Geotechnical Properties of Tel-Afar Gypseous Soils

A.M.H. Al-Marsoumi ; M.J. Kadhum* and S.K. Kadhum
College of Science/ Basrah University
** College of Engineering/Barsah University*

Abstract

Six gypseferous soil samples were collected from Tel-Afar area, northern Iraq. geotechnical properties were determined. Tests were conducted on specimens containing different gypsum contents. The testing program comprises the determination of the natural gypsum content effect on the shear strength characteristics of the soil specimens under consideration. The results showed that the shear strength of Tel-Afar soils increases as gypsum content increases, while shear characteristics (cohesion= C, and the angle of internal friction=Ø) revealed different behavior when gypsum added to a natural soil. When the gypsum content increases the C value decreases whereas the Ø increases.

الخصائص الجيوتكنيكية للترب الجبسية في منطقة تلعفر

عبدالمطلب حسون المرسومي ، محمد جواد كاظم* و شيماء خالد كاظم
قسم علم الارض-كلية العلوم- جامعة البصرة
**قسم الهندسة المدنية-كلية الهندسة-جامعة البصرة*

الخلاصة

ستة نماذج ترب جبسية جمعت من منطقة تلعفر,شمال العـراق بغيـة تعـين المواصـفات الهندسـية والجيوتكنيكية لها, الفحوص نفذت على نماذج ذات محتوى مختلف من الجبس. برنامج الفحص شمل قياس تاثير محتوى الجبس على مقاومة القص للنماذج المختارة للدراسة, اظهرت الدراسة ان مقاومـة القـص للترب تلعفر تزداد بزيادة محتوى الجبس في حين تظهر خاصيتي التماسك وزاويـة الاحتكـاك الـداخلي سلوك مختلف عند اضافة مقادير مختلفة الى الترب الجسية المختارة للدراسة, اذ وجد ان قيمة التماسك تقل في حين زاوية الاحتكاك الداخلي تقل.

Introduction

Gypseferous soils have a wide distribution in Iraqi territories. The total area of Iraqi gypseferous soils is about 4780 Km^2 equivalent about 11% of the total area of Iraq (FAO, 1990). However, Al-Barazanji (1973) estimated that gypseous soils cover about 20% of the total area of Iraq . The gypseous soils commonly found in arid and semi arid areas where the annual quantity of rainwater is inadequate for leaching the annually accumulated gypsum mineral from these soils. Owing to Sonnenfield (1984) this mineral is characterized by high solubility under surface condition, on the other hand, James and Lupton (1993) found that the amount of soluble gypsum in distilled water is about 2.531 gm/l, So the gypsum content in soils is of temporal fluctuations, it is either increasing by new precipitation or decreasing by dissolution of pre-existing gypsum due to ground water flow, irrigation , and rainwater. Petrukin and Arakelyan (1985), and Kadhum (2005) found that the presence of gypsum in soils affect their engineering properties. Taking in consideration the fact that the gypsum content is changeable, therefore, these properties are in turn changes with the time. It is worth to be mentioned that, gypsum is unstable mineral; commonly survive reversible changes to anhydrite via losing two water molecules.

Based on Buday (1980), gypsum occurs as isolated strata within Fat'ha Formation (Middle Miocene). This formation represents the main source of gypsum that contributed to Iraqi soils. In soils or quaternary sediments, gypsum could be found in many different forms; i.e., soft, powdery, well-developed crystals, rock sharpnels, crust and petrogypsum (Nashat, 1990).

The gypseous soils cover considerable areas of Iraq, the dissolution of gypsum within soils causes serious engineering problems such as catastrophic settlements. Consequently it is necessary to study their engineering properties at different gypsum contents behavior at different conditions to realize the effect of gypsum contents on the engineering properties of Tel-Afar gypseous soils.

Geologic Setting

Tel-Afar located about 40 Km northwest Mosul city (Fig.1). From geological point of view; it is located at the foothill zone (Buday, 1980). The stratigraphic succession in the studied area is represented by Eocene and Miocene formations; Jeribi, Euphrates, and Fat'ha Formations. The first two are composed of limestone and dolomitic limestone respectively, whereas, the third one is composed of gypsum, limestone, and marl (Al-Rawi and Amin, 1979). Structurally, many asymmetrical anticlines and synclines were concentrated in Tel-Afar Area. The gypseous soils occur in the synclines vicinity. The relative high rainfall in this area accelerate the dissolution of gypsum beds yielding weathering solutions enriched with dissolved gypsum. These solutions play an important role in the evolution of gypseous soils under study (Buringh, 1960). The most outstanding geomorphic feature of Tel-Afar soils is represented by the occurrences of small hills 0.2-0.3 m high and 0.5-1.0 m in diameter (microtopography) formed as a result of the secondary gypsum expansion.

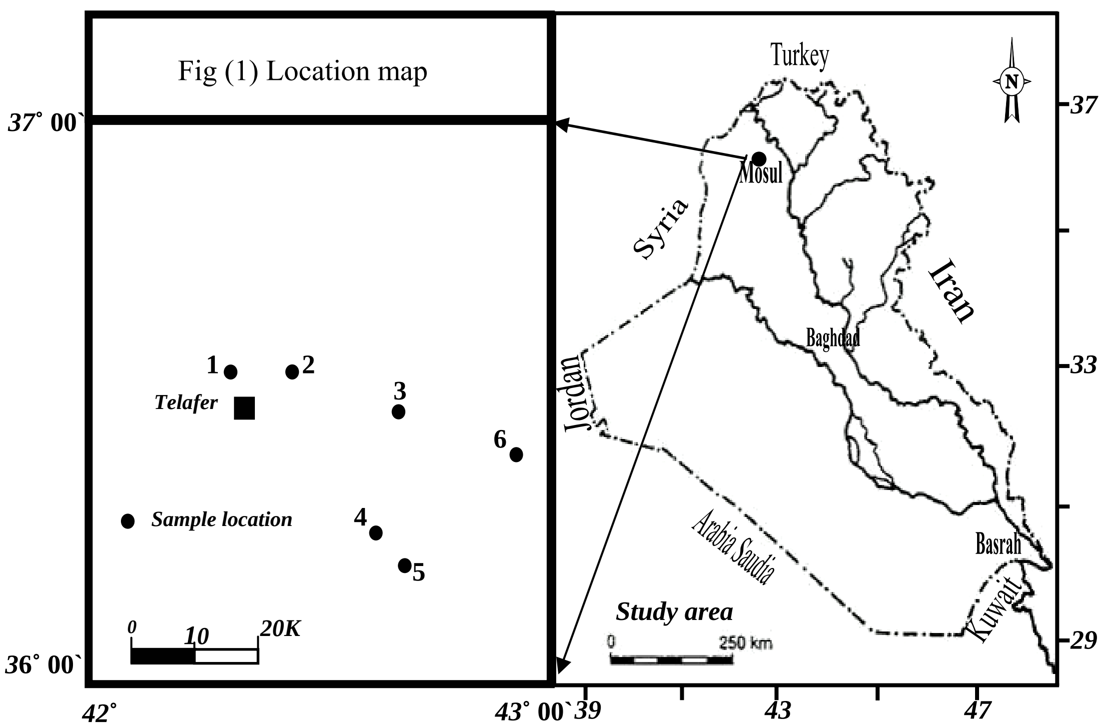


Fig (1) Location map

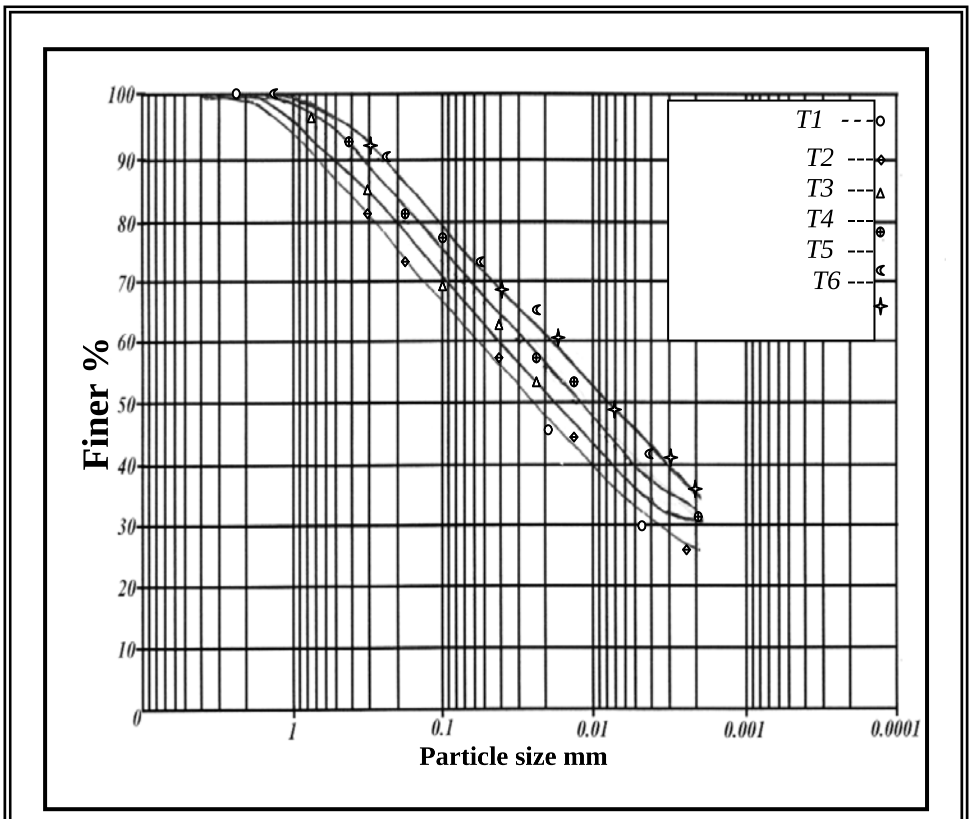
Methodology

Six disturbed specimens were selected from gypseous soils in Tel-Afar area; Ain Talawi (T1), Al-Mizraa (T2), Adaii (T3), Mahalabia (T4), Ain Mahabia (T5), and Al-Musaad (T6). An attempt undertaken to make specimens selection covering the whole area as possible as it could be done. The specimens were taken at 1-1.5 m depth to get ride of the top shallow layer, which usually contains organic matter such as plant roots using hand auger. Thereafter, each specimen was cleaned; air dried and kept in nylon bags for further use.

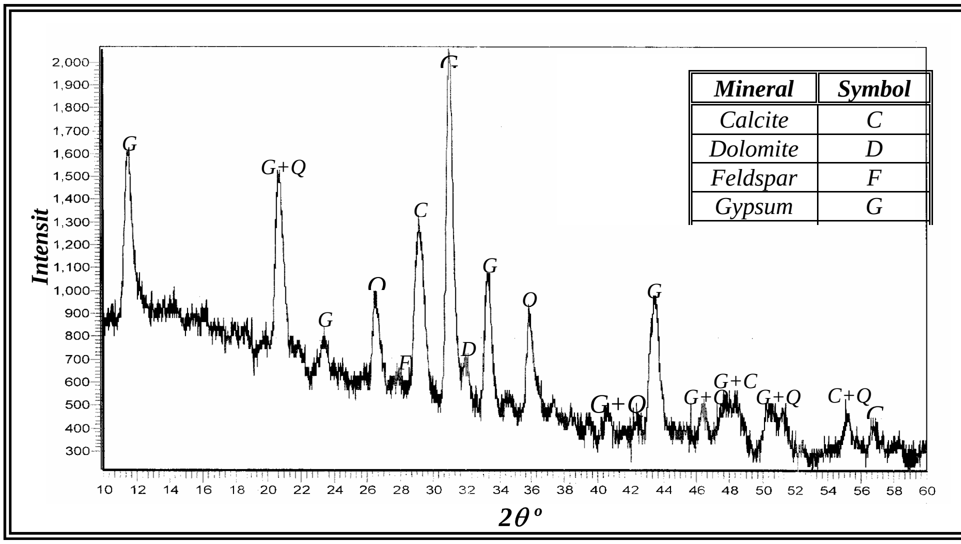
Grain size analysis for soil specimens were done according to the ASTM D422-63(ASTM, 1983). The wet sieving and hydrometer method was adopted for coarse and fine grained soils, respectively. The result was illustrated in Figure (2). X-ray technique was employed to shed light on the overall mineralogical contents of gypseous soils investigated. On the other hand, the soil clay minerals have been diagnosed as extremely problematic due to their expansive and swelling characteristics, mainly because of its smectite content (Abduljauwad and Al-Sulaimani,1993 cited in Al-Shayea, 2001). Therefore, the clay mineral contents of the studied area were taking inconsideration during consistency limits determination. The overall clay mineral contents of Tel-Afar area was abstracted from Kassim *et al.*(1990). The amount of natural gypsum contents were determined chemically following USDA-Agricultural Hand Book No. 60 method. Atterberg's limits were achieved according to the ASTM (D423-66) and (D424-59) (ASTM, 1983) at different gypsum contents in order to study the effect of gypsum on these limits. To clarify the effect of different gypsum contents on the engineering properties of investigated soil specimens, many laboratory tests were carried out. Unconfined compression test(Cu) was conducted owing to the ASTM D2166-66 (ASTM, 1983) using compression apparatus WF-No. 10204 produced by Wykeham Ferrance Engineering Ltd. This apparatus was also used to conduct the confined or triaxial compression test (C) but with applying of confining pressure.

