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RESEARCH ARTICLE

Gypsiferous Soil Analysis of Samara-Tikrit Area-Iraq

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Abstract

The soil properties are an important parameter for architectural and structural design of structures. Samara-Tikrit area in Iraq is a tourist destination, so in the last decade a number of multistory buildings, roads, etc. have been constructed. This study investigates the properties of the soil to give a base data, which can be used for the future construction design. This work aims investigating the gypsiferous soils texture, mineralogy and to interpret their geotechnical characteristics in Samara-Tikrit area, Iraq. A total of thirteen (13) soil samples were taken of gypsiferous soils distributed on three (3) sites. The results of grain-size analysis show that mixture of sand with variable percentages of clay and the silt fractions. The soil profile in site 1 reflect that the upper (0.9) m. is of sandy clayey silt, whereas the lower (2) m. is of silty sandy clay. The deep soil is of silty and clayey sand that reach 4.5 in depth. Concerning the soil profiles in site 2 and 3 representing silty sandy clayin general and silt beds occur at site 3. The soils within the three sites are fine-grained, yellowish light brown, moderately to highly gypsum, ranging from friable to very hard gypsiferous soil. The results of thin section are indicating that gypsum ranges from 12.3-35.4 %; clay comprise 12.0-26.2 %, while calcite and dolomite are from 9.6- 23.2 %. Quartz and Chert grains are ranging from 11.3- 26.0 %. Feldspar is ranging between 9.3- 19.0 %, while rock fragments is ranging from 7.2-15.7%, with heavy minerals ranging from 0.8 -1.9%. The X-ray diffraction analysis reflects that non-clay type minerals are quartz, calcite, dolomite, gypsum and feldspar; while the clay minerals are chlorite, smectite, kaolinite, illite and palygorskite .The geotechnical properties results reflect that six samples (1a, 1c, 1d,2c, 2d, 3b) are classified as gypsiferous soil with less than 25% gypsum content and with less values of initial void ratio, coefficient of curvature, uniformity coefficient, collapse potential %, compression strength, cohesion, and plasticity index % while the other seven samples (1b,1e,2a,2b,2e,3a,3c) are classified as highly gypsiferous soil with more than 25% gypsum content and with relatively higher values of initial void ratio, coefficient of curvature, uniformity coefficient, collapse potential %, compression strength, cohesion and plasticity index% .

Keywords: *Gypsiferous soil, Texture, Mineralogy, Samara-Tikrit area, Iraq.*

Introduction

The soil properties are an important parameter for architectural and structural design of structures. Samara-Tikrit area in Iraq is one of the famous tourist destinations, so in the last decade a number of multistory buildings, schools, etc. have been constructed. This study investigates the properties of the soil to give a base data, which can be used for the future construction design. The basic objectives of research are to predict the properties of the stratigraphy and nature of subsurface materials, then analyze it and their expected behavior under the structure loadings and to permit savings in design and constructions costs. The soil samples used in the study were brought from Samara-Tikrit area east of Tigris River. The soil samples were obtained from a depth of about (0-4.6) m below the natural ground surface; the textural and mineralogical properties of the soils are investigated. The secondary gypsum-rich crust soil is the main constituents of gypsiferous soils that are widely spread in Iraq. Gypsiferous soils are common in the Quaternary sediments of continental origin and appear to have developed in certain episodes of arid and warm climatic conditions. The gypsiferous soils represent one of the poorest agricultural soils that only a few crops can survive their salinity, where gypsum reduces the fertility of the land by decreasing its clay content. Gypsum authigenically grows within the soil on the expense of original soil components including the clay. It is developed after sedimentation of the soil material by increasing evaporation of saline and sulphate-rich groundwater in arid and warm regions. It replaced the original soil components physically and chemically. Gypsum may be transported by wind from the erosion of the primary and secondary gypsum deposits to form gypsiferous sand dunes and sand sheets composed mostly of gypsarenite. Gypsiferous soils retain most of the original soil components (clay, silt and sand) but, impregnated by variable amounts of gypsum; as nests or disseminations. Fine-grained soils contain more gypsum than coarse grained soils [1] Almost; all gypsum accumulates above capillary water zone; in dry areas at which water table is located at about 3 m below ground surface [2, 3].

However, the Gypsiferous Soils are believed to be constructed from the primary gypsum within Al-Fatha Formation that had been precipitated by sea water, while secondary gypsum formed by dissolving primary gypsum rocks at source area and deposited at younger formations as river terraces and river sediments in Holocene [1]. A large part of gypsum accumulation occurs at subsoils, fine-grained soils contain more gypsum than coarse grained soils. Almost all gypsum accumulates above capillary water zone in dry areas at which water table is located (2.5-3) m. from surface; ground water will evaporate [2].

The Gypsiferous Soils and gypcrete are more consolidated and may form mechanically solid crust. This work deals with study of gypsiferous soils in Samara-Tikrit area. The Geology of the studied area lies in the unstable shelf of the Arabian plate within the northern part of the Mesopotamian zone . The exposed Geological units are Al-Fatha, Injana and Miqdadiya Formations of the Tertiary sediments at Al-Fatha northwards and Himrin mountain eastwards. Al Fatha Formation is enriched with gypsum and gypseous rocks and is a significant source area of gypsiferous soil and gypcrete formation within the area. Quaternary sediments cover the underlying Tertiary formations as constitutes almost all the soil of the studied area, as follows:

Alluvial fan deposits: Al-Fatha alluvial fan deposits are of significance source area for river terraces formation in the area, flood plain deposits of the Tigris River, and the erosional surfaces deposits of the surrounding hilly area. River terraces consist of conglomerates, sandstone, siltstone and claystone interfering with sand lenses appearing along Tigris river bank having width of (2.5) km in Samarra and covered by gypsiferous soil and gypcrete deposits of Holocene age.

Gypsiferous soil and Gypcrete deposits is a secondary gypsum enriched soil covers the studied area, extends to Al-Fatha northwards and to Al-Shari saltern eastwards. This soil is characterized by forming hard crust which is consolidated when dry and friable when moist [1], its thickness ranges from (30-100) cm from surface. Top Soil is a recent deposit consists from eolian deposits, different products of weathering and erosion, of which the texture is a mixture of clay, silt, sand, gravel, secondary gypsum and little carbonate, enriched with plant remnants, ranging in depth from (1-30) cm [1].

Many researchers had work on gypsiferous soils with different objectives either doing agricultural soil classification [4,5], or studying the characteristics of Sabkha and Shura Soils in some Iraqi regions for engineering purposes and preparing maps [6-8] There are some Iraqi studies dealing with different properties of the gypsiferous soil, such as the mineralogy and geochemistry of gypsiferous soils [9,10].The main aim of this work is to investigate the gypsiferous soils in terms of soil texture, mineralogy and geochemistry and to interpret the geotechnical characteristics of the gypsiferous soils in Samara-area Tikrit.

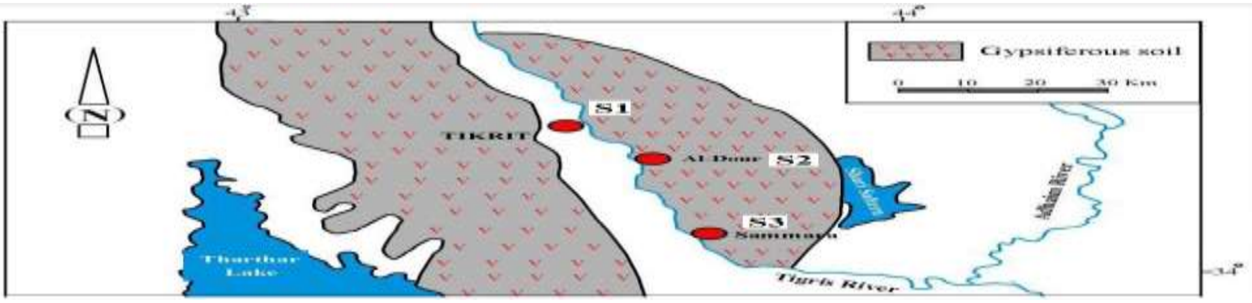

Fig. 1: Location map of the area studied (after Sissakian and Ibrahim, 2005 [6])

Methods of Work

Site Description

The study areais situated east of Tigris River, and included Samara-Tikrit area, which is located between latitudes 34º 00' and 35º 30', and longitudes 43º 30' and 44º 00' (Fig.1).Samples were collected from the Samara-Tikrit areawithin the northern part of the Mesopotamian zone in the Quaternary sediments of gypsiferous soils. Samples were collected when change in color and lithology occurs. A total of thirteen (13) soil samples were taken from this area distributed on three (3) sites, (Fig. 1).

