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Evaluate the clay minerals physicochemical properties on Bonab swelling soils

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ABSTRACT

The aim of this study is investigation of the swelling potential of the Bonab city's soils and created the empirical relations between physicochemical properties of the clayey soils of Bonab with the swelling potential. The studied area is located about 130 km southwest of Tabriz in northwest of Iran. Geologically Bonab is covered by the Quaternary alluvials and recent soils which mostly is fine-grained contains different amounts of clay minerals where causes several events like swelling. In order to assessment of the swelling potential and characteristics of Bonab soils and establish relationships between these properties, the extensive field study especially on the agricultural fields (Bonab is the agricultural-based city), sampling and laboratory tests (classified in physical, chemical and mechanical) are conducted. For the reducing the investigation's errors, the 20 different location is selected and sampling is taken as representative. The results of laboratory tests are classified based on United States Department of Agriculture (USDA) classification which indicated the most of Bonab soils are clay, clay loam and silty clay with the sandy clay and salt. Also, according to the swelling potential indirect assessment, these soils are located in medium to high swellability.

1. Introduction

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 behavior were is very important to agriculture, engineering, manufacturing and human sciences. The structural of clays is the sheet form and common weathering products (including weathering of feldspar) form rock and soils were mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure (between sheets). Clays has plastic behavior due to them fine-grained particle size and geometrical conditions as well as water content which originates from the clays structures and make hard, extensive and unpredictable behaviors (Savage, 2007). Clay minerals based on the sheet structures classified in the 1:1 or 2:1 groups where originates because they are fundamentally built of tetrahedral silicate sheets and octahedral hydroxide sheets (Azarafza et al., 2018):

- 1:1 class: consist of a tetrahedral sheet and a octahedral sheet,
- 2:1 class: consists of an octahedral sheet sandwiched between two tetrahedral sheets.

According to this classification, the clay minerals are categorized in Kaolin, Illite, Mica, Serpentine, Talc, Chlorite, Vermiculites and smectite main groups (Figure 1) which each group are divided into the more subgroups (Mitchell and Soga, 2005) which is the vermiculites and smectite groups are under the swelling occurrence (Farrokhpay et al., 2016). Thus, the vermiculites and smectites increase in clayey soils, the potential of swelling is increase too. Expansive clay is a phenomenon of clay minerals/soils which that is prone to large volume changes (swelling-shrinking) were directly related to water content changes (Yazdandoust and Yasrobi, 2010). According to the various researchers who work in this field, the smectites group

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including montmorillonite and bentonite has the most dramatic shrink-swell capacity (Nagaraj et al., 2010).

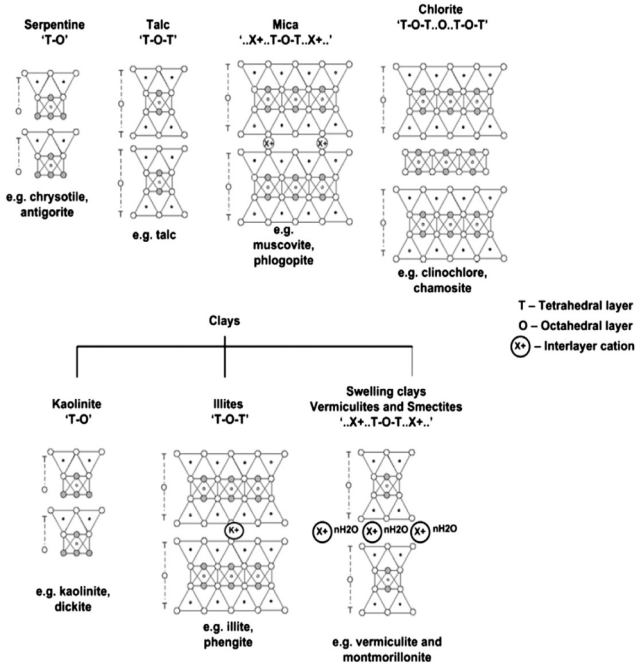

Figure. 1. The clay minerals type and groups (Farrokhpay et al., 2016)

2. Studied area

The Bonab city and Bonab county is located in west of Maragheh county on the outwash Urmia Lake plain in East-Azerbaijan province, NW of Iran. The people speak Azerbaijani Turkish and according to the 2012 census, its population was 75,332, in 19,922 families which divided into the one city, 25 villages (Statistical Center of Iran, 2012). The city name is origin old Turkish means '1000 houses' which other meaning is 'water base city' where can be considered the Urmia Lake water changes (digging ground for 5 meters gained your access to water in Bonab). But today due to the Urmia Lake drying, has lost its meaning (Lak et al., 2012). The location of the Bonab in East-Azerbaijan and Iran is illustrated in figure 2. In this figure; the city is completely under the control of the lake conditions. The main economic work of this city is traditional agriculture such as cantaloupe, apple, wheat, barley, grapes, onions, medicinal herbs, shallot, etc. which is requires varies water were supplied form the lake and Maragheh-Bonab plain groundwater (Azarafza et al., 2014). Geologically the Bonab located on the Quaternary alluvial which include detached sediments and organic/inorganic soils. The figure 3 is presented the geological map of the studied area and Urmia Lake (Azarafza and Mokhtari, 2013; Azarafza and Ghazifard, 2016). The alluvium is the main in agricultural pastures classified in the fine-grained soil included clay to silt soil and sand. The clayey soil is the most important part of the described soils and mainly contained smectite group.

3. Methodology and Materials

For assessment Bonab clay's swelling potential, 20 different locations is selected for sampling and disturbed samples is taken from the soil layers in 0 to 2 m. As known form the geological map of the studied area was mostly covered by Quaternary alluvials and recent soils which is fine-grained contains different amounts of clay minerals. The samples are taken and transferred to the department of Agriculture, University of Mohaghegh Ardabili 'soil physicochemical laboratory' and laboratory tests were performed in three categories:

- Physical tests,
- Chemical tests,
- Mechanical tests.

The tests were conducted in accordance with the ASTM. The water absorption, porosity, dry density, saturated density, specific-gravity, clay particles tests were performed to determine the physical characteristics, the X-ray diffraction analysis (XRD), sulfate-chloride and pH tests were performed to determine the chemical characteristics and the sieve analysis, hydrometer, plastic limits, clay particles, swelling tests performed to determine the mechanical characteristics of Bonab city's soils. The samples were classified by United States department of agriculture (USDA) classification system. Finally, the results of the laboratory tests were evaluated, classified and used to investigation of the swelling potential of Bonab clay.

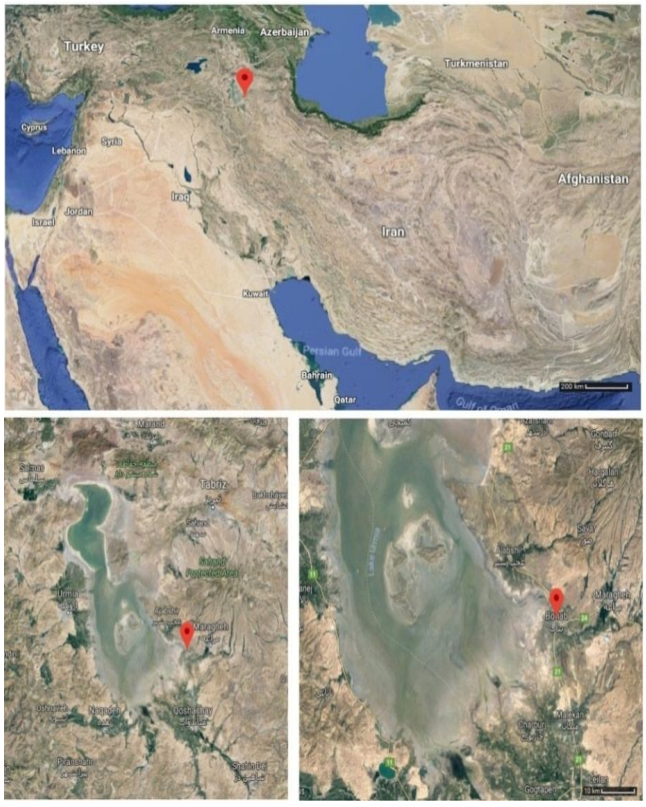

Figure. 2. Bonab city location in Iran (Google-earth, 2018)

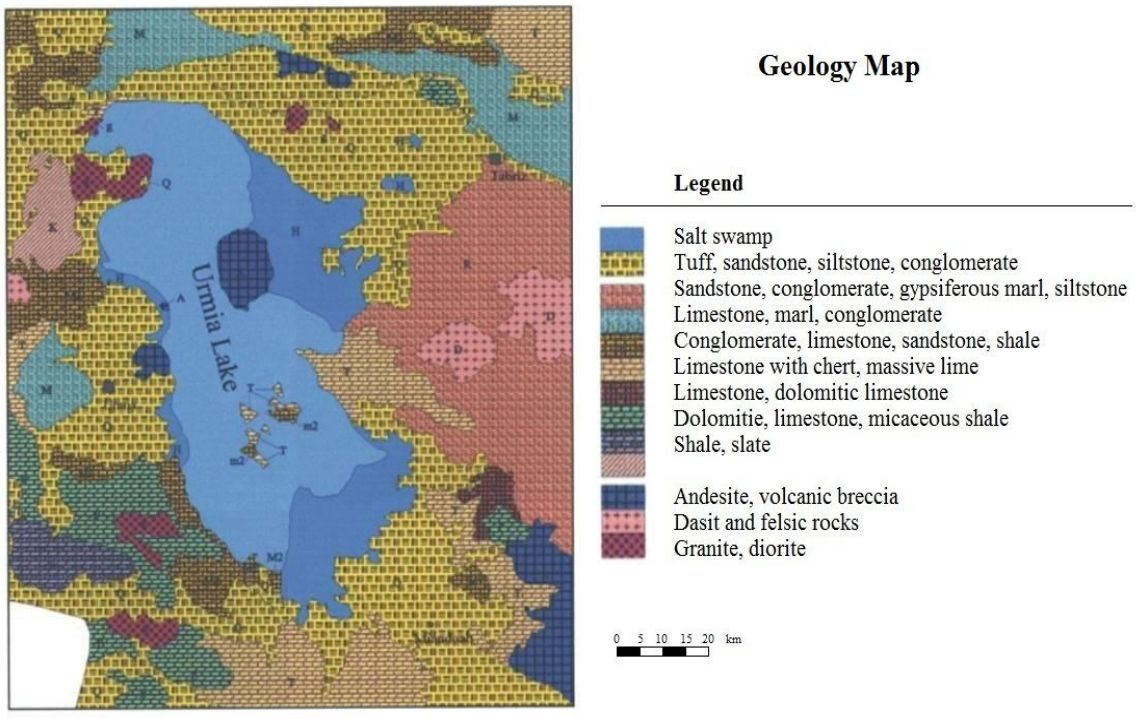

Figure. 3. The geological map of studied area (Azarafza and Mokhtari, 2013)

4. Results and discussions

4.1. Physical tests results

According to the results of the physical tests were conducted on the samples the Bonab clay has wide which is related to the climatic and geological conditions of the Bonab region. The Urmia Lake and Sahand volcanic mountain is the main geological structures were controlled these elements. Results of these tests are presented in the Table 1.

4.2. Chemical tests results

The chemical analysis is classified in XRD, sulfate-chloride and pH tests were performing by ASTM standards. The XRD is a determination technique used for structural study of materials crystals which is commonly used to the detection of the clay minerals (Drits and Tchoubar, 2012). For the XRD analysis, the samples are passed form the #200 sieve (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 minerals. The results of the XRD detection of the Bonab clay are illustrated in Table 2. As seen in this Table, the most minerals are detected form clay groups is smectite.

The sulfate-chloride and pH tests are conducted on some selected samples. As previously mentioned, the geological condition of East Azerbaijan (Azarafza et al., 2018) and Urmia Lake (Azarafza and Mokhtari, 2013) situation is make difficulty in Bonab region. The results of the sulfate-chloride and pH tests for Bonab clay are shown in Table 3.

4.3. Mechanical tests results

The mechanical properties of soils are performed for classification and swelling potential assessment of Bonab clay. The main mechanical tests is classified in sieve analysis, hydrometer, plastic limits, clay particles, swelling tests were conducted on the samples based on the ASTM standard. The sieve analysis was used for particle size distribution and hydrometer was used to fine-grained particles (silt and clay) calculation (ASTM C136/C136M). In the plastic limits is contains liquid limit (LL), plastic limit (PL), plastic index (PI) were obtained from the Casagrande standard test (ASTM D4318-10). The swelling test was used to the Bonab clay swelling potential assessment form the samples (ASTM D4546-14). The results of the mechanical investigation of the Bonab clay are illustrated in Table 4. Also, the USDA classification (Budhu, 2010) of the Bonab soil is presented in Figure 4.