Results and Discussion

The grain size analysis results (Fig.2) showed that the clay, silt, and sand fraction ranged between (48-62%),(26-29%)and (12–27%),respectively. Owing to the Unified Soil Classification (USC) system, the texture of the studied soils could be classified as siltyclay. The overall mineralogical analysis revealed the occurrence of the following minerals; gypsum, calcite, quartz, feldspar, and dolomite (Fig.3). The natural gypsum contents of Tel-Afar ranges between 35- 65%, with an average value of 49.1%. Basing on their gypsum contents, the soils understudy could be classified as gypseous comprising more than 50% gypsum (Ain Mahalabia, Mahalabia, and Adaia), and gypsferous soil (Ain Tawali, Al-Mizra, and Al-Masaad) for which gypsum constitutes less than 50%.

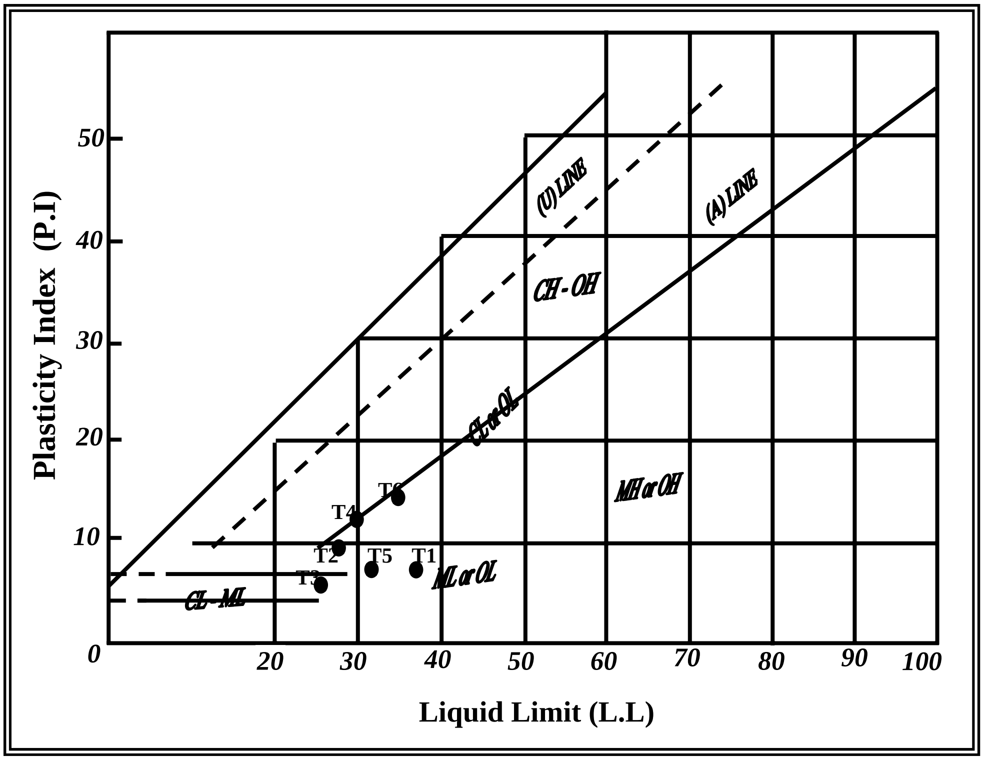


Fig(2) Grain size distribution of Tel Afar Soils.



Fig(3)X-ray diffractogram of Tel –Afar soil sample.

Atterbergs's limits of the studied soils are provided in Table (1), Consequently, these tested soils lie above and below the A-line in the plasticity chart(Fig.4). Therefore, according to the unified soil classification system, these fine grained soils are classified as (CL and ML). The liquid limit varies from 26.5 to 37, the plastic limit varies from 18 to 30, and the plasticity index varies from 6 to 14 (Table.1). Generally, after the soil treatment the liquid and plastic limits decreases as the gypsum content increases, also it could be noticed that the plasticity index slightly decreases. The decreases in liquid limit and plasticity index possibly attributed to the increases in calcium cations in soils, which may reduce their ability to adsorbing water as previously interpreted in similar cases by Al-Obydi (1992). On the contrary, the liquid limit and plastic limits indicate that there is a close correlation between those limits and sediment size, this finding agree with that of Thabit *et al.(*1980). Based on Al-Shayea (2001), this result could be attributed to the occurrence of smectite clay mineral in soil samples under study(Kassim et al., 1990). Since this type of clay mineral has unbalanced negative charges, therefore, posse's high cation exchange capacity, as well as, smectite has a noticeable adsorption ability, and hence high swelling potential.



Fig(4) Plasticity chart.

Table (1) The consistency limits of Tel-afar soils.

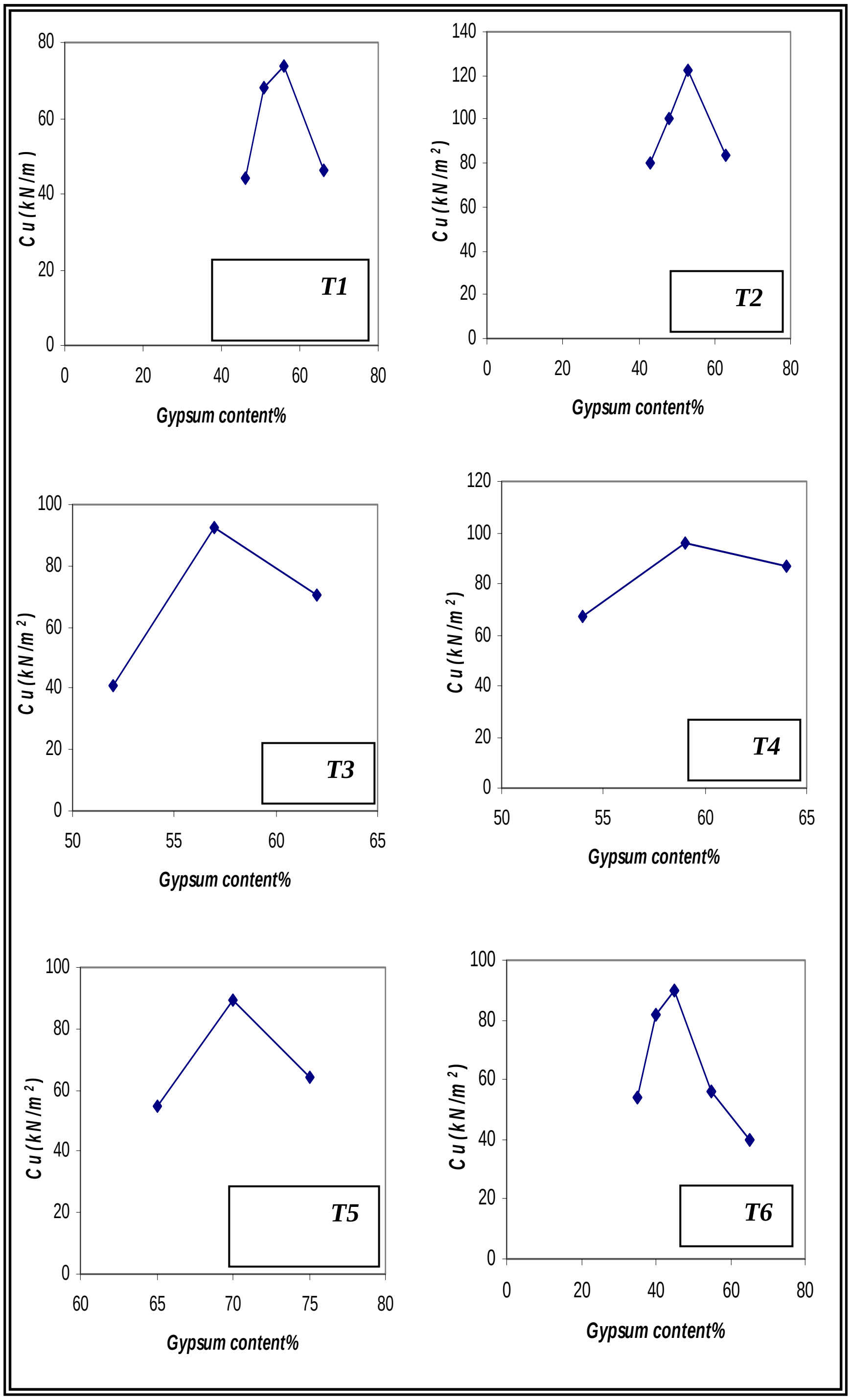
sample No.	Sp.Gr.	Gyp.%	Atterbergs Limits %			Grain size Analysis %			U.C.S. Soil Type
			L.L	P.L	P.I	Clay	Silt	Sand	
T1	2.34	46	37	30	7	48	26	17	ML
T2	2.32	43	27	18	9	60	21	19	CL
T3	2.41	52	26	20	6	53	30	27	CL
T4	2.34	54	30	18	12	44	34	22	ML
T5	2.33	65	32	25	7	47	35	15	CL
T6	2.30	35	34	20	14	48	35	18	CL