Five samples from site one (4.5 m.thick), which are (1a, 1b, 1c, 1d and 1e), five samples from site two (4.6 m.thick), (2a, 2b, 2c, 2d and 2e) and three samples from site three (3.8m. thick) (3a, 3b and 3c).Regarding the soil profile in site 1, it is noticeable that the upper (0.9) m. is of sandy, clayey silt, the lower (1.2)m. is of silty, sandy clay, whereas to 3.9 m depth is clayey silty sand and to 4.5 m depth is silty clayey fine sand (Table 1).Concerning the soil profiles in site 2the soil profile is of alternating sandy silty clay and silty sandy clay until 4.6m depth ,while site 3 representings and y clayey silt to depth 1.7m, and clayey sandy silt to 2.6 depth ,whereas the lower part is sandy silty clay to depth 3.8m.In all sections the gypsum % generally show variable percentages Table 1.

The Field Work

The field work included collection of samples from earthsurface, or existing quarries within Samara-Tikrit area (Fig.1). Samples were taken at a maximum depth of 4.6 m. thirteen samples were taken distributed on three sites, (Table 1).

The Laboratory Tests

The laboratory tests included the following:

Grain size analysis was carried out for all samples using wet sieving and hydrometer method following [11]. Thirteen samples were thin sectioned and the textural components were studied under the optical microscope [12,13].As well as petrographic analysis (microscopic study) of these soil samples was performed on 13 thin sections. Moreover, Mineralogical analyses of Clay minerals and non-clay minerals analyses were performed on three representative soil samples (1b, 2a and 3a), which contain relatively high content of fines (silt + clay) using X-ray diffraction method.

Results and Discussion

Grain-size and Mineralogical Analyses

Grain-size Analysis results show that the soil samples are containing sand size grains with variable percentages of clay fraction and the silt fraction (Table 1). Regarding the soil profile in site 1, it is noticeable that the upper (0.9) m. is of sandy clayey silt, whereas the lower (1.0- 2.1) m. is of silty sandy clay, followed by clayeysilty sand from 2.2- 3.9.while from depth 4.0 to 4.5 is silty clayey sand. Concerning the soil profile in site 2 it is of alternating sandy silty clay and silty sandy clay from the surface to 4.6m depth. As to the soil profile in site 3, it is remarkable that the upper (1.7) m. is of sandy clayey silt, whereas the lower (1.8- 2.6) m. is of clayey sandy silt, while it is sandy silty clay from 2.7-3.8 m.

Comparing the soil within the three sites, it is evident that the lower part of the sites and the upper parts of the sites varies with different percentages of sand silt and clay. The gypsum mineral is dominated in all sections and increase relatively downward (Table 1). Moreover, it was found that the soils within the three sites are fine-grained, yellowish light brown, moderately to highly gypsiferous, ranging from friable to very hard gypsiferous soil.

Results of Thin Section Description

The results of thin section for all the studied sites 1, 2 and 3 are indicating that gypsum content ranges from 12.3-35.4 % with average value of 23.58 % ; claystone grains comprise 12.0-26.2 %with average value of 19.13%, while calcite and dolomite are ranging from 9.6- 23.2 %with average value of 13.41%.

Quartz and Chert grains of detrital origin are ranging from 11.3- 26.0 %with average value of 17.94%. Feldspar is represented by orthoclase, albite, and microcline ranging between 9.3- 19.0 %with average value of 11.65%, while rock fragments is represented by Igneous and metamorphic rock fragments ranging from 7.2-15.7%with average value of 12.7%. Minor heavy minerals detected in trace amounts; such as: hornblende, grains of iron oxide, biotite, chlorite, epidote, muscovite mica, amphibole, pyroxene, zircon, and tourmalineare present and ranging from 0.8 -1.9 %with average value of 1.3%. However, the average values of the soil content indicated that these constituents from the high percentages in descending order are as follow: gypsum, claystone, quartz and chert, calcite and dolomite, rock fragments, feldspars and heavy minerals. Such results reflect the relation of gypsum and claystone grains.

Table 1: Grain-size analysis of the studied samples (%)

Site	Sample No.	Depth, m	Clay %	Silt %	Sand %	Soil Description	Nomenclature [11]	Classification [14]
Site1	1a	0.1-0.9	32	37	31	Friable light brown, moderately gypsiferous.	sandy, clayey, silt	gypsiferous
	b	1.0-2.1	35	31	34	Very hard whitish light brown,highly gypsiferous	silty, sandy, clay	Highly gypsiferous
	c	2.2-2.9	30	34	36	Very hard whitish light brown, moderately gypsiferous	clayey, silty, sand	gypsiferous
	d	3.0-3.9	27	32	41	Very hard whitish light brown, slightly gypsiferous	clayey silty, sand	gypsiferous
	e	4.0-4.5	33	29	38	Friable yellowish light brown, highlygypsiferous.	silty, clayey sand	Highly gypsiferous
Site2	2a	0.1-1.0	39	31	30	Friable yellowish light brown, moderately gypsiferous.	sandy, silty, clay	Highly gypsiferous
	b	1.1-1.9	37	29	34	Friable light brown, highly gypsiferous	silty, Sandy, clay	Highly gypsiferous
	c	2.0-3.2	41	33	26	Friable whitish light brown, slightly gypsiferous.	sandy, silty, clay	gypsiferous
	d	3.3-4.1	45	25	30	Friable light brown, slightly gypsiferous.	silty, sandy, clay	gypsiferous
	e	4.2-4.6	43	30	27	Very hard light brown, highly gypsiferous	sandy, silty, clay	Highly gypsiferous
Site3	3a	0.2-1.7	32	39	29	Friable light brown, highly gypsiferous	sandy, clayey, Silt	Highly gypsiferous
	b	1.8-2.6	29	37	34	Friable light brown, slightly gypsiferous.	clayey, sandy, Silt	gypsiferous
	c	2.7-3.8	39	34	27	Hard light brown, highly gypsiferous	sandy, silty, clay	Highly gypsiferous

Table 2: Petrographic study results (%) as revealed by thin-section examination

Sample No.	Gypsum	Quartz and Chert	Feldspar	Calcite and/or Dolomite	Rock Fragments	Claystone Grains	Heavy Minerals
1a	18.3	19.9	11.2	17.5	13.4	17.7	1.9
B	28.3	13.3	9.3	13.7	15.3	18.7	1.2
C	12.3	26.0	10.0	23.2	15.1	12.0	1.3
D	14.0	21.2	19.0	9.6	12.0	23.2	0.9
E	30.7	19.8	12.4	11.5	10.9	13.3	1.3
2a	25.3	12.1	8.4	12.2	13.3	26.2	1.9
B	28.5	22.9	11.7	12.5	11.3	12.2	0.8
c	17.0	17.2	10.2	14.6	14.3	25.2	0.8
D	16.7	18.2	15.8	11.2	14.3	22.1	1.6
E	35.4	11.3	9.8	9.9	10.7	20.6	1.1
3a	32.3	12.4	10.5	12.6	11.6	18.9	1.5
B	21.2	18.6	13.4	9.6	15.7	19.5	1.7
C	26.5	20.3	9.7	16.2	7.2	19.1	0.9
Range	12.3 – 35.4	11.3 – 26.0	9.3 – 19.0	9.6 – 23.2	7.2 – 15.7	12.0 – 26.2	0.8 – 1.9
Average	23.58	17.94	11.65	13.41	12.7	19.13	1.3

The Results of X-ray Diffraction

The soil of the study area is examined by X-Ray diffraction method (XRD). Representative samples were prepared as bulk samples in order to study clay and non-clay minerals. The results reflect that non-clay type minerals, in the studied soils are: quartz, calcite, dolomite, gypsum and feldspar; while the clay minerals are chlorite, smectite, kaolinite, illite and palygorskite (Figs. 2, 3 and 4).

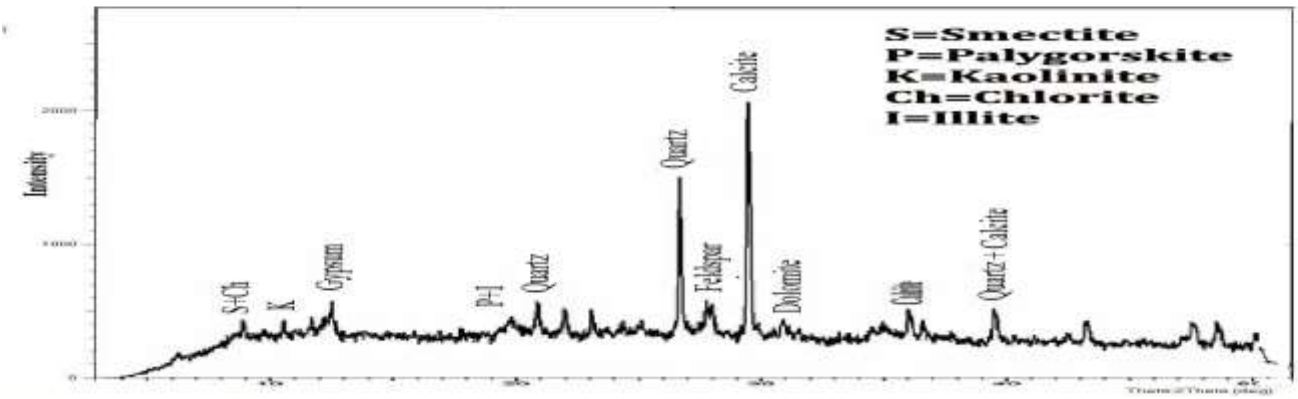

Figure 2: X-ray difractogram of gypsiferous soil at site 1, sample 1b

The results of X-ray diffraction show that the soil profile in site 1 is dominated by palygorskite, illite, kaolinite, smectite and chlorite. Non-clay minerals are dominated by dolomite, quartz and gypsum with amounts of calcite and feldspar (Fig.2 and Table 2). The mineralogy of the sediments in site 2 shows more variation than that in site 1, following the more frequent changes in lithology. However, palygorskite and illiteare the dominant clay mineral here with minor amounts of kaolinite, smectite and chlorite. The non- clay minerals are dominated by quartz, Feldsparecalcite, dolomite and gypsum (Fig.3).

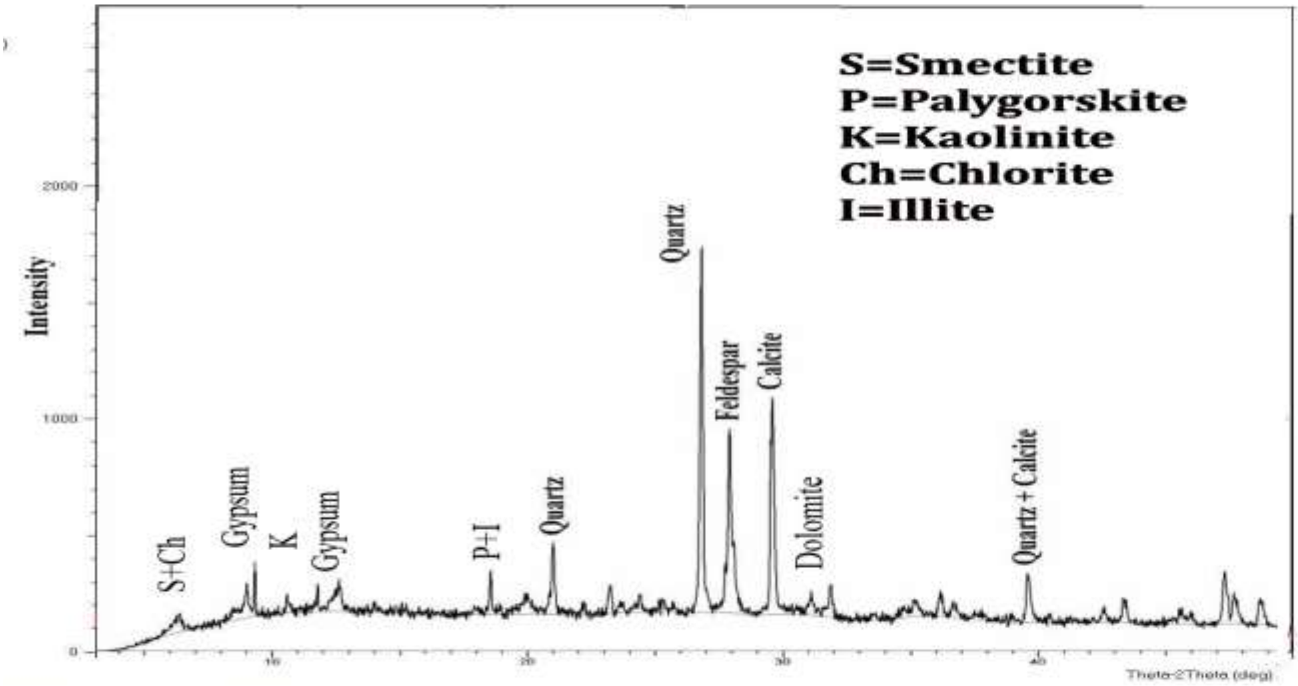

Figure 3: X-ray difractogram of gypsiferous soil at site 2, sample 2a

The mineralogy of the sediments in site 3, the non- clay minerals are dominated by gypsum associated with calcite, dolomite and quartz, Feldspar. However, Palygorskite and illite that are the dominant clay mineral here, associated with smictite and chlorite (Fig.4). The dominant presence of palygorskite and smectite among the clay minerals reflects the arid and semi-arid climatic conditions. These clay minerals require alkaline environment and high to moderate Mg-salinity.

The aridity and hot climate is obvious in the studied area, indicated by the gypsiferous soils in Sites 1, 2 and 3 as well as the aeolian sand (gypsarenite) is dominate in site 3.The high gypsum values are related to a remarkable increase in the sand content, which demonstrates the nature of the gypsum presence in the upper part of site 3, being aeolian sediments, where gypsum was transported by wind mostly as silt- and sand-size grains (gypsarenite)

