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## Mineralogy of Gypsiferous Soil and the Effect of a dditiveLime Stone waste powder on its Physical Properties

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### Abstract

The presence of gypsum in soil as bonding agent alters its behavior with a large influence on its physical properties. Soil samples were taken from two locations of different gypsum content (S1 = 30.5% and S2 = 20%) in Makhmur area. The Unified soil classification system indicated that soil type was clay with low plasticity (CL). Basic methods of physical testing of soils, such as grain size analysis, specific gravity and atterberg limit were applied. Stabilization of the gypsiferous soil was performed by adding limestone waste powder taken from Said sadiq and Pirmam areas, with different percentages (5%, 15%, 25%). The results show that the addition of limestone powder to the tested soils decreases their liquid and plastic limits.

**Keywords:** Gypsiferous Soil , Limestone waste powder, Atterberg Limit, Grain size analysis

معدينية التربة الجبسية وتأثير إضافة نفايات مسحوق الكلس على خواصها الفيزيائية

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### الخلاصة

وجود الجبس في التربة كعامل رابطة يغير سلوكه، يؤثر الجبس بدرجة كبيرة على الخصائص الفيزيائية للتربة. أخذت التربة من موقعين يختلف فيها المحتوى الجبسي (S1 = 30.5 % و S2 = 20 %) من منطقة مخمور. صنفت التربة حسب نظام تصنيف التربة الموحد تيننتيان التربة الطينية ذات درجة مرونة منخفضة (CL). الطرق الأساسية للاختبار الفيزيائي للتربة هي تحليل حجم الحبيبات، الوزن النوعي وحدود الأتربرغ. معالجة التربة الجبسية مع إضافة مسحوق نفايات الحجر الجيري المأخوذ (سيد الصادق، البيرمام) بنسب مختلفة (5%، 15%، 25%). أظهرت النتائج أن إضافة مسحوق الحجر الجيري إلى التربة يقلل من حد السيولة والحد من اللدونة.

### 1-Introduction

Gypsiferous soils are usually stiff when dry, especially because of the cementation of the soil particles by gypsum, but the problem becomes complicated when water flows through the gypsiferous soils causing leaching and then its continuous collapse [1]. There are many problems that have been noticed when structures were constructed on gypsiferous soils in the last three decades in Iraq. These problems are related to collapsing of the soil, increasing leakage of water through the soil, softening of the soil and attack of sulfate to concrete. All these are related to the continuous and slow dissolution of gypsum by

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seeping water through the gypsum-containing soil[2]. Several studies on stabilization of soil by using lime were conducted[3, 4, 5, 6, 7].

## **2-Geology of the study area**

Two locations of Makhmur area around Erbil Governorate, located within the Foothill Zone, were selected for the present study[8]. Makhmur area is a good exposure of the Mukdadiya, Injana and Fatha Formations [9]. The Fatha Formation comprises cycles of reddish brown mudstone, limestone and evaporates [10]. The Injana Formation is composed of continental and sub-continental clastic materials. This formation is locally covered by Mukdadiya Formation sediments represented by alternation of claystones, sandstones, and conglomerate, along with quaternary deposits generally composed of conglomerate, sand and clay, especially in the slope sediments and river terraces in high folded zones [11].

## **3-Materials and methods**

In the present study, two different limestone waste powder samples, originally taken from Pirmam and Said Sadiq areas, were obtained from Erbil Marble factory. These were used as additive materials to the disturbed samples of soil taken from two locations in Makhmur area; the first location is of a high gypsum content and the second location is of a low gypsum content.

### **3-1 Sample preparation**

The samples of soil were divided into seven parts. The first part of each sample was left in its natural state, while the other six parts were mixed with limestone waste powder at different percentages (5% , 15% , 25%) of the powder collected from both areas (Said Sadiq and Pirmam).

### **3.2 Test Program**

Samples of both natural soil and those mixed with the three different percentages of limestone waste powders were analyzed for grain size, liquid limit, and plastic limit, along with specific gravity and x-ray diffraction.

#### **3-2-1 Grain size analysis**

Particle size analysis for soil specimens was performed according to the standard American Society Test Method [12].

#### **3-2-2. Liquid Limit**

Liquid limit test procedure of liquid limit was conducted using the cone penetration method [13].

#### **3-2-3. Plastic limit**

Plastic limit test was performed according to a previously described method [13].

#### **3-2-4. Specific Gravity**

The specific gravity (GS) was determined according to the standard method of the American Society for Testing and Material [14].

## **4-Results and Discussion**

### **4-1 Grain size analysis**

Grain size was analyzed using the sieve and hydrometer method for two types of soil (S1 and S2). The diameter of the soil grains was first computed, followed by plotting the relation between the diameter and the percentage finer of soil. The results showed that S1 soil sample contained clay (< 0.002 mm, 21.28%), silt (0.002-0.075mm, 50.77%), sand (0.075-2mm, 25.61%), and Gravel (>2mm, 2.34%) (Figure-1). S2 soil sample was composed of clay (6.33%), silt (76.12%), sand (11.62%), and gravel (5.93%) (Figure-2).

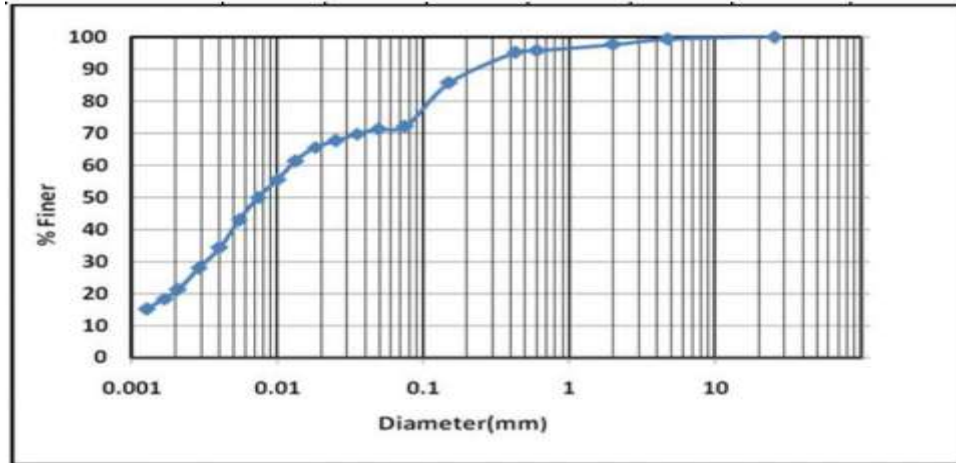


Figure 1-Grain size analysis of untreated (S1) soil.

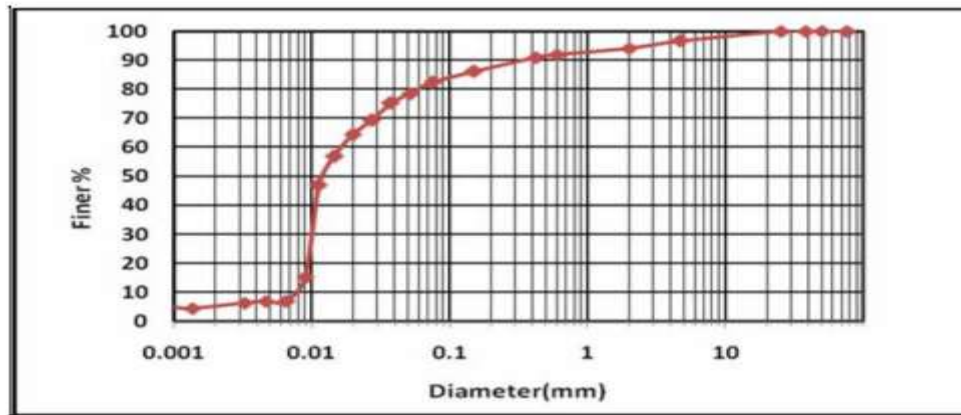
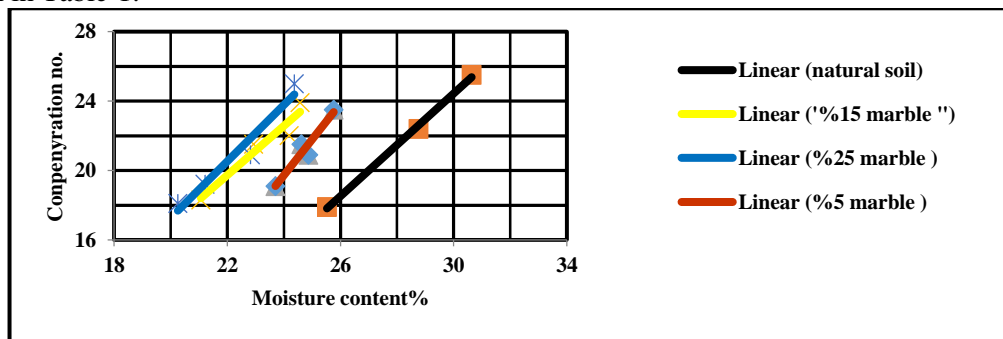


Figure 2-Grain size analysis of untreated (S2) soil.

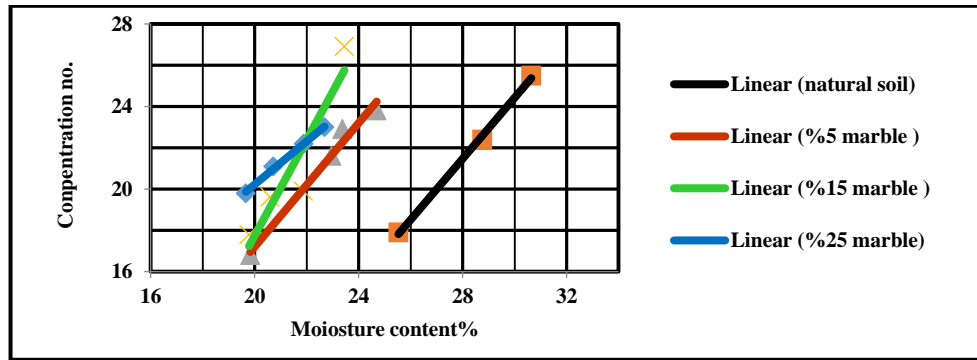
**4-2Liquid limit**

The figure below shows that the liquid limit(LL)of S1 soil was 27(Figure-3 (a, b, Table-1), while it was 31.85 for S2(Figure-(4a, b, Table-2).By adding the three percentages (5% , 15% , 25%) of limestone waste powder fromPirmam and Said Sadiq to S1 and S2 samples,the liquid limit decreasedas the stabilizerconcentration increased. The maximum reduction of liquidlimit in S1 wasfrom 27 to 19.8 and in S2 from 31.85 to 24.3, both achieved by adding the concentration of 25%of the limestone waste powder collected from Said Sadiq area.

The liquid limit is more affected by addition of the limestone waste powder of Said Sadiq To the soils ,as shown in Table-1.



(a)

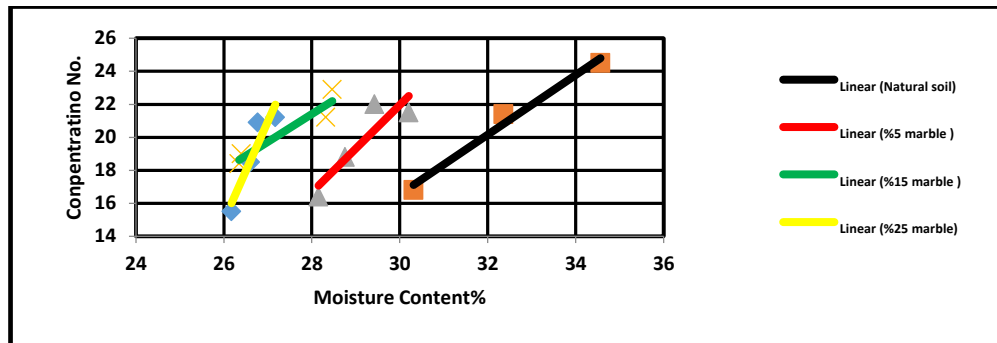


(b)

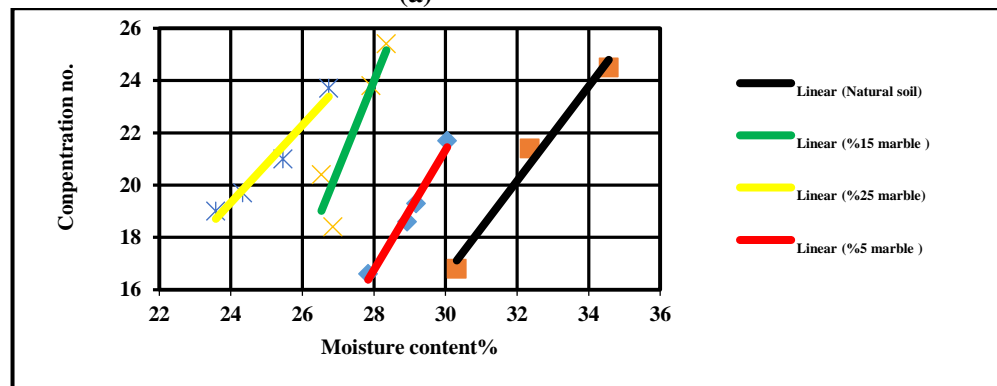
**Figure 3**-Relationship between moisture content% and cone penetration of untreated and treated S1 with three different percentage of limestone waste powder from(a) Pirmam (b) Said Sadiq.

**Table 1**-Liquid limit of S1 untreated and treated soils with three differentpercentage of two different limestone waste powders.

Type of soil	Liquid Limit			
	Untreated	Untreated soil with adding limestone waste powder		
S1	27	5%	15%	25%
Pirmam		24.1	22.2	21.6
Said Sadiq		22	21	19.8



(a)



(b)

**Figure 4**-Relationship between moisture content% and cone penetration of untreated and treated S2 with three different percentage of limestone waste powder from (a) Pirmam (b) Said Sadiq.

**Table 2-**Liquid limit of S2 untreated and treated soils with three different Percentage of two different limestone waste powders.

Type of soil	Liquid Limit			
	Untreated	Untreated soil with adding limestone waste powder		
S2	31.85	5%	15%	25%
Pirmam		29.2	27.15	26.82
Said Sadiq		29.4	26.75	24.3

The maximum reduction of the liquid limit was 19.8% for S1 and 24.3% for S2, both resulting from the treatment with 25% of limestone waste powder from Said Sadiq. The effect of the addition of limestone waste powder of Said Sadiq was stronger than that of Pirmam, due to the composition of the limestone waste of Said Sadiq.

#### 4-3 Plastic Limit

As a result of the addition of limestone waste powder to the gypsiferous soil, the plastic limit value (PL) of both S1 and S2 samples decreased as the stabilizer percentage increased. The maximum reduction of plastic limit in S1 soil was from 19.3 to 15.84 (Table-3), while in S2 soil it was from 23.94 to 19.3 (Table-4), both achieved by the addition of 25 % of the limestone waste powder from Said Sadiq.

**Table 3-**Plastic limit of untreated and treated soils (S1) by adding three different percentages of two different limestone waste powders

Type of soil	Plastic Limit			
	Untreated	Untreated soil with adding limestone waste powder		
S1	19.3	5%	15%	25%
Pirmam		18.26	17.01	16.61
Said Sadiq		17.33	16.71	15.84

**Table 4-**plastic limit of S2 untreated and treated soils by adding three different percentages of two different limestone waste powders.

Type of soil	Plastic Limit			
	Untreated	Untreated soil with adding limestone waste powder		
S2	23.94	5%	15%	25%
Pirmam		21.44	20.01	19.8
Said Sadiq		21.6	19.6	19.3

#### 4-4 Plasticity index

The maximum reduction value of the plasticity index (PI) of S1 soils was 3.96 (Table-5), while that of S2 was 5 (Table-6), both caused by adding 25% of limestone waste powder from Said Sadiq. In this test, the plasticity index of S1 was more affected as compared to S2 by the addition of limestone waste powder from Said Sadiq. These results indicate that the plasticity index decreased by increasing the stabilizer percentage in the gypsiferous soil.

**Table 5-**Plasticity index of S1 untreated and treated soils with three different percentages of two different limestone waste powders.

Type of soil	Plasticity index			
	Untreated	Untreated soil with adding limestone waste powder		
S1	7.7	5%	15%	25%
Pirmam		5.84	5.19	4.99
Said Sadiq		4.67	4.29	3.96

**Table 6**-Plasticity index of S2untreated and treated soils with three different percentages of two different limestone waste powders.

Type of soil	Plasticity index			
	Untreated	Untreated soil with adding limestone waste powder		
S2	7.91	5%	15%	25%
Pirmam		7.76	7.14	7.02
Said Sadiq		7.8	4.29	5

The classification of S1 and S2 soils according to the Unified Soil Classification system revealed that they belonged to the class of low plasticity clay soil.

**4-5Specific Gravity (GS)**

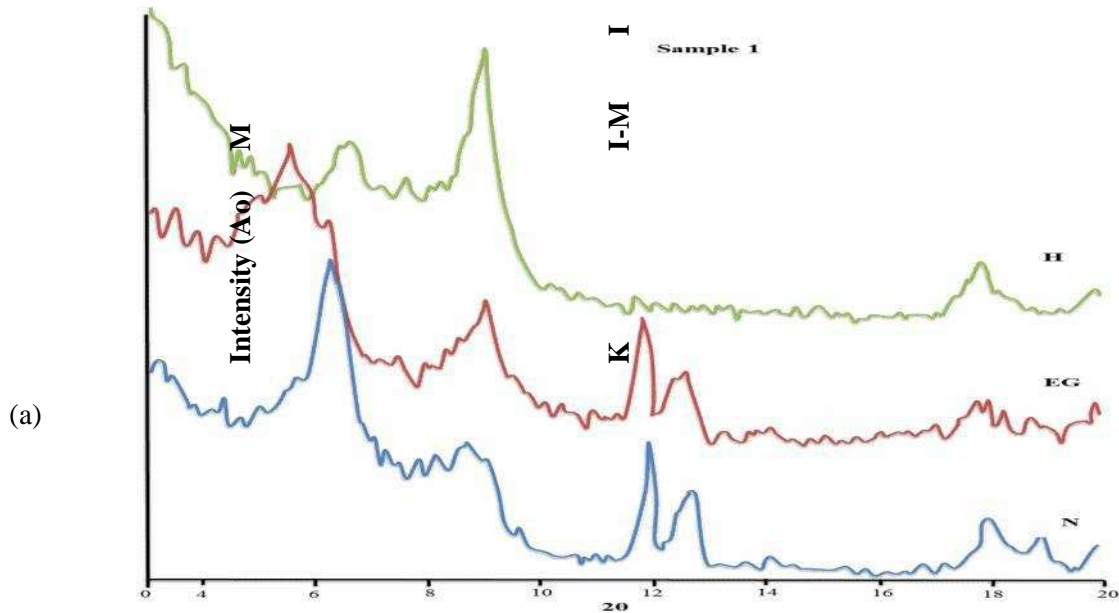
The specific gravity of S1 soils was about 2.52 gm/cm<sup>3</sup> while that of S2 soils was about 2.60gm/cm<sup>3</sup>(Table- 3.10 ).

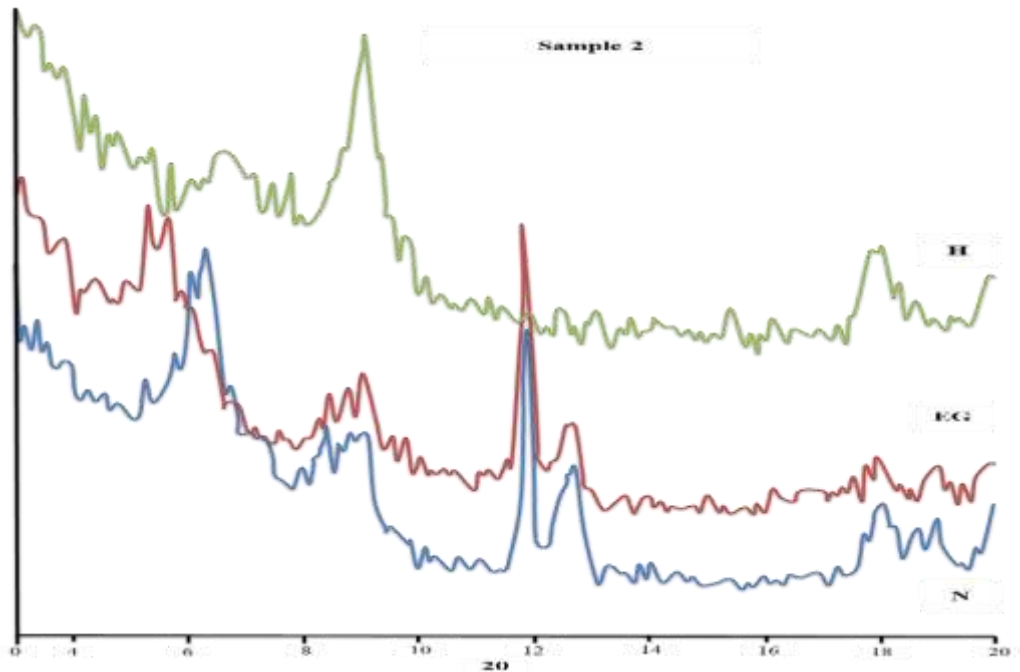
**5-Mineralogical Tests**

Several XRD runs were applied for untreated soil samples (S1 andS2) of both locations in the studied area. Clay minerals existing in the studied soils were identified according to the first reflection (001) and other reflections. The results of these tests indicated that montmorillonite, illite, kaolinite and mixed layer (I-M) dominated clay mineral components (Figure-5) while gypsum , quartz, calcite, anhydrite, feldspar and dolomite were the dominant non-clay minerals (Figure-6; Table-7).In addition, the bulk mineralogy of waste limestone of Said Sadiq and Pirmam areas revealed the presence of calcite, quartz, and dolomite [15].

**Table7**-composition of the studied natural soils (S1 and S2)

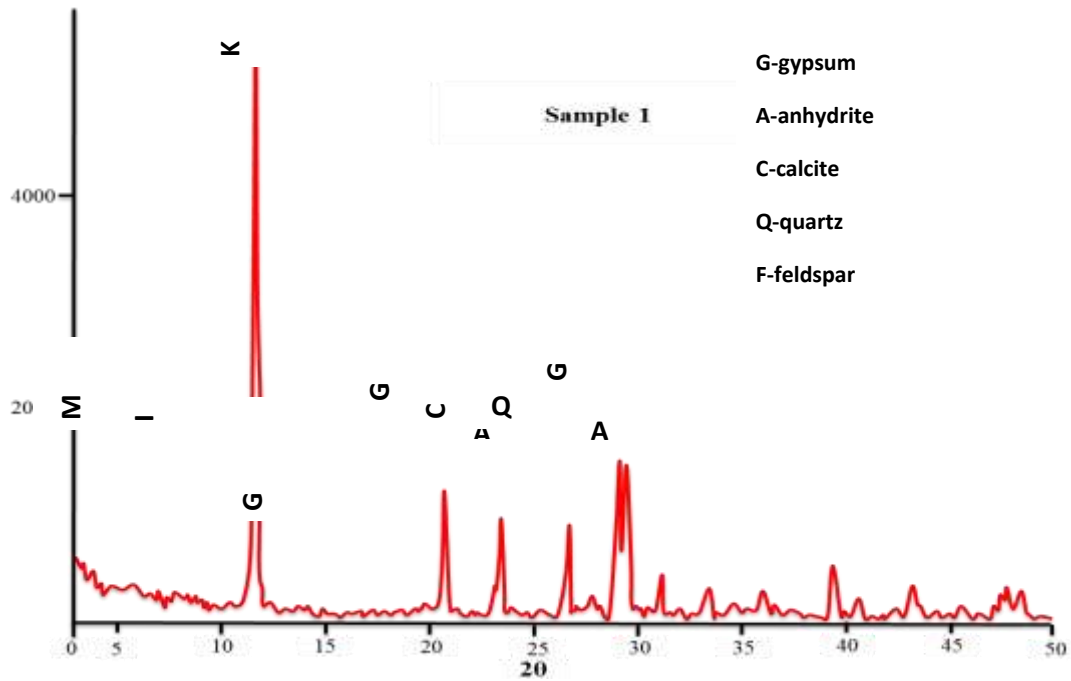
Soil types	Arrangement of minerals	
	Clay minerals	Non- Clay minerals
S1	Montmorillonite, palygoreskite, kaolenite,illite, and mixed layer (I-M).	gypsum, quartz , calcite, feldspars and anhydrite
S2	Montmorillonite, palygoreskite, kaolenite,illite, and mixed layer (I-M)	gypsum, quartz , calcite, anhydrite, and feldspars





(b)

Figure5-X-ray Diffraction pattern of the clay fraction of natural soil (S2) soils (a) S1 (b) S2



(a)

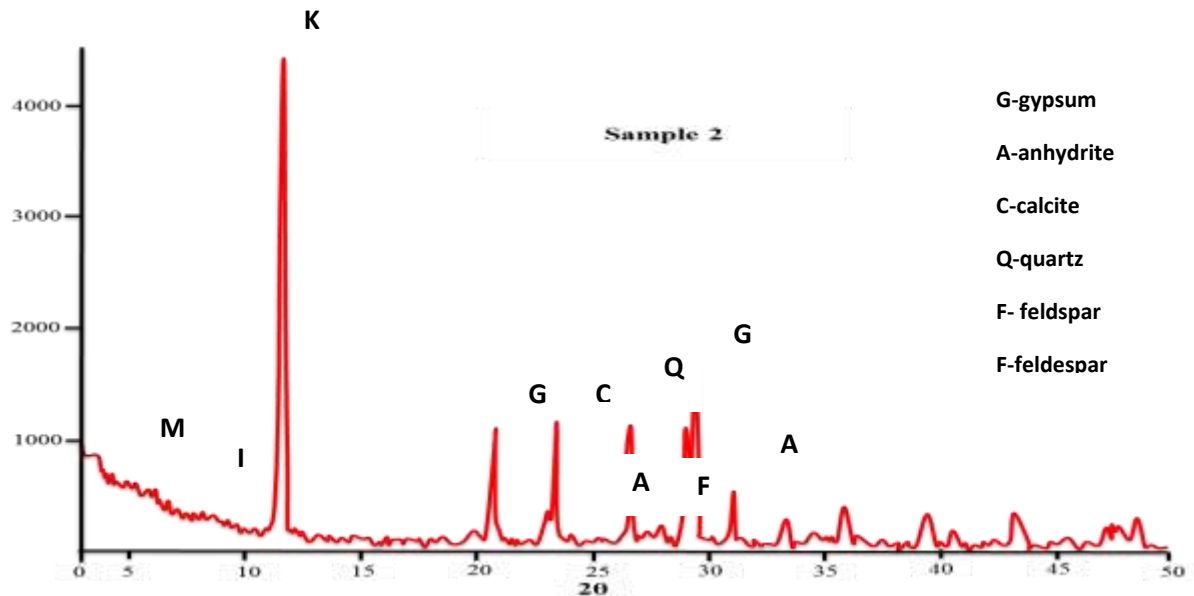


Figure 6-X-ray diffractogram of the bulk natural soil (S2) (a)S1 (b) S2

## 6-Conclusions

The grain size analysis of S1 and S2 demonstrated various percentages of clay (21.28 %,6.33% ), silt (50.77%,76.12% ), sand ( 25.61%,11.62 %), and Gravel (2.34%,5.93% ), respectively.

According to the Unified Soil Classification System (USCS), the soils were classified as CL. The specific gravity of the untreated S1 was about (2.52 gm/cm<sup>3</sup>), and that of S2 was 2.60 gm/cm<sup>3</sup>, with increasing gypsum content causing decreased specific gravity of soils, because the specific gravity of gypsum is as low as about 2.31-2.33 gm/cm<sup>3</sup>.

The addition of 10 %, 20 % and 30 % of the limestone waste powder from Said Sadiq and Pirmam areas to the natural soil of S1 and S2 led to decreases in liquid limit, plastic limit and plasticity index values.

XRD analysis of soil samples from the two locations in Makhmur area revealed the presence of gypsum minerals and, hence, the soils are defined as gypsiferous soil. Other clay minerals such as (Montmorillonite, Illite, and Kaolinite) were present, in addition to a mixed layer between Montmorillonite and Illite (I-M). Non-clay minerals included gypsum, Anhydrite, Calcite, Quartz, and Feldspar.

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