SWELLING POTENTIAL AND MINERALOGY OF THI – QAR UNIVERSITY SOIL

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Abstract:

In this study, the results of geotechnical (physical) properties were used for assessing the swelling potentials of the studied area (Thi – Qar University) in addition to the mineralogical composition for these soils. Mineralogically, Montmorillonite was identified as being the main clay mineral, followed by Illite and Kaolinite in addition to the presence of non – clay minerals Calcite, Quartz, Feldspar and Dolomite. Geotechnical studies show that Liquid limits and plasticity indexs range from 38% - 61% and from 13% - 30% respectively. According to USCS, these soils are mainly high liquid limit sandy silty clay (CH), low liquid limit sandy silty clay and low liquid limit sandy clayey silt (CL and ML) respectively. Activity values revealed that the soils are mainly non active (80%) – normally active (20%) and the consistency of the soil is (plastic – semisolid).The assessment of soil expansivity based on index properties and activity show a large percentage of the expansive soil. Also, there is concordance between the results of the soil expansivity which obtained from the soil swelling assessment based on the analyses of its index properties and the results of mineralogical tests for these soils.

Introduction

Expansive (swelling) soils are under some changes in natural conditions, environmental factors are capable of increasing or decreasing their volume when wetted or dried (Komorowska, 2003). Then, they cause sever problems for road construction, building foundation, underground work and slope stability such as cracks, collapse and slips (Venkataswamy *et al*., 2003).The change in volume is influenced by the kind and amount of clay in the soil because of the presence of clay minerals especially Montmorillonite and Illite in any percentage is to be the most important controlling factor for many geotechnical properties such as swelling and shrinkage, and the knowledge of clay minerals composition provides an understanding of the empirical test which will simplify geotechnical problems and perhaps avoid construction failure. The objective of the present work is to study the ability of the studied soil to swell according to the results of the physical properties in addition to the results of mineralogical tests for this soil.

Selected site and geological setting.

The target area is located in Al - Nassiriya city, the centre of Thi – Qar Governorate which is located in South of Iraq. The study area includes two sites, namely, University Main site (site1) and Medical and Pharmacy College site (site2), Figure1.

Climate in the Nassiriya region is characterized by dry continental, hot summer and cold rainy winter. From the tectonic view point, Al-Nassiriya city is located in the Euphrates Subzone of the Mesopotamian Zone of Unstable Shelf. The sites are covered by recent alluvial sediments of Euphrates river which are composed of clay and silt (Mandhour, 2008).

Methods of research

One pit was excavated from the surface to depth of 5.00m and four soil samples were collected at site1 during (2007) in addition to the soil investigations which were conducted by the Consulting Engineering Bureau – University of Kufa at site2 (2000). The physical properties of soil samples: mechanical sieve analysis and hydrometer analysis, liquid limit(LL), plastic limit (PL) and plasticity index (PI), the natural water content (mc) were determined according to the British standard (BS1377; 1975) and American Society for Testing and Materials (ASTM; 1973 and 1984). Mineralogical tests (Clay Minerals and Non Clay Minerals) were done at the State Company of Geological Survey and Mining according to (Thorez, 1976; Grim, 1968).

The soil of the Mineralogy

study area is examined by X – Ray diffraction method (XRD) to determine Clay and Non Clay minerals, the Figures 2and 3 show typical XRD patterns for a selected The mineral content of soil which is collected from typical samples.

two sites (at depth 1.0 – 2.0m) appear to be formed from group of Non Clay minerals (Calcite, Quartz, Feldspar and Dolomite) and group of Clay Minerals (Montmorillonite and Illite) which are the dominated clay minerals with less amount of Kaolinite. Summary of the XRD results are given in Table1.

The physical properties of the soil

The grain size analyses of the study area are summarized inTable2.In site1, the percentage of the silt fraction ranged between 52 – 63 % on average 58 %, clay 30 – 45%, averaging 37% and sand 3 – 7%, averaging 5%.While in site2, silt ranges 47 - 64%, averaging 56.83%, clay 22 – 50%, averaging 35.5% and sand 1 – 16%, averaging 7.66%.

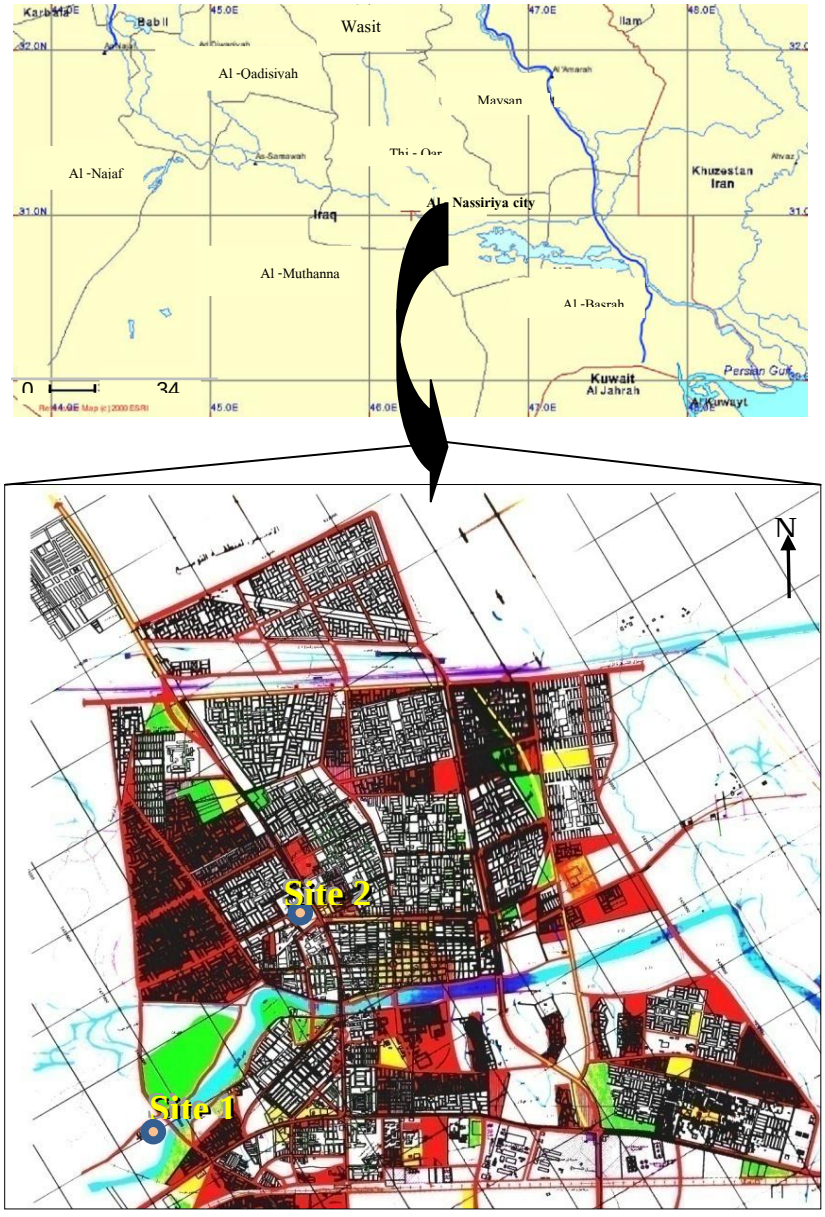
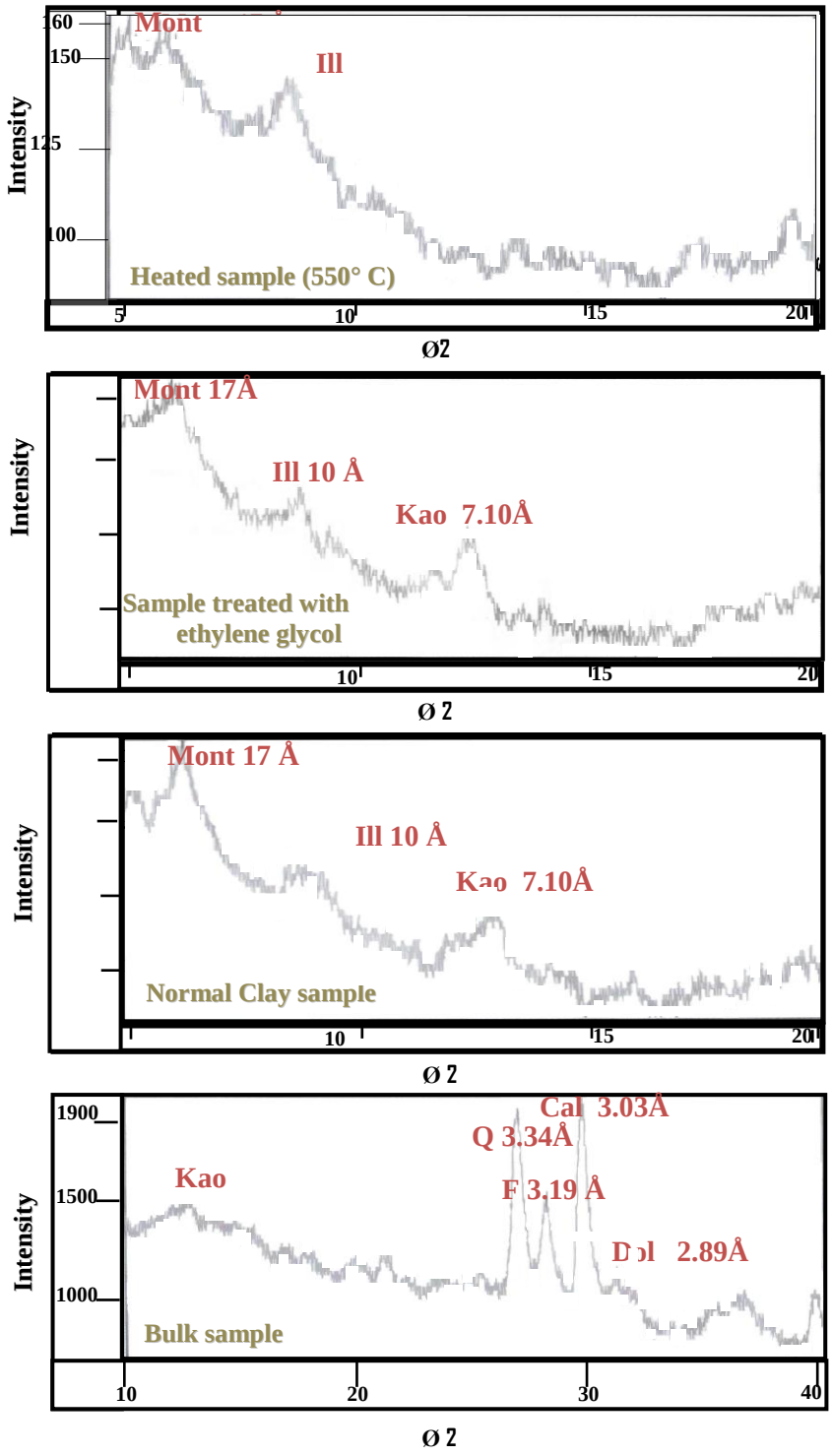


Figure 1. Illustrates maps of Al-Nassiriya city and locations of the study area

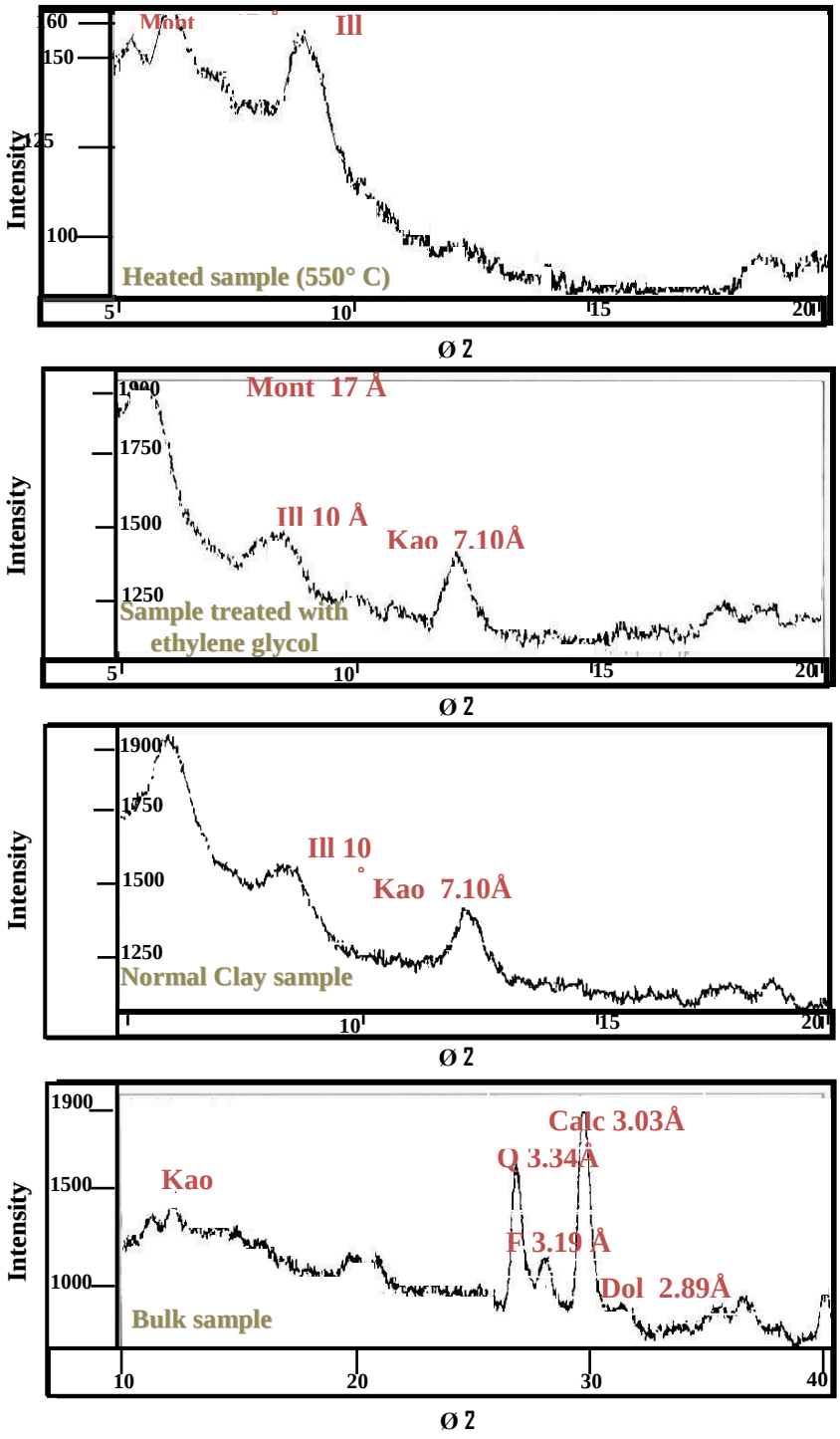
It can be seen that the particle size distribution for samples showed high percentage of fine soil with low different percentage of sand. On the other hand, these results showed that 100% of samples in site1 are sandy silty clay while in site 2, 83% of samples are sandy silty clay and 17% are sandy clayey silt (Table3). In site1, liquid limit(LL) values of the soil range 48 – 60%, averaging 53%.While in site2, liquid limit values of the soil range 38 – 61%, averaging 50.30% (Table3).The high or low percentage of liquid limit and plasticity index might be influenced by the percentage of different clay minerals.



