ARTICLE

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Evaluation of Dispersion for Soil Properties from Faw City- Southern Iraq

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تقييم تشتت خواص التربة في مدينة الفاو جنوب العراق

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ABSTRACT

Four boreholes were drilled in four different places of the AL- Faw city using a hand auger, disturbed samples were collected at depths of 0.5 and 1.5 meters. The soil of the study area was determined by classification tests to be silty clay, CL-type soil in the Unifined Classification System of Soils. Soil dispersion tests such as the Crumb test, chemical analysis and XRD tests were conducted, and the results of crumb test showed that the soil of the study area was low dispersive from grade 2 except for the fourth site was a non-dispersive soil. The values of Total Salts Dissolved (TDS) in the pore water of the soil, was determined by estimating the total concentration of dissolved cations (Na, K, Ca and Mg) .The ETDA titration technique (for Ca and Mg) and the flame photometer were used to test this pore water (for Na and K), and it showed that the soil of the study area in the four sites within the C zone represented the Intermediate dispersive soil classification chart, and the results from Sodium Absorption Ratio (SAR) values showed that the soil in the area was dispersive.

The XRD data showed that the minerals quartz, calcite, dolomite, and clay made up the majority of the soil samples. The principal clay minerals included Smectite (Montmorillonite), Palygorskite and Kaolinite. The results of the Total dissolved salts test showed a variety of the Crumb test for a difference in the soil content of mineral and chemical components. It is necessary to conduct further research on the XRD analysis with detailed interpretation of the minerals present, the importance of clay mineral types like Smectite should be assessed. The study of dispersion processes, the identification and classification of soils from specific tests and the identification of soils are the main objectives of this research.

Key words: dispersive soil, total dissolved salts, Crumb test, clay minerals and SAR .

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الخلاصة

في هذه الدراسة تم حفر اربعة حفر وبعمق 0.5 متر و عمق 1.5 متر في اماكن مختلفة في مدينة الفاو باستخدام الة لثقب وجمع العينات. تم تحديد تربة منطقة الدراسة باختبارات التصنيف لتكون التربة طينية غرينية من نوع (CL) في نظام التصنيف الموحد للتربة.ايضا اجريت اختبارات تشتت التربة مثل اختبار تشتت خصائص التربة والتحليل الكيميائي واختبار الاشعة السينية الحائدة . واظهرت نتائج هذه الاختبارات ان تربة منطقة الدراسة منخفضة التشتت من الدرجة الثانية باستثناء الموقع الرابع كان تربة غير مشتتة.

تم تحديد قيم الاملاح الكلية الذائبة في المياه المسامية للتربة بتقدير التراكيز الكلية للكاتيونات الذائبة (Ca, Mg, Na, k) و استخدام تقنية معايرة (ETDA) للكالسيوم والمغنيسيوم وتقنية اللهب. اظهرت ان ترب منطقة الدراسة في المواقع الاربعة في النطاق (C) تمثل منطقة تشتت متوسطة حسب مخطط تشتت الترب. و اظهرت نتائج نسبة امتصاص الصوديوم (SAR) ان قيمها تمثل ان التربة في المنطقة المشتتة.

كما بينت نتائج الاشعة السينية الحائدة ان معادن الكوارتز والكالسايت والدولومايت والطين تشكل غالبية عينات التربة. وتشمل معادن الاطيان الرئيسية السمكتايت (مونتموريلونايت) والباليكورسكايت والكاؤولينايت.

كما بينت نتائج اختبارات الاملاح الكلية الذائبة تنوع في اختبارات تشتت الترب واختلاف المحتوى المعدني والكيميائي للترب.

ومن الضروري اجراء المزيد من البحث والتفصيل للمعادن الموجودة وتقييم اهمية المعادن الطينية.

وتعد عمليات التشتت وتحديد التربة وتصنيفها من اهداف البحث الرئيسة.

الكلمات المفتاحية: ترب مشتتة، املاح ذائبة، اختبارات تشتت، معادن طينية، نسبة امتصاص الصوديوم.

1. INTRODUCTION

Al-Faw is One of Iraq's ports, it is located at south of Basrha having a view of the Arabian Gulf. In addition to its strategic, commercial, and touristic importance, this city is regarded as a crucial area of urban development. As a result, it is essential to evaluate the local soil and identify any engineering issues it may have, such the phenomenon of soil dispersive.

Dispersive soils experience de-flocculation in the presence of running water and are especially sensitive to erosion and the piping phenomena [1]. Colloidal erosion, which occurs when individual clay particles are suspended in slowly flowing water, causes it to erode quickly, causing damage to earth dams, canals, and other hydraulic systems, and creating tunnels and deep gullies[2].

Dispersive soils are clay soils with a high sodium content that are prone to erosion, the mineralogy affects the clay' stability to disperse or de-flocculate and soil chemistry, as well as the amount of dissolved salts in the water eroding and pore water [3]. Dispersive soils are usually sodic, containing greater than 6% sodium within the clay structure [4]. The sodium thickens the diffused double water layer that surrounds the individual clay particles in dispersive soils, in the presence of water the particles easily go into suspension because the repulsive forces outweigh the attractive forces as a result. The clay's surface has the sodium ions adsorbed on it, Large and weakly charged, these ions look to be like a normal clay, which is stable and has some erosion resistance, but in

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practice they can be highly erosive and vulnerable to serious damage or failure [5]. [6] noted that soil with a high total dissolved concentration (TDS) has a different fabric than soil with a low total dissolved concentration, while dispersive soils with high TDS concentrations have a granular fabric without any smooth clay zones, those with low TDS concentrations are controlled by a turbostratic fabric.

Furthermore, it was found that pore spaces in dispersive soils with high TDS concentrations are greater than those soils with low TDS concentrations. The salt increases the thickness of the diffused double water layer surrounding the individual clay particles in dispersive soils, when there is water present, the particles easily get into suspension because the repulsive forces outweigh the attractive forces [3].

On the clay's surface, the sodium ions are adsorbed, also the big and weak charge and the an ion, these appear to be stable, moderately resistant to erosion clays like other clays, yet they can really be very erosive and vulnerable to severe damage or collapse [5]. Sodium adsorption ratio (SAR) is an additional parameter that is usually studied to determine how much sodium contributes to dispersion when free salts are present, where is a SAR value greater than 6 indicates that the soil is susceptible to leaching. [7], on the other hand, according to [8], dispersive soil occurs when the SAR is more than 10. Previous research has shown that clay active minerals like montmorillonite, low electrolyte concentrations and the presence of exchangeable sodium all contribute to emergent dispersive behavior [9]. The dispersivity of soil can be determined by comparing the results of several experiments performed on soil with and without a dispersing agent, such as the Atterberg limits, unconfined compression test [10], and shear strength test [4]. [11], use of the methodologies and their relationship to the dispersivity estimated using different methods have been justified. It has been asserted that dispersivity determined by strength tests is more trustworthy. In nature, dispersive soils are formed by weathering sedimentary rocks, in which sodium is transferred from rocks to soil, or in a dry climate area, where water evaporates from the upper layers and provides quantities of sodium ion, particularly when the lower layers are impermeable or when the soil is exposed to marine water runs off [12].

Dispersive clays typically have low- medium plasticity and are categorized as CL in the Unifined Soil Classification System (USCS), class in the USCS that may also include clays that dispersive are ML, CL and CH categorizing soil as dispