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Effect of Fly ash powder on the physical properties of expansive soils

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ABSTRACT

Expansive soils have a large variation in volume depending on the quantity of water in them, causing structural and geotechnical problems. Fly ash powder could be used as a stabilizing material for high-plasticity clay in five different locations in Erbil city that has caused damage to different buildings and roads. Grain size analysis, specific gravity, and Atterberg limit were the main methods of physical testing of soils. The expansive soil was stabilized by adding three different percentages of Fly Ash Powder (5%, 10%, and 15%). The results show that liquid limit, plastic limit, and plasticity index were decreased with increasing Fly ash powder to expansive soil. Mineralogically these soils are composed of Montmorillonite, Chlorite, Chlorite- swelling, Kaolinite, Illite, Palygoriskite, and mixed layer - dominated clay mineral components ,and the non-clay minerals consisting of calcite, muscovite, and quartz, and Fly ash powder composed of Muscovite and Calcite.

1. Introduction

Expansive soils are among the most extensively distributed and costly geologic hazards. They have been termed the "Hidden Disaster" in the building sector, and result in millions of dollars in continuous treatment, and repair of homes, commercial structures, highways, and underground infrastructure around the country each year. Expansive soils signify clayey soils that possess the ability to swell or expand in volume and shrink or reduce in volume when the prevailing moisture state is permitted to alter. Rain, floods, or sewage line leaks can cause these soils' moisture content to fluctuate [1]. [2, -3 and 4-] used fly ash content for expansive soil with different percentage (0%, 10% and 20%),they noted that the fly ash was the good stabilization for expansive soil and noted that with increasing fly ash decreasing swelling potential, swelling pressure, and they showed that fly ash has a good potential to be used as an additive for treating the geotechnical engineering properties of swelling soil.[5] concluded that the internal friction angle(ϕ) increased and cohesion decreased with an increasing 25% of waste glass powder to the swelling soil.

[6] This shows that the swelling in expansive soil presents significant geotechnical and structural engineering challenges. This is a worldwide problem that presents different facets in different parts of the world. From engineering points of view, Expansive soils are troublesome. Such problem is connected to physical properties, soil collapse and damage, by increasing the water content of the soil structure [7].The most widely distributed and costly geologic hazards may be considered to be one of the foundations and engineering problems and still facing because of the potential danger of unpredictable upward movements of different structures founded on such soil [8]. For improving the physical and chemical properties of the expansive soils, different stabilization methods have been used, such as chemical, mechanical, electrical, thermal, or combination between them [9-10]. The treatment of geotechnical engineering properties of swelling soils consists of decreasing the plasticity and the potential of swelling-shrinking, and increasing the strength, stiffness, and durability of the soil [11-12]. Stabilization of fly ash is one of the techniques of soil improvement, to enhance the geotechnical properties of difficult soils and make them suitable for construction.

[13] Studied the physical properties of expansive soil by using different percent of marble waste powder from different areas, the result displays a decrease in the Atterberg limit.

[14] Shows the percentage of free swell for samples prepared by applying 0 to 25% limestone powders. After increasing 10% of limestone powder, free

swelling is reduced. Investigation of some geotechnical properties of cement mixed soil using a different type of rice husk ash, the result that showed an increase in unconfined compressing stress (UCS) and decrease in the plastic limit (PL) [15].

Showing the importance of taking up systematic research on the swelling characteristics of Erbil soils in five different areas such as Rashkin (L1), Mosul road (L2), Italy City(L3), Traffic station (L4), Bahrka (L5) with varying percentages of addition of Fly Ash Powder (FAP) that mixed with the natural soil to treat or minimize the swelling potential of the expansive soils of Erbil, geotechnical experiments were carried out on treated soils by improvement physical properties of soils to bring about the needed enhancements the expansive soil and protect the environment from the pollution of the FAP, and this study has been taken.

2- Study area

The study area is Erbil City located in NE of Iraq. Five locations (L1, L2, L3, L4, and L5) within Erbil City were chosen for the present study. L1 is located NW of Erbil, (Lat.36° 12'44" N; Long. 43° 57'53"E). (L2) area located near the SW of Erbil city (Lat.36° 10' 32" N; Long.43°56'13"E).(L3)area located NE of Erbil City ;(Lat. 36°14'30''N 43; Long.44°2'47''E). (L4) area located SE of Erbil city. (L5) area is located SE of Erbil City. **(Fig.1)**

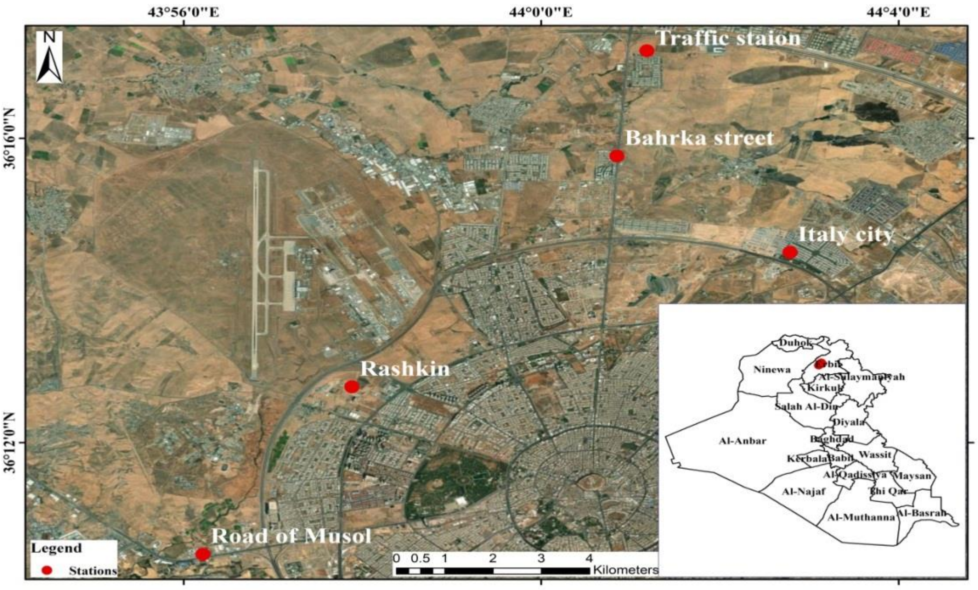


Fig.1: Location map of soil sample of the study area

3. Materials and Methods

The first step was choosing appropriate locations for the current study and then taking soil samples consisting of Fine grain soils at the depth about (~1m) from five locations studies in Erbil City (L1, L2, L3, L4, and L5); these soils are classified as high plasticity clayey soil according to the Unified Soil Classification System (USCS).Each samples of soil was divided into four parts. The first part of each sample was left in its natural state, whiles the other three parts of each sample which includes dry natural soil, were mixed with different percentages (%5, %10, and %15) of (FAP). For the estimation of the maximum dry density and the optimum moisture content (OMC), the standard proctor test was followed by [16].

For Particle Size Analysis test uses two methods; the first approach, sieve analysis, is used to measure the percent of coarse grain particles (sand and gravel). In contrast, the second method, the hydrometer method, is used to assess the percent of grain particles (silt and clay).In the hydrometer test the grain size distribution of fine- grained soils having particles that are smaller than (0.075mm) per standard [17], and this analysis is based on Stock's Law [18].

The Atterberg Limits are a basic measure of the water contents of a fine-particle soil, such as its shrinkage limit, plastic limit, and liquid limit. As dry, clayey soil takes on increasing amounts of water, distinct changes in behavior and consistency. The Atterberg Limit is divided in to three types the first type is Liquid Limit (LL) was determined by con-penetration method according. The Plastic limit (PL) test was conducted by the American Society Test. The Plasticity Index (PI) is the difference between the liquid limit and the plastic limit. Then the final test is Specific Gravity (Gs); Specific gravity was calculated according to the test described previously [17]. Mineralogy was performed by analysis was carried out using X-ray diffraction (XRD). Clay minerals are identified by the routine test, and include the many procedures briefed by [19] are; non-treatment (Bulk samples), treatment with acid (normal samples (N), treating samples with ethylene glycol (EG), and heated samples (up to 550C° for 1hr (H550).

4. Results and Discussion

4.1 Grain size analysis

The distribution of grain size analysis was done by using sieve and hydrometer analysis for five samples of soils (L1, L2, L3, L4, and L5). After computing the diameter of the soil grains and plotting the relation between the diameters versus the percent of the finer. The percentages of gravel, sand, silt and clay shows in (**Fig.2**) and **(Table1).**

Table 1: Percent of fine and coarse grain within the samples

	Particle %			
Locations	**Gravel%**	**Sand%**	**Silt%**	**Clay%**
L1	0	5.3	42.3	52.4
L2	4.05	5.35	51.1	39.5
L3	2.7	4	42.3	51
L4	0	3.55	35.98	60.47
L5	0	10.15	39.39	50.46

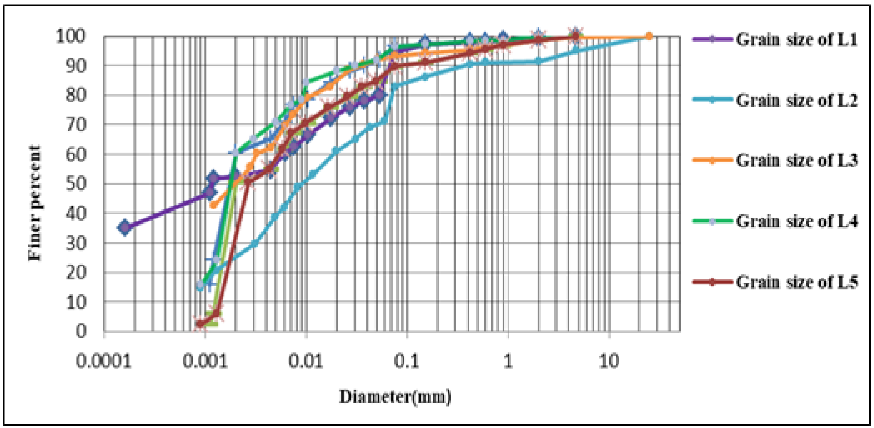


Fig.2: Grain size analysis of (L1, L2, L3, L4, and L5) soils.

4.2 Atterberg Limit

4.2.1 Liquid Limit

The liquid limit was decreased when increasing percentages (5%, 10%, and 15%) of FAP to (L1, L2, L3, L4 and L5)**. (Fig.3 (a, b, c, d and e), and (Table 2)**. The maximum reduction of the liquid limit of (L1) changes from (50.5%) to (34%), and the liquid limit of (L2) changes from (51%) to (38.6%), (L3) liquid limit changes from (55.6%) to (42%), (L4) liquid changes from (50.6%) to (37.5%) and the liquid limit for (L5) changes from (50%) to (38.5%) by adding 15% FAP.

Table 2: Liquid limit of n soils and treated soils by adding the different percentages of FAP

	Liquid Limit%			
Locations	**Natural**	**Natural soil with Additional FAP%**		
		5%	10%	15%
L1	50.5%	45	38	34
L2	51.0%	48.4	44	38.6
L3	55.6%	50	44.8	42
L4	50.6%	46.2	42.5	37.5
L5	50.0%	47.2	43	38.5

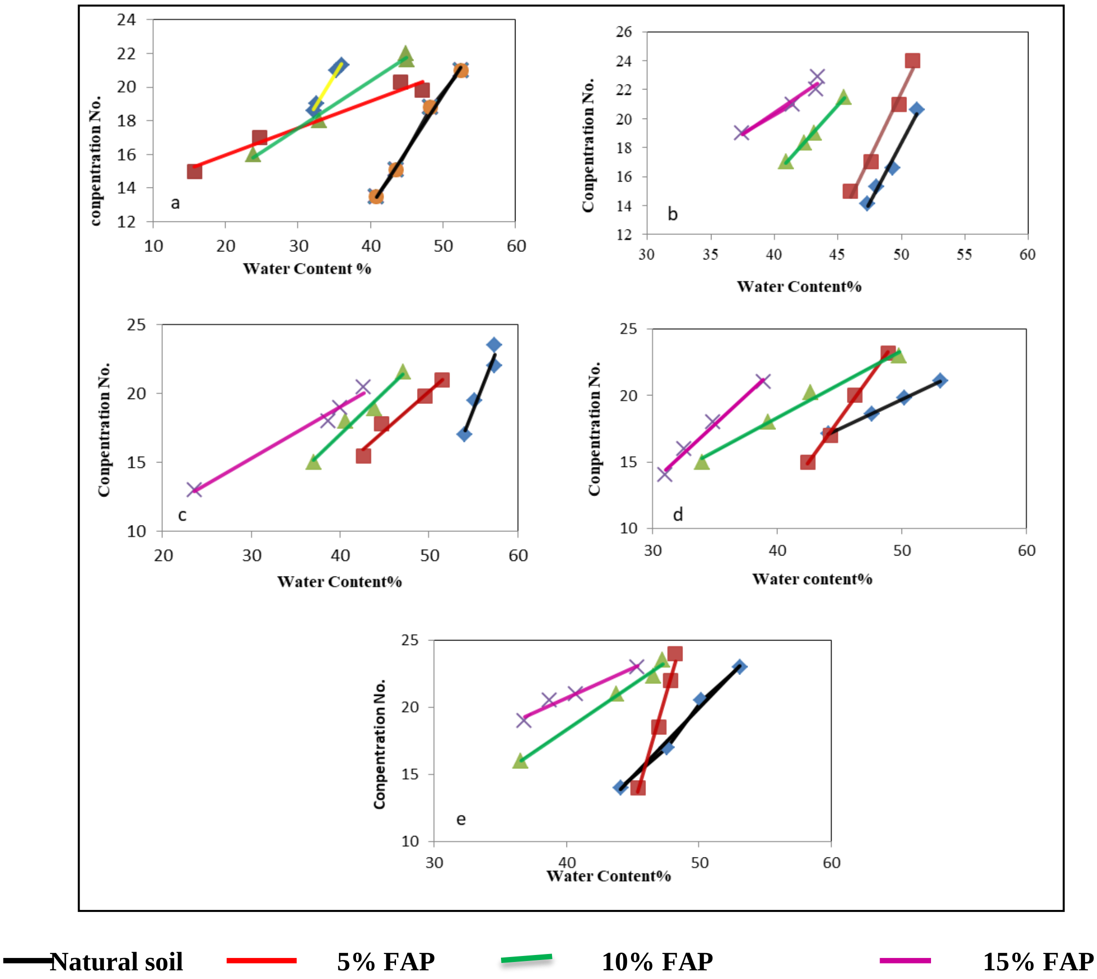


Fig.3: Relation between water content% and cone penetration no. with additional different percentages of FAP to (a) L1, (b) L2, (C) L3, (d) L4, and (e) L5 soils.

4.2.2 Plastic Limit

The decreasing (PL), when increasing FAP to expansive soil as stabilization. The maximum reduction of (L1) is (18.4%) (L2) is (17.39%), (L3) is (20.57%), (L4) is (14%), and (L5) is (18.3%) by adding (15%) FAP **(Table 3).**

Table 3: (PL) of Soils untreated and treated soils by adding the different percentages of FAP

	PL (%)			
		Natural soil with adding FAP		
Locations	**Natural**	**5%**	**10%**	**15%**
L1	23.38	21.24	19.28	18.4
L2	24.72	23.07	19.97	17.39
L3	26.9	24.19	21.12	20.57
L4	26	22.03	18.95	17
L5	22.42	21.01	19.42	18.3

4.2.3 Plasticity Index

Table 4 Shows the decrease (PI) with the addition FAP to expansive soil as stabilization percentages. The maximum reduction of (L1) is (15.6%) (L2) is (21.21 %), (L3) is (21.43%), (L4) is (20.5 %), and (L5) is (20.20%) by adding (15%) FAP.

Table 4: (PI) of Soils untreated and treated soils by adding the different percentages of FAP

Locations	PI (%)			
		Natural soil with additional Fly ash powder		
	Natural	**5%**	**10%**	**15%**
L1	26.63	23.76	18.71	15.6
L2	26.28	25.33	24.03	21.21
L3	28.7	25.81	23.68	21.43
L4	24.6	24.17	23.65	20.5
L5	27.58	26.19	23.58	20.2

4.3 Specific Gravity (Gs)

The specific gravity of (L1) soils is about (2.79 gm/cm^3), (L2) is (2.61 gm/cm^3), (L3) is (2.63 gm/cm^3) ,(L4) is (2.7 gm/cm^3) and (L5) is (2.75 gm/cm^3) **(Table 5)**.

Table 5: Specific gravity of samples

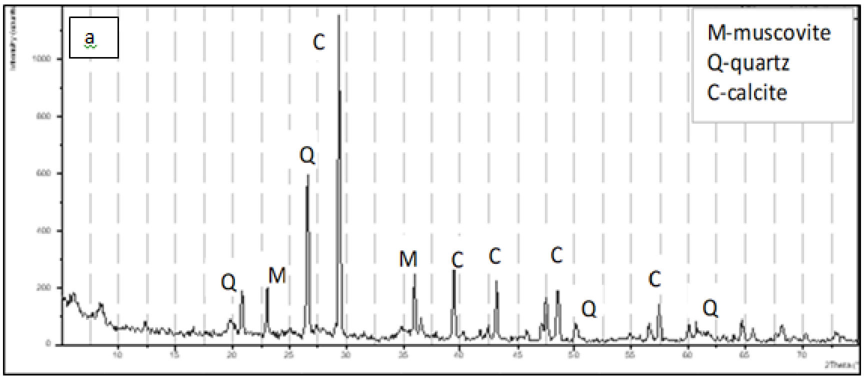
Locations	**Gs (gm/cm^3)**
L1	2.79
L2	2.6
L3	2.63
L4	2.7
L5	2.75

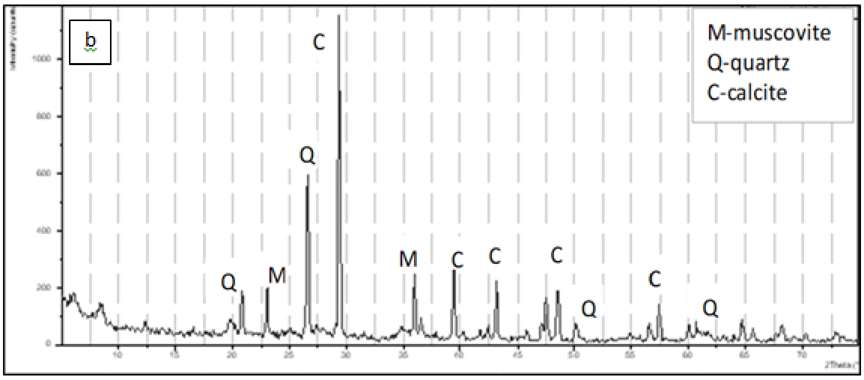
4.4- Mineralogical analysis

Several XRD runs were applied for untreated soil samples (L1, L2, L3, L4 and L5) of five locations in the studied area of Erbil. Clay minerals existing in the studied soils were identified according to the first reflection (001) and other reflections. The results of these tests revealed that, non-clay minerals such as Muscovite, Quartz, and Calcite**. (Fig.4 (a, b, c, d, e, and f)** and (**Table 6**).In addition, the bulk mineralogy of FAP revealed the presence of Muscovite and calcite. Whereas clay mineral components such Montmorillonite (M),Chlorite(C), Chlorite- swelling, Kaolinite, Illite (I) , Palygoriskite (P) and mixed layer (I-M) ,(I-C),(C-M) dominated clay mineral components **(Fig. 5 a, b, c, d, and e)** and (**Table 6).**

Table 6: Mineralogical Composition of studied natural soils and FAP

Locations	**Arrangement of minerals**	
	Clay minerals	**Non- Clay minerals**
L1	Chlorite, Chlorite swelling, Kaolinite, Illite and mixed- layer (C - I), and Palygorskite	Muscovite, Quartz , Calcite
L2	Sepiolite, Illite, Serpentinite, Montmorillonite, and Chlorite- swelling	Muscovite, Quartz , Calcite
L3	Montmorillonite, (C-M) ,Palygoriskite, and Kaolinite	Muscovite, Quartz , Calcite
L4	Montmorillonite,(C-M) mixed layer, Kaolinite, palygoriskite	Muscovite, Quartz , Calcite
L5	Montmorillonite , Chlorite swelling,(C-M) mixed- layer, Palygoriskite, and Kaolinite	Muscovite, Quartz , Calcite
FAP		Muscovite and Calcite





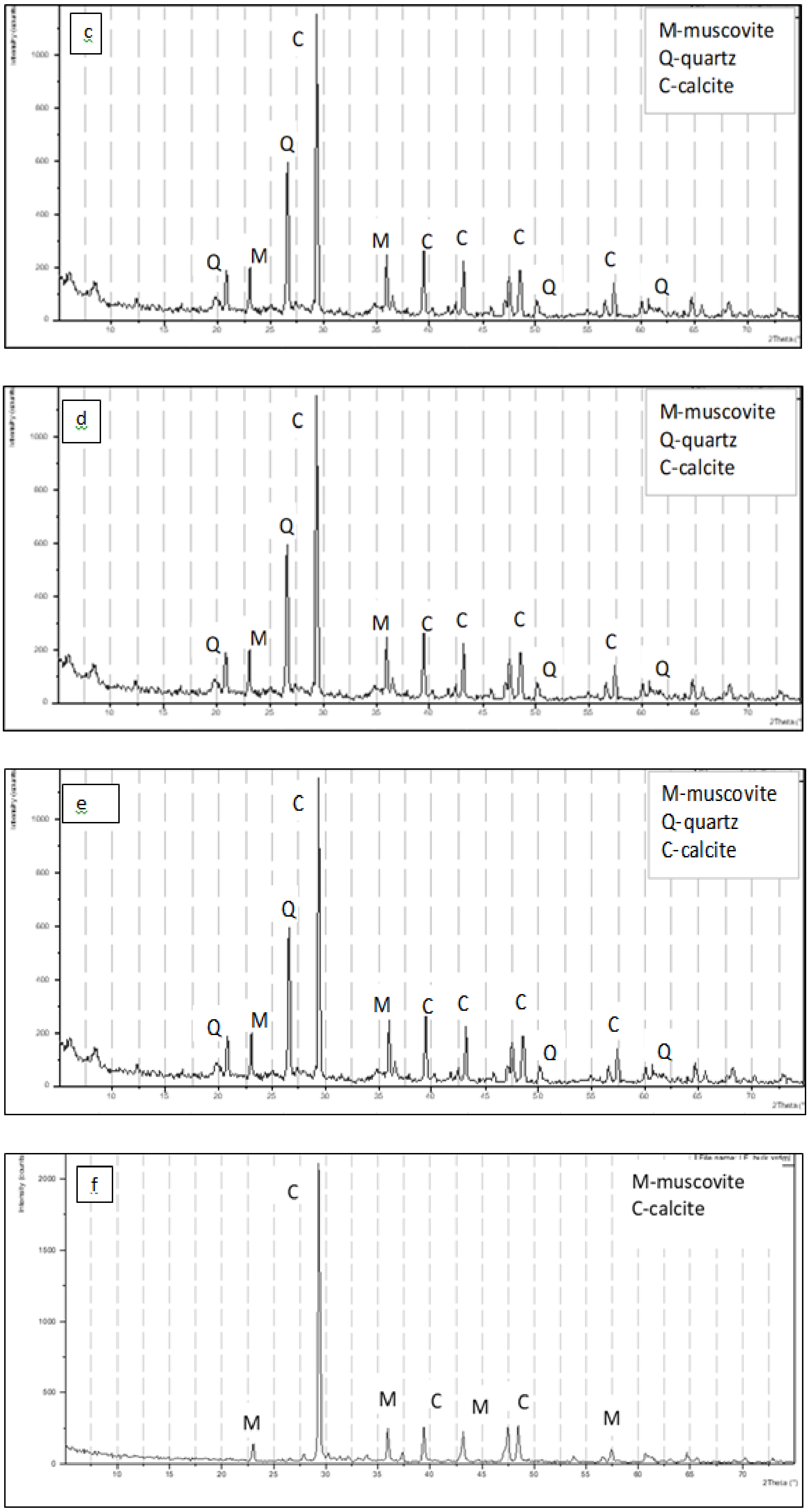
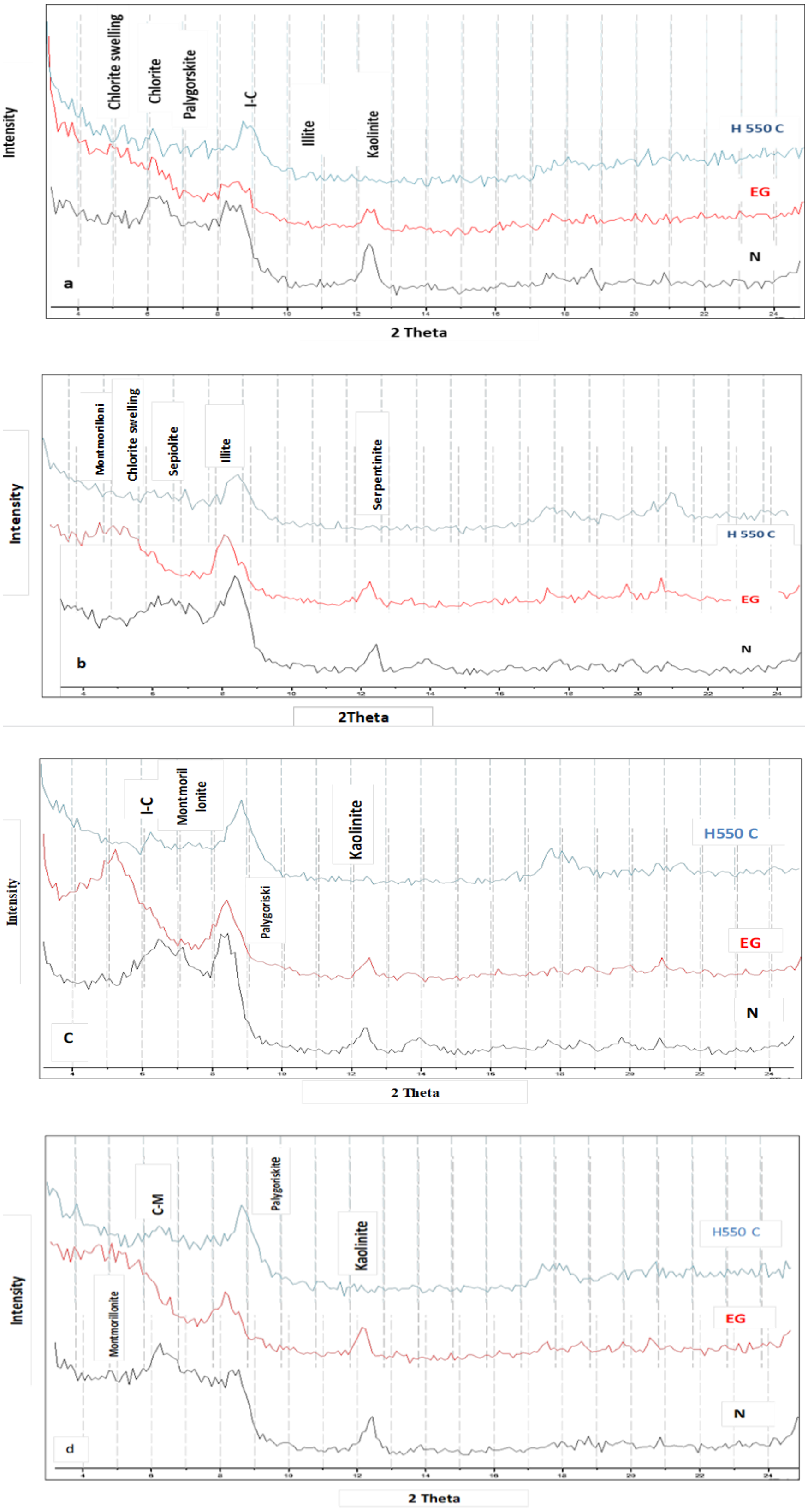


Fig.4. X-ray Diffractogram of the Bulk natural soils (a) L1, (b) L2,(C) L3, (d) L4 ,(e) L5 and (f) is FAP


Intensity
Chlorite swelling
Chlorite
Palygorskite
I-C
Illite
Kaolinite
H 550 C
EG
N
a
2 Theta
Intensity
Montmorilloni
Chlorite swelling
Sepiolite
Illite
Serpentinite
H 550 C
EG
N
b
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Intensity
I-C
Montmoril lonite
Kaolinite
Palygoriski
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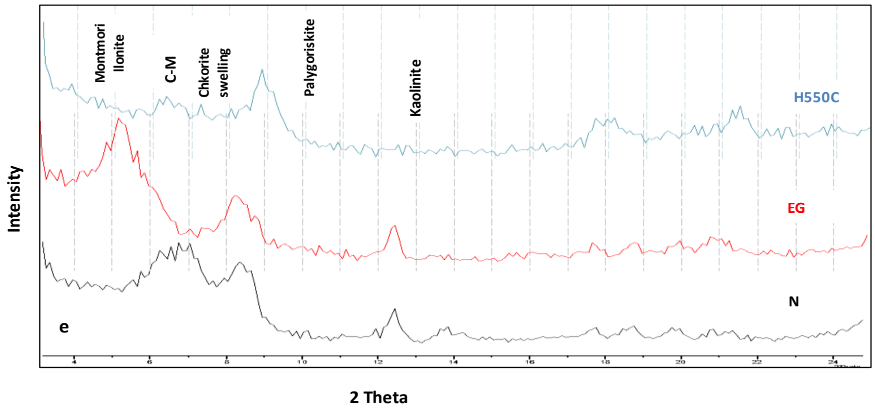

Fig. 5: X-ray Diffraction pattern of the clay fraction of natural soils (a) L1, (b) L2, (C) L3, (d) L4, and (e) L5

According to grain size analysis the L1 consist of (52.4% clay, 42.3% silt, 5.3% sand, 0% gravel), L2 is (39.5% clay, 51.1% silt, 5.35% sand, 4.05% gravel), L3 is (51% clay,42.3% silt, 4% sand, 2.7% gravel) L4 is (60.47% clay, 35.98% silt, 3.55% sand, 0% gravel) L5 is (50.46% clay, 39.39% silt, 10.15% sand,0% gravel) (**Table 1**).

The Atterberg Limit has decreased with increasing different Percentage of FAP (5%,10%, and 15%) to the swelling soil of the locations (L1, L2, L3, L4, and L5); because of FAP material consist of (Muscovite and calcite) which are non-clay minerals according to XRD analysis. The maximum reduction of the LL of each locations (L1, L2, L3, L4, and L5) were about (50.5%) to (34%), (51%) to (38.6%), (55.6%) to (42%), (50.6%) to (37.5%), and (50%) to (38.5%) respectively with additional the 15% of the FAP. The maximum reduction of the PL of each locations (L1, L2, L3, L4, and L5) were about is (23.38%) to (18.4%), (24.72%) to (17.39%), (26.9%) to (20.57%), (26%) to (17%) and (22.42%) to (18.3%) respectively by adding (15%) FAP. The maximum reduction of the PI of each Locations (L1, L2, L3, L4, and L5), L1 is (15.6%) (L2) is (21.21%), (L3) is (21.43%), (L4) is (20.5%), and (L5) is (20.20%) by adding (15%) FAP. With additional three different percentages the classification of soils changes from CH to CL according to USCS, because LL and PL decreased and then (PI) will decrease. The specific gravity of each sample is between (2.6 - 2.79) $gm/cm^{3.}$

5 - Conclusions

- At the study area (L1, L2, L3, L4 and L5),the grain size analysis have various percentage of gravel about (0%, 4.05%, 2.7%, 0%, 0%), sand (5.3%, 5.35%, 4%,3 .55%, 10.15%), silt (42.3% ,39.5% ,51.0% ,60.47%, 50.46%) and clay (52.4%, 39.5%, 51.0%, 60.47%, 50.46%) respectively.
- These soils were classified as CH according to the (USCS), after adding of three different percent of FAP the classification of soils changed from CH to CL.
- The specific gravity of the natural soils (L1, L2, L3, L4 and L5) were about (2.79gm/cm^3, 2.6gm/cm^3, 2.63gm/cm^3, 2.7gm/cm^3, and 2.75gm/cm^3) respectively.
- The Atterberg Limit of the natural soils of L1, L2, L3, L4 and L5 decreased with increasing three different percentages (5%, 10%, and 15%) of FAP.
- The LL decreased from (~12% to 16%), PL from (~4%- 9%), and PI from (~4.1%- 11.03) by adding the different percentages of FAP to the natural soils.
- XRD analysis of each sample from the five locations in Erbil City revealed that clay mineral such as (Montmorillonite, Illite, and Kaolinite, Palygorskite, Chlorite, Chlorite swelling, Sepiolite, Serpentinite) were present, in addition to a mixed layer between Montmorillonite and Illite (I-M), (I-C) and (C-M), non-clay minerals included Muscovite, Calcite and Quartz. While the FAP is content of (Muscovite and Calcite without Quartz).

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تأثير مسحوق الرماد المتطاير على الخواص الفيزيائية للتربة المنتفخة

ته لار عثمان رشيد، نظمية نجم الدين مجيد

قسم علم الارض والنفط ، كلية العلوم ، جامعة صلاح الدين ، اربيل ، العراق

الملخص

تتميز التربة المنتفخة باختلاف كبير في الحجم اعتمادًا على كمية المياه فيها، مما يتسبب في مشاكل هيكلية وجيوتقنية. استخدمت مسحوق الرماد المتطاير لمعالجة التربة المنتفخة عالية اللدونة التي تسببت في اضرارللمباني والطرق في خمسة مواقع مختلفة من مدينة أربيل .

الطرق ألاساسية للاختبار الفيزيائي للتربة هي تحليل حجم الحبيبات، الوزن النوعي وحدود أتربرغ. تم تثبيت التربة المنتفخة بإضافة ثلاث نسب مختلفة من مسحوق الرماد المتطاير (5٪ ، 10٪ ، 15٪). أوضحت النتائج بانخفاض حد السيولة، حد البلاستيك و معامل اللدونة مع زيادة مسحوق الرماد المتطاير إلى التربة المنتفخة. من الناحية المعدنية ، تتكون هذه التربة من المونتموريلونيت، الكلوريت، الكلوريت المنتفخ، الكاولينيت، الإيليت، الباليغورسكيت والطبقة المختلطة (I-M)، (I-C)، (C-M) المكونات المعدنية الطينية والمعادن غير الطينية المكونة من الكالسيت والمسكوفيت والكوارتز.