Where

Kao: Kaolin Ill: Illite Mont: Montmorillonite
Q: Quartz Calc: Calcite
F: Feldspar Dol: Dolomite

Figure 2. X-ray diffraction for site 1.



Where

Kao: Kaolin Ill: Illite Mont: Montmorillonite
Q: Quartz Calc: Calcite
F: Feldspar Dol: Dolomite

Figure 3. X-ray diffraction for site 2.

Table1: The clay mineral composition of the tested soils

Tested soil	Percentage of valid clay minerals		
	Montmorillonite	Illite	Kaolinite
Site1	50%	28%	22%
Site2	62%	18%	20%

Table 2: Percentage of soil components for samples of soils in the studied area.

site	Depth of samples (m)	Particle size distribution%				Fine fraction%
		clay	silt	sand	gravel	
1	1.0 - 2.0	38	56	6	0.00	94
	2.0 - 3.0	45	52	3	0.00	97
	3.0 - 4.0	30	63	7	0.00	93
	4.0 - 5.0	34	62	4	0.00	96
2	1.0 - 2.0	45	54	1	0.00	99
	2.0 - 3.0	34	59	7	0.00	93
	4.0 - 5.0	23	61	16	0.00	84
	6.0 - 7.0	22	64	14	0.00	86
	7.0 - 8.0	39	56	5	0.00	95
	9.0 – 10.0	50	47	3	0.00	97

Table 3: Classification of the soils in the studied areas according to USCS.

site	Depth of samples (m)	Atterberg Limits%			mc	Ic Ic = (LL-mc)/PI	Soil class	Description of soil
		LL	PL	PI				
1	1.0 - 2.0	50.5	27.5	23	26.95	1.023	CH	Sandy silty clay
	2.0 - 3.0	60	30	30	32.158	0.928	CH	Sandy silty clay
	3.0 - 4.0	48	26	22	33.3	0.668	CL	Sandy silty clay
	4.0 - 5.0	53	27	26	31.75	0.817	CH	Sandy silty clay
2	1.0 - 2.0	57.66	29	28.66	29.83	0.971	CH	Sandy silty clay
	2.0 - 3.0	51.5	26.5	25	27.55	0.958	CH	Sandy silty clay
	4.0 - 5.0	41.66	24.33	17.33	28.93	0.734	CL	Sandy silty clay
	6.0 - 7.0	38	25	13	29.9	0.623	ML	sandy clayey silt

	7.0 - 8.0	52	27.5	24.5	18.83	1.353	CH	Sandy silty clay
	9.0 – 10.0	61	31	30	38.6	0.746	CH	Sandy silty clay

CH = in organic clays of high plasticity; CL = in organic clays of low plasticity; ML= in organic silts of low plasticity; LL = liquid limit; PL = plastic limit; PI = plasticity index; mc = natural water content; Ic = consistency index.

Plastic limit(PL) values in site1, range between 26– 30%, averaging 28% while in site2, plastic limit values range between 24.33 – 31%, averaging 27.22% (Table3). plasticity index (PI) values of the soil in site1, range between 22 – 30%, averaging 25% (Table3). In site2, plasticity index values of the soil range between 13 – 30%, The soil of the study area were classified according to liquid limit averaging 23.08%. depending on (Kerbs and Walker, 1971) classification. (Table 4). Accordingly, in site1, 75% of samples are of high liquid limit and 25% of intermediate liquid limit while in site2, 67% of samples are of high liquid limit and 33% of intermediate liquid limit. On the other hand, the soil of the study area were classified according to plasticity index depending on (Kerbs and Walker, 1971) classification. Accordingly, all samples in site1 are plastic (100%) while in site 2, 83% of samples have plastic and 17%of moderately plastic (Table 4).