Table 1 Results of the physical tests on Bonab soils

Parameters	Maximum	Minimum	Average
Water absorption (%)	15.5	8.3	11.9
Porosity (%)	72.6	40.1	56.3
Dry density (kN/m^3)	23.4	18.4	20.7
Saturated density (kN/m^3)	25.7	21.5	23.6
Specific gravity (G_s)	2.67	2.52	2.60

Table 2 Results of the physical tests on Bonab soils

Sample No.	XRD results (%)		
	Smectite	Kaolinite	Illite
Bonab-xrd-1	65	22	18
Bonab-xrd-2	45	40	15
Bonab-xrd-3	52	30	18
Bonab-xrd-4	58	21	21
Bonab-xrd-5	55	23	22
Bonab-xrd-6	73	24	3
Bonab-xrd-7	37	50	13
Bonab-xrd-8	35	46	19
Bonab-xrd-9	33	37	30
Bonab-xrd-10	67	22	11
Bonab-xrd-11	37	40	23
Bonab-xrd-12	66	22	12
Bonab-xrd-13	72	5	23
Bonab-xrd-14	55	374	11
Bonab-xrd-15	15	76	9
Bonab-xrd-16	55	27	18
Bonab-xrd-17	43	35	22
Bonab-xrd-18	38	32	30
Bonab-xrd-19	58	21	21
Bonab-xrd-20	42	28	30

Table 3 Results of the physical tests on Bonab soils

Sample No.	SO_4^-	Cl^-	pH
SC1	0.06	0.02	7.3
SC2	0.07	0.07	7.6
SC3	0.03	0.04	7.3
SC4	0.06	0.01	7.7
SC5	0.15	0.01	7.1
SC6	0.11	0.03	7.4
SC7	0.08	0.1	7.3
SC8	0.13	0.01	7.4
SC9	0.06	0.06	7.7
SC10	0.03	0.07	7.3
SC11	0.05	0.1	7.5
SC12	0.07	0.1	7.6
SC13	0.08	0.03	7.7
SC14	0.14	0.08	7.3
SC15	0.11	0.03	7.1
SC16	0.16	0.02	7.3
SC17	0.14	0.01	7.3
SC18	0.13	0.01	7.3
SC19	0.11	0.06	7.6
SC20	0.08	0.03	7.1

Table 4 The results of mechanical assessment from the Bonab clay

Sample No.	Classification	Sieve-hydrometer tests			Plastic test		
	USDA	Passing #200	Clay (%)	Silt (%)	LL (%)	PL (%)	PI (%)
B1	Clay	51	32	19	66	32	34
B2	Clay	49	24	25	49	30	19
B3	Silty clay loam	63	19	44	50	22	28
B4	Clay	57	30	27	55	27	28
B5	Silty clay	22	9	13	41	23	18
B6	Clay	74	45	29	57	34	23
B7	Silty clay	57	33	24	50	23	27
B8	Clay	80	64	16	67	35	32
B9	Clay	70	57	13	51	20	31
B10	Clay	62	43	19	66	33	33
B11	Silty clay	39	17	22	39	26	13
B12	Clay	74	54	20	43	27	16
B13	Clay	82	53	29	86	43	43
B14	Clay	78	67	11	51	33	18
B15	Silty clay	91	49	42	80	30	20
B16	Clay	13	10	3	51	30	21
B17	Silty clay	80	47	33	57	32	25
B18	Clay	73	54	19	70	35	35
B19	Silty clay	51	30	21	89	42	47
B20	Silty clay loam	22	7	15	33	20	13

5. Evaluation of swelling potential

The swelling is the clay minerals capability to water absorption and dilatation which causes many things to happen. In term of the geotechnical engineering, the swelling is assigned as risk for civil engineering projects especially light structures such as buildings, hydraulic channel, highways, power-transmission lines, wastewater installations and pavements (Soltani et al., 2017), but term of the agricultural, the swelling in limited range is suitable to forming (Velde, 2001). However, having a proper view of clay minerals characteristics help to know the swelling

phenomenon. In other hand the quantitative changes of clay particles and types is directly affected on swelling potential which base on some researchers works the smectite increases compared to the other clay groups taking further stimulate swelling which by using the empirical equations/methods is clearly measurable and main factor to clayey soil behaviors pre-assessment. Ylmaz is prsented the plastical based diagrams for the assessment of the swelling activity of clayey soils (Yilmaz, 2006) which is used to classification of Bonab clay was shown in Figure 5. According to this figure, the Bonab clay have medium to high and very high swelling potential and some samples shown the low activity.

The classification of the swelling potential in medium to high and very high potential for Bonab clay is shown the mentioned clay is located the special case of consideration and good to bad potential for the forming and very bad condition for the construction based on the geotechnical activity. Thus, looking the Bonab as agricultural region is suitable but form any civil activity must be serious consulting with geotechnical advisors before any constructions.

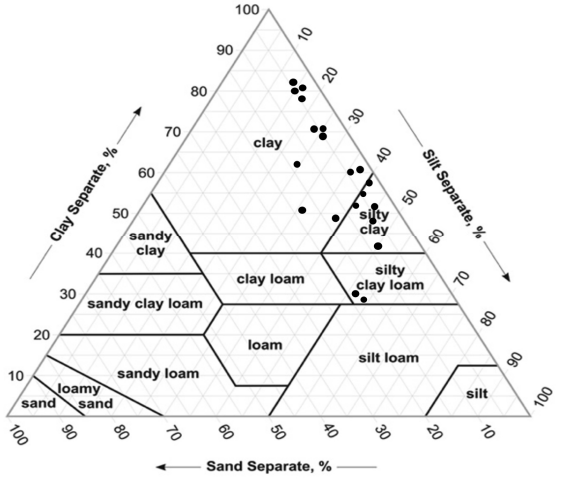

Figure. 4. The USDA classification of the Bonab soils (Budhu, 2010)

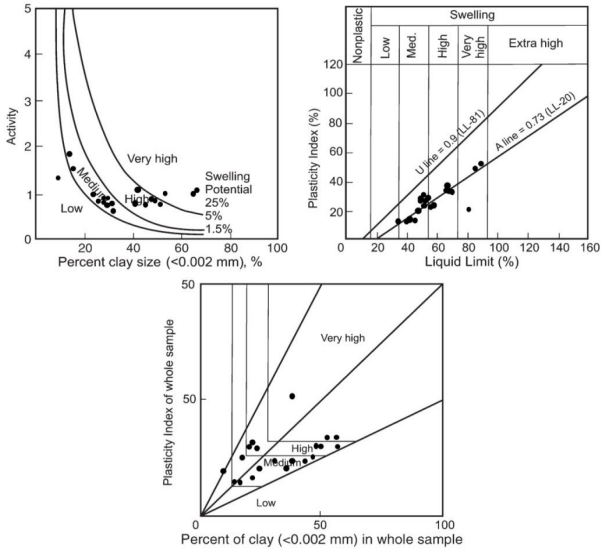

Figure. 5. The swelling activity chart (Yilmaz, 2006)

6. Conclusion

This study focused on the Bonab clay characteristics were located in west of Maragheh county on the outwash plain of Urmia Lake in East-Azerbaijan province, NW of Iran. Geologically Bonab is covered by the Quaternary alluvials and recent soils which mostly is fine-grained contains different amounts of clay minerals where causes several events like swelling. In order to assessment of the swelling potential and characteristics of Bonab soils and establish relationships between these properties, the extensive field study especially on the agricultural fields (Bonab is the agricultural-based city), sampling and laboratory tests (classified in physical, chemical and mechanical) are conducted. For the reducing the investigation's errors, the 20 different location is selected and sampling is taken as representative. According to the results of these tests, water absorption (%) is 8.3 to 15.5, porosity (%) is 40.1 to 72.6, dry density (kN/m3) is 18.1 to 23.4, saturated density (kN/m3) is 21.5 to 25.7 and specific gravity is 2.52 to 2.67 estimated as physical features. In term of chemical evaluation of Bonab clay, the SO4- is measured as 0.013 to 0.15, Cl- is measured as 0.01 to 0.08 and pH is measured as 7.1 to 7.7. Regarding the mineralogical test results from the XRD, the main clay mineral groups is classified as smectite, kaolinite, illite and the secondary groups is classified as chlorites and vermiculites. By using the USDA classification for Bonab clay, these soils are classified in clay, silty clay and silty clay loam. According to the mechanical results, USDA classification and indirect method which utilized on swelling potential assessment, the Bonab clay is investigated were shown have medium to high and very high swelling potential and some samples shown the low activity. Although, this classes of clay is proper to bad assortments agriculture, but is certainly is bad for construction and geotechnical projects.

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