Cohesion can be attributed to a combination of true and apparent types, including; cementation, adhesion due to compaction, electrostatic and electromagnetic attractions, and capillary sunction. All of these cohesions increases with increase of water and clay mineral contents (Mitchell, 1993 in Al-Shayea, 2001). Increasing clay mineral content may attained in high cohesion value.

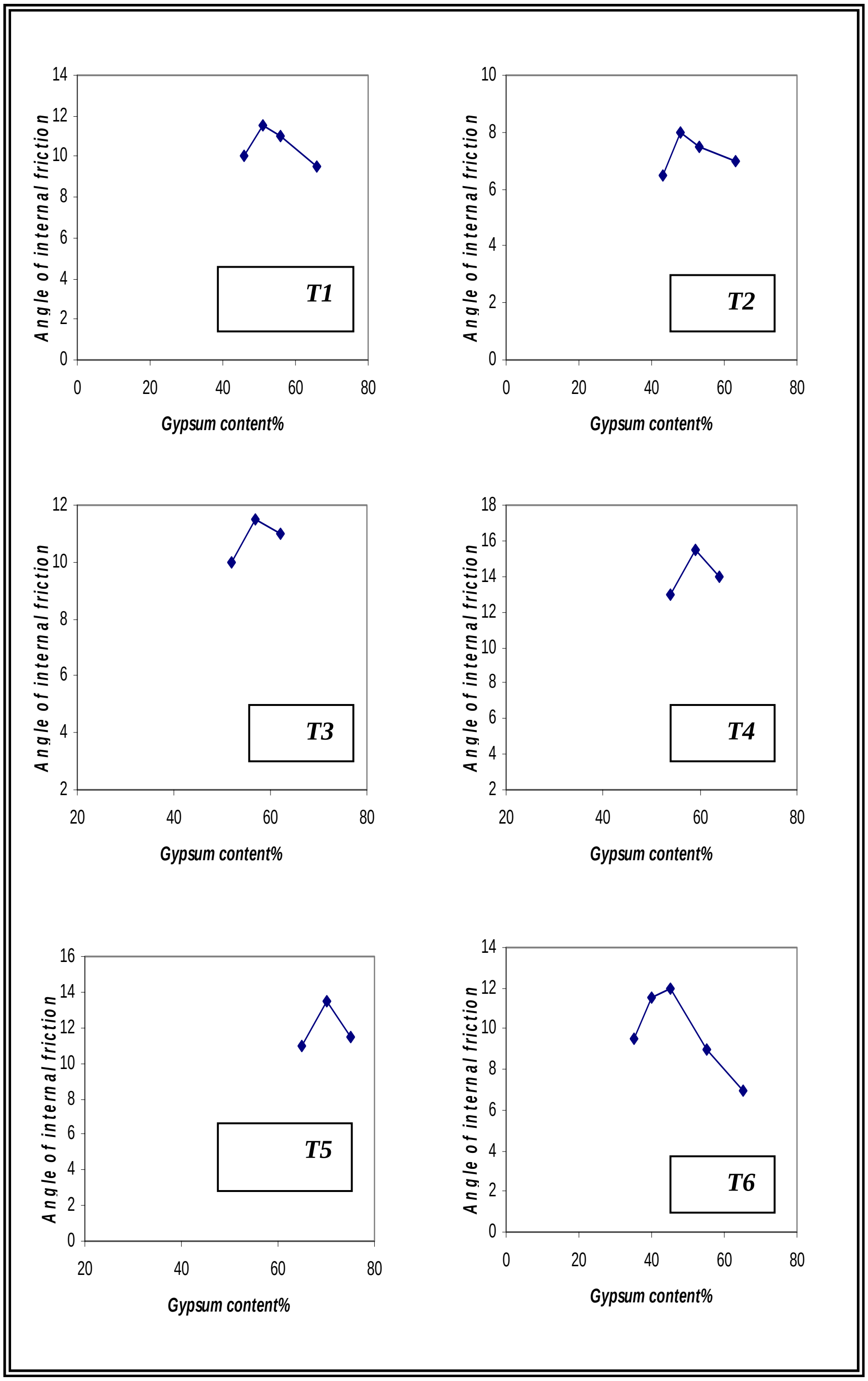
The results of the siltyclay soil shear strength using unconfined and confined (Triaxial) compression tests emphasized the effect of gypsum contents on strength of studied soils (Table, 2). The obtained value of (Cu) and (C) tests were varies among the selected locations in Tel-Afar area, which most probably related to the variation in cohesion value within soils. On the other hand Figure (5) exhibit the relationship between the cohesion value and the amount of the added gypsum in wt%. The same figure clarifies that the cohesion value of soils contain more than 50% gypsum increases after adding 5% gypsum and dropping after adding of 10% gypsum. Moreover, under the same condition the internal friction angle changes in the same manner(Fig. 6), this result could be interpreted as follows; firstly gypsum act as cement material supporting the soil grains, as well as, the friction angle between the gypsum grains is grater than that between soil grains themselves. Consequently, enhance the soil properties, but when the additive gypsum exceeds certain limits (i.e. fill all the intergranular space) it plays an important role in dispersed soil grains apart causing the deterioration of soil properties, i.e. soil grains are flocculated and dispersed . On the other hand, the value of Ø varies among specimens; this variation could be attributed to variation in natural soil gypsum contents, water adsorption, and the type of clay mineral content.

Table (2) The effect of gypsum on confined and unconfined compressive tests.

Sample No.	Gypsum%		Water cont. %	Unconfined Test	Undrained Triaxial Test	
	Natural	Added		Cu (kN/m^2)	C (kN/m^2)	Ø º
T1	46	0	24	44	45	10
		5		68	72	11.5
		10		74	66	11
		20		46	38	9.5
T2	43	0	30	80.5	86	6.5
		5		100	120	8
		10		122	104	7.5
		20		84	88.5	7.5
T3	52	0	28	41	45	10
		5		92.5	91	11.5
		10		70.5	60	10
T4	54	0	18	67.5	65	13
		5		96	93	15.5
		10		87	85	14
T5	65	0	22	55	53	11
		5		89	80	13.5
		10		64	68.5	11.5
T6	35	0	30	54	55	9.5
		5		82	74	11.5
		10		90	92	12
		20		56	60	9
		30		40	46	7



Fig(5)Unconfined shear strength tests of Tel –Afar Soil samples.



Fig(6) Angle of internal friction of Tel –Afar Soil samples

Conclusion

Two types of gypseferous soils were prevailed at Tel-Afar area; gypseous and gypseferous, which could attributed to spatial distribution relative to gypsum beds and to a lesser extent differential weathering. Smectite is the most abundant clay minerals in the studied area. The variability in the geotechnical properties of Tel-Afar soils is attributed to their mineralogical composition, textural contents. The increasing in liquid and plastic limits in Tel-Afar soils is often related to their clay mineral content. The shear strength of Tel-Afar gypseferous soil under consideration increase with increase of gypsum contents for certain limits then decline. This phenomenon could be attributed to gypsum acting firstly as filler for the empty space among soil grains.

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