Table 4: Classification of the the fine grained soils in the studies areas according to (Kerbs and Walker,1971).

site	Depth of samples (m)	Liquid limit		Plasticity index	
		Percent	Description	Percent	Description
1	1.0 - 2.0	50.5	High liquid	23	Plastic
	2.0 - 3.0	60	High liquid	30	Plastic
	3.0 - 4.0	48	Intermediate liquid	22	Plastic
	4.0 - 5.0	53	High liquid	26	Plastic
2	1.0 - 2.0	57.66	High liquid	28.66	Plastic
	2.0 - 3.0	51.5	High liquid	25	Plastic
	4.0 - 5.0	41.66	Intermediate liquid	17.33	Plastic
	6.0 - 7.0	38	Intermediate liquid	13	Moderately plastic
	7.0 - 8.0	52	High liquid	24.5	Plastic
	9.0 – 10.0	61	High liquid	30	Plastic

Figure 4 gives a clear overview over the plasticity properties of study area, the soil type in site1 is mainly sandy silty clay of high plasticity of CH – group 75% and sandy silty clay of low plasticity of CL – group 25%.While in site2, the soil type is mainly sandy silty clay of high plasticity of CH – group 67%, sandy silty clay of low plasticity of CL and sandy clayey silt of low plasticity of ML groups (16.5% for each one) (Table3).

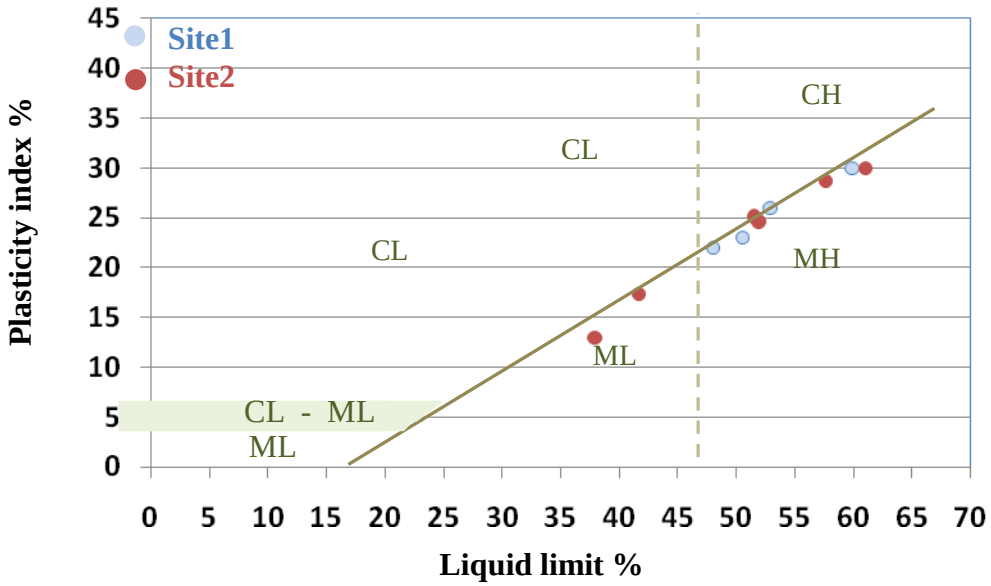


Figure 4. Plasticity chart for the soil of the study area.

Consistency index (Ic) values of the soil area are computed according to (Lambe and Whitman, 1969) therefore in site1, consistency index values range between 0.668 - 1.023, averaging 0.859 (Table3). In site2, consistency index values range between 0.623 – 1.353, averaging 0.897. Both sites have values of consistency index more than zero (0.00) and almost less than one (1.00) except one sample in each site has a value of more than one (1.00), that means the soils are plastic state in general to semisolid state.

Swelling potential and degree of expansion

Swelling potential refers to the amount of volume increase due to swelling that is possible in a clay in its natural environment. The soil expansion assessment is based on such parameters such as: activity, percentage of clay and types of clay minerals, liquid limit and plasticity index.

The effect of activity and clay percentage on expansion:

The activity of soil is computed according to the following relation (Bowles, 1984).

$$\text{Activity} = \frac{PI}{Clay\ (less\ than\ 2\ micron)\%}$$

The soil activity in the studied area is classified according to Skempton classification (1953). Accordingly, activity of the soil in site1, ranges between 0.605 – 0.764, averaging 0.692 indicating non active to normally active clay (Table 5 and Figure 5). In site2, activity of the soil ranges 0.59 – 0.753, averaging 0.557 indicating non active to normally active. The swelling potential for soil is related to its activity and clay content (Seed *et al.*, 1962).

$$S = K.ACT^{2.44}.C^{3.44}$$

Where:

S = swelling potential.

K = a constant for all types of clay mineral ≈ 3.6×10^{-5}

ACT = activity.

C = clay content.

Accordingly, from the values obtained from the studied soils, we notice that the values of swell potential for the study area in site1 depending on activity method range between 3.177 – 8.679, averaging 5.25 (Table5). In site2, the values of swell potential range between 0.774 – 9.333, averaging 4.814. According to the results of swelling potentials, 50% of samples (2 samples) have high degree of expansion and the same percentage, 50% of samples (2 samples) have medium degree of expansion in site1.While in site2, 50% of samples (3 samples) have medium degree of expansion, 33% of samples (2 samples) have high degree of expansion and 17% of samples (1 sample) have low degree of expansion.

Table 5: Activity, Swelling and Degree of Expansion for samples of soils in the studied area.

site	Depth of samples (m)	Activity		Swelling potential and degree of expansion according to activity method	
				Swelling potential	Degree of expansion
1	1.0 - 2.0	0.605	Non active	4.043	Medium (M)
	2.0 - 3.0	0.666	Non active	8.679	High (H)
	3.0 - 4.0	0.733	Non active	3.177	Medium (M)
	4.0 - 5.0	0.764	Normally active	5.107	High (H)
2	1.0 - 2.0	0.636	Non active	7.75	High (H)
	2.0 - 3.0	0.735	Non active	4.647	Medium (M)
	4.0 - 5.0	0.753	Normally active	1.583	Medium (M)
	6.0 - 7.0	0.59	Non active	0.774	Low (L)
	7.0 - 8.0	0.628	Non active	4.802	Medium (M)
	9.0 – 10.0	0.6	Non active	9.333	High (H)

It can be seen that the swelling potential values are fluctuating with depth corresponding with the variation of clay content since the swelling of soil depend on grain size distribution, the percentage content of clay fraction in addition to the mineralogical composition of the soil mainly the clay fraction (Komorowska, 2003). Therefore, the reduction in the value of swelling potential and in turn in the

expansion degree may be due to the decrease in clay percentage and increase in sand percentage (Table2).

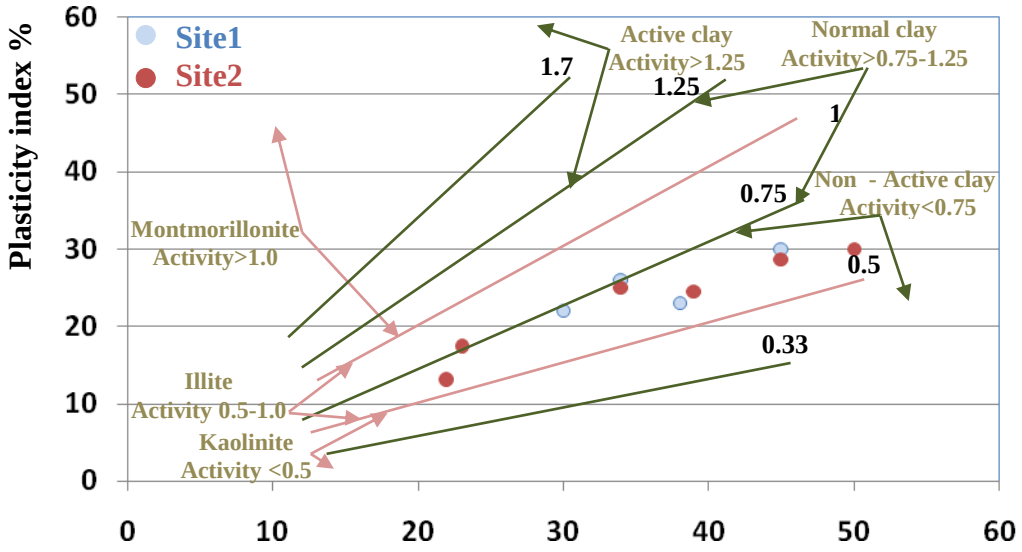


Figure 5. Activity values of samples in the studied area on activity chart (Skempton, 1953).

The effect of liquid limit or plasticity index on expansion:

The expansion of soil can be obtained from a single parameter depending on liquid limit or plasticity index (Tables 6) according to BIS1498 (Bureau of Indian Standards),1970 (cited in Sridharan and Prakash, 2000). Accordingly, the studied area in two sites has medium – high expansion (Tables 7 and 8). Thus, in site1, 75% of samples have high degree of expansion and 25% of samples have medium degree of expansion while in site2, 67% of samples have high degree of expansion and 25% of samples have medium degree of expansion depending on liquid limit or plasticity index.

According to Chen (1975), the studied area in site1 has high expansion depending on liquid limit and medium – high depending on plasticity index (Tables 7 and 8). Thus, 100% of samples have high degree of expansion depending on liquid limit and 100% of samples have medium to high degree of expansion depending on plasticity index.

The studied area in site2 has medium – high – very high expansion depending on liquid limit and low – medium – high expansion depending on plasticity index (Tables 7 and 8). On the other hand, 67% of samples have high degree of expansion, medium and very high degree of expansion (16.5% for each one) depending on liquid limit. While depending on plasticity index, 67% of samples have medium to high degree of expansion and the remaining low to medium and medium degree of expansion (16.5% for each one).

According to Seed *et al.* (1962), the expansion

degree of the soil has been assessed based on the relation between their liquid limit and swelling potential.

$$S = 3.75\times10^{-4}\times LL^{2.658}$$

Where:

S = swelling potential.

LL= liquid limit

Accordingly, 100% of samples have high degree of expansion in each site (Table 7).

Table6: Soil expansion prediction by liquid limit or plasticity index.

Degree of expansion	LL		PI	
	BIS 1498 (1970)	Chen (1975)	BIS 1498 (1970)	Chen (1975)
Low	20 - 35	<30	<12	0 -15
Medium	35 – 50	30 – 40	12 – 23	10 – 35
High	50 – 70	40 – 60	23 – 32	20 – 35
Very high	70 - 90	>60	>32	>35

Table 7: Soil expansion prediction by liquid limit.

site	Depth of samples (m)	LL	Degree of expansion according to			
			Seed *et al.* (1962)		BIS 1498 (1970)	Chen (1975)
			Swelling%	Degree of expansion		
1	1.0 - 2.0	50.5	12.629	High	High	High
	2.0 - 3.0	60	19.969	High	High	High
	3.0 - 4.0	48	11.034	High	Medium	High
	4.0 - 5.0	53	14.360	High	High	High
2	1.0 - 2.0	57.66	17.965	High	High	High
	2.0 - 3.0	51.5	13.305	High	High	High
	4.0 - 5.0	41.66	7.572	High	Medium	High
	6.0 - 7.0	38	5.930	High	Medium	Medium
	7.0 - 8.0	52	13.651	High	High	High
	9.0 – 10.0	61	20.865	High	High	Very High

Table8: Soil expansion prediction by plasticity index.

site	Depth of samples (m)	PI	Degree of expansion according to	
			BIS 1498 (1970)	Chen (1975)
1	1.0 - 2.0	23	High	Medium - High
	2.0 - 3.0	30	High	Medium - High
	3.0 - 4.0	22	Medium	Medium - High
	4.0 - 5.0	26	High	Medium - High
2	1.0 - 2.0	28.66	High	Medium - High
	2.0 - 3.0	25	High	Medium - High
	4.0 - 5.0	17.33	Medium	Medium
	6.0 - 7.0	13	Medium	Low - Medium
	7.0 - 8.0	24.5	High	Medium - High
	9.0 – 10.0	30	High	Medium - High

Means and parcher (1963) suggest that the liquid limits greater than 50% indicates the presence of Montmorillonite (cited in Erguler and Ulusay, 2003). Accordingly, 70% of the samples in this study satisfies this condition and in turn there is good agreement between the liquid limits values and XRD tests results.

According to Tables 7 and 8, the classification do not give the same assessment of the swelling potential of the soils, but on the other hand in general all the studied soils Vijayvergiya and Ghazzaly (1973) are expansive according to these parameters. classification was used to assess the soil expansion on the basis of the plasticity limit and the plasticity index (cited in Djedid and Mamoune, 2001). The Casagrande plasticity chart is divided into two zones by the line A, expansive soils above the line and non – expansive soils below the line. Accordingly, analyses of the Casagrande chart suggests that almost all samples from both sites show intermediate and high plasticity, in turn a medium and high expansive soil should be expected (Figure 6).

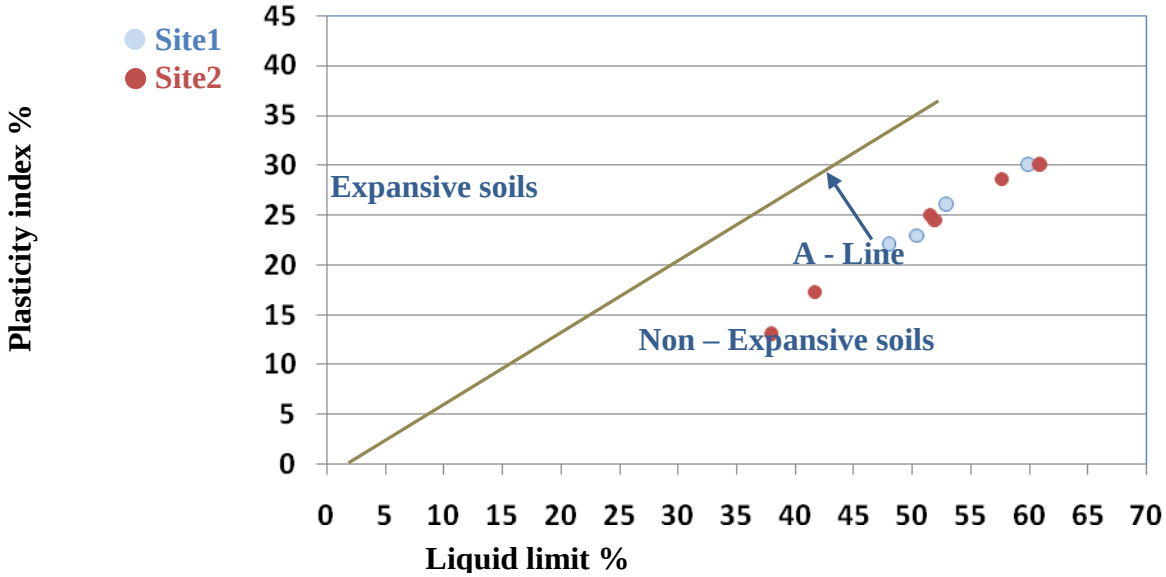


Figure 6. Effect of Plasticity on Expansion potential Vijayvergiya and Ghazzaly , 1973 (cited in Djedid and Mamoune, 2001)

The effect of clay minerals on expansion:

X –Ray diffraction was used for identifying types of clay minerals in soil in order to assess its activity for swelling potential. Most of researchers tend to agree that soil expansion is related to type and amount of clay minerals. Also they prone to agree that clay minerals are the primary cause of soil volume change (Mojekwu, 1979). The active clays provide the most potential for swelling and the
Kaolinites are the least active, followed by Illites. Montmorillonite is the most active and has the capacity to swell by taking water molecules directly into its space lattice (Thomas, 1998). On the other hand, the expansive soils are characterized by the presence of high active minerals of the Montmorillonite which are responsible for the pronounced volume change capability of the soils (Sridharan and Prakash, 2000). Three clay mineral are identified in studied area (sites 1 and 2),
Montmorillonite is dominant, followed by Illite and Kaolinite (Kaolinite is a non expansive clay minerals). Generally, because of the content of clay minerals and the domination of montmorillonite, the clay should be expansible. On other hand, the presence of clay minerals especially Montmorillonite (the dominant mineral) gives a good agreement with the assessment of a soil expansivity based on index properties.

Conclusions:

From the above discussions it can be said that:

1- **The soil in the studied area might be considered as a high plasticity sandy silty clay (CH) and as a low plasticity sandy silty clay or sandy clayey silt (CL and ML).**
2- **Liquid limit classification (Kerbs and Walker, 1971) reveals that the soils of the studied areas are of intermediate – high plasticity.**
3- **Plasticity index classification (Kerbs and Walker, 1971) reveals that the soils of the studied areas are plastic in almost all samples except one sample in site 2 has moderate plasticity.**
4- **The soils are plastic – semisolid according to the results of the consistency index.**
5- **Activity values reveal that the soils of studied area are mainly (80%) non active and (20%) normally active.**
6- **The criteria based on liquid limit, plasticity index and activity show a large percentage of the expansive soils.**
7- **All of the examined soils in the studied area are expansive according to Casagrande plasticity chart.**
8- **The assessment of soil expansivity based on index properties don't give the same results.**
9- **Clay fraction of the studied area are composed of Montmorillonite, Illite and Kaolinite respectively. Montmorillonite is the main clay minerals reaching to 50% and 62% at sites 1 and 2 respectively,followed by Illite 28% and 18% and Kaolinite 22% and 20% for sites 1 and 2 respectively.**
10- **The non clay minerals are Calcite, Quartz, Feldspar and Dolomite.**
11- **In spite of that the index properties such as liquid limit, plasticity index and related parameters cannot satisfactorily predict the soil expansivity compared with the results of the clay mineralogy for soils, there is concordance between the results of the**

soil expansivity which obtained from the analyses of its properties and parameters in addition to the results of mineralogical tests for these soils.

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جهد انتفاخ ومعدنية تربة جامعة ذي قار

إسراء عبد الأئمة منذور الفتلاوي
دكتوراه جيولوجيا هندسية ـ جيوتكنيك

المستخلص

تم في هذه الدراسة استخدام نتائج الخواص الجيوتكنيكية (الفيزيائية) لتقدير جهد انتفاخ تربة منطقة الدراسة (جامعة ذي قار) بالإضافة إلى التركيب المعدني لهذه التربة.
أظهرت الدراسة المعدنية إن هذه الترب تتكون بصوره رئيسة من معدن المونتيمورلونايت يليه الألايت والكاؤولينايت على التوالي إضافة إلى وجود المعادن غير الطينية (الكالسايت والكوارتز والفلسبار والدولومايت).
أظهرت الدراسة الجيوتكنيكيه بان التربة لها حدود سيوله ومعاملات لدونه تتراوح بين ٣٨% - ٦١% ومن ١٣% - ٣٠% على التوالي.
وحسب نظام التصنيف الموحد (USCS)، هذه الترب تتكون بصورة رئيسة من طين غريني رملي عالي اللدونة من مجموعة CH وتربة طين غريني رملي واطئ اللدونة من مجموعة CL وغرين طيني رملي واطئ اللدونة من مجموعة ML.
قيم فعالية التربة تشير بصوره رئيسه إلى أطيان غير فعالة ٨٠% وأطيان ذات فعالية اعتيادية ٢٠% وان قوام التربة (لدنة – شبه صلبه).
حسب معاملات القوام وفعالية الأطيان فالتصنيفات المستخدمة في تقدير الانتفاخ للتربة أظهرت بأنها تربة انتفاخية بنسب كبيره مع إن هذه التصنيفات لم تعط نفس النتائج.
أظهرت الدراسة وجود توافق بين نتائج انتفاخية الترب المستنبطة من تقدير الانتفاخية بواسطة تحليلات معاملات القوام وبين نتائج الاختبارات المعدنية لهذه الترب.