clay-24	Clay	71	74	26	75	29	46
AS-Clay-25	Clay	77	62	38	64	27	37
AS-Clay-26	Silty clay	75	53	47	60	21	39
AS-Clay-27	Silty clay	75	53	47	33	21	12
AS-Clay-28	Silty clay loam	63	30	70	37	20	17
AS-Clay-29	Clay	60	54	46	35	25	10
AS-Clay-30	Clay	58	56	44	60	33	27

5. Swelling potential of Ajabshir soil

Swellability is clay minerals capability for absorption and inflation of fine-grained soil. In order to estimation of clayey soil's swellability, the direct and indirect procedures were proposed by several scholars. Direct methods are utilized based on laboratory tests such as the uniaxial consolidation and the inflatability tests, which usually involve additional costs. Indirect methods are usually ancillary methods that can be estimated based on soil mechanics tests results such as plasticity and soil activity indices. Yilmaz (2006) present the soil activity charts for simple application to obtain swelling potential by indirect procedures. Fig. 4 is shows the indirect swelling potential for studied soils. As seen in this figure, the most of samples classified as low to moderate swellability which some samples shows high potential of swelling. In this regard, it can be said that fine-grained soils in the study area have extensive and special conditions in terms of swelling. Thus, this area needs special attention in terms of inflation.

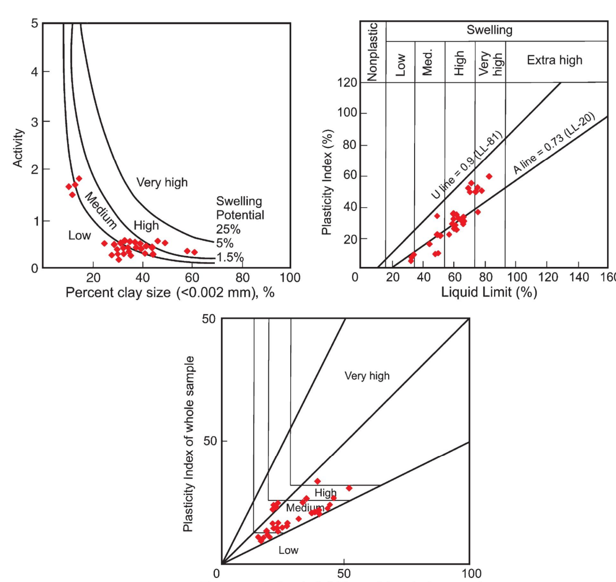

Figure 4. Yilmaz (2006) indirect swelling chart

6. Conclusion

Presented study attempted to evaluate the swellability status of Ajabshir fine-grained soils against of inflatability. In this regard, the physicochemical characteristics of the studied soils are estimated by using the comprehensive sampling and conducting the laboratory experiments included physical, chemical and mechanical tests. The physical tests were classified as water absorption, porosity, dry and saturated densities, and specific-gravity. The chemical tests were classified as X-ray diffraction analysis, sulfate-chloride and pH tests. According to the results of the experiments, the estimated water absorption, porosity, dry and saturated density, specific gravity of soils is 12.5%, 57.1 %, 19.9 and 23.1 kN/m^3 and 2.60, respectively. As Casagrande results, the plasticity indexes indicated the extensive variations in LL, PL and PI values which is covered 33-80 for LL, 20-41 for PL and 10-50 for PI. The USDA system was used for clustering of fine-grained soil materials which the results shows most of Ajabshir soils is classified as 'Clay' class and some are classified as 'Silty clay' and 'Silty clay loam'. In order to evaluate the swelling potential of studied clayey soils, used indirect methods based on swellability charts which presented by Yilmaz (2006) were results shows extensive and special conditions in terms of swelling from low to high swelling potential for studied specimens. Thus, this area needs special attention in terms of inflation.

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