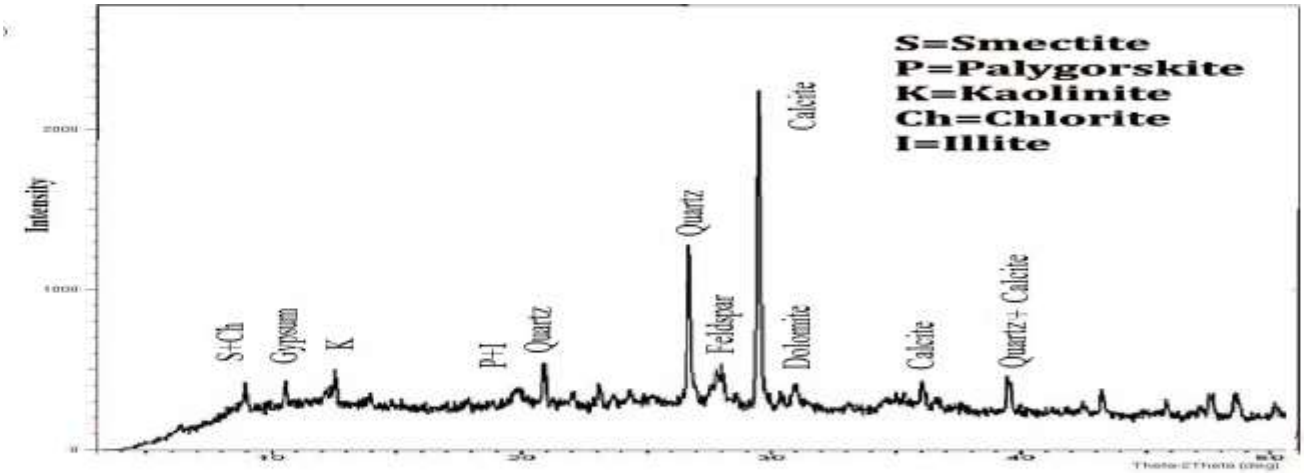

Figure 4: X-ray difractogram of gypsiferous soil at site 3, sample 3a

Geotechnical Properties is Cussion

Many soil scientist and engineers, worldwide have studied the gypsiferous soils in different locations of the world and for variable purposes, i.e. agriculture, surveying, civil engineering, etc., among those scientists and engineers, some had suggested different gypsiferous soils classifications.

Those classifications often are limited to their own specialization and to solve limited engineering problems [15, 16]. In this research [14] gypsiferous soil classification is applied that combines not only gypsum content in the soil, but also involves relevant physical, chemical, and engineering properties such as plasticity index, cohesion, unconfined compressive strength and collapse potential. It is believed that applying [14] classification will give better, more reliable and comprehensive classification for Iraqi gypsiferous soils that could be used widely by all pedologists, geologists, engineers and other scientists(Table 3). The total studied gypsiferous soils were 13 distributed on 3 sites within Samara- Tikrit area (Fig.1 and Table 3). The results reflect that six samples (1a, 1c, 1d,2c, 2d, 3b) with less than 50 % fine grains according to ASTM (1986) classified as gypsiferous soil by applying Al-Dabbas et al, classification with less than 25% gypsum content and with less values of initial void ratio, coefficient of curvature, uniformity coefficient, collapse potential %, compression strength, cohesion, and plasticity index % .While the other seven samples (1b,1e,2a,2b,2e,3a,3c) with more than 50% fine grains classified as highly gypsiferous soil with more than 25% gypsum content and with relatively higher values of initial void ratio, coefficient of curvature, uniformity coefficient, collapse potential %, compression strength, cohesion, and plasticity index %.

Table 3: The applied [14] classification for gypsiferous soils

Gypsum %	Class	Initial Void ratio	Coeff. Of Curvature	Uniformity Coeff.	Collapse Potential %	Comp. Strength MN/m²	Cohesion KN/m²	Plasticity Index %	Fine Grained Soils%	Samara -TikritSamples
0.5-25	Gypsi. Soil	< 0.45	< 2.5	< 25	< 1.5	< 1	< 15	< 10	< 50	1a, 1c, 1d,2c, 2d, 3b
25-> 50	Highly Gypsi. Soil	> 0.45	> 2.5	> 25	> 1.5	> 1	> 15	> 10	> 50	1b,1e,2a, 2b,2e, 3a,3c

Conclusions

- The results of grain-size analysis show that sand size grains are associated with variable percentages of clay fraction and the silt fraction in soil profile of site 1.Concerning the soil profiles in site 2 and 3 representing clay and silt were dominated more than the fine sand. The soils within the three sites are fine-grained, yellowish light brown, moderately to highly gypsum, ranging from friable to hard gypsiferous soil.

- The results of thin section and the X-ray diffraction analysis reflect that non-clay type minerals are quartz, calcite, dolomite, gypsum and feldspar; while the clay minerals are chlorite, smectite, kaolinite, illite and palygorskite.

- The domination of palygorskite and smectite reflects the arid and semi-arid climatic conditions. The aridity and hot climate is obvious in the studied area, indicated by the gypsiferous soils in Sites 1 and 2 areas and Aeolian sand (gypsarenite) in site 3 .

- The geotechnical properties results reflect that six samples (1a, 1c, 1d,2c, 2d, 3b) are classified as gypsiferous soil with less than 25% gypsum content and with less values of initial void ratio, coefficient of curvature, uniformity coefficient, collapse potential %, compression strength, cohesion, and plasticity index % while the other seven samples (1b,1e,2a, 2b,2e,3a,3c) are classified as highly gypsiferous soil with more than 25% gypsum content and with relatively higher values of initial void ratio, coefficient of curvature, uniformity coefficient, collapse potential %, compression strength, cohesion, and plasticity index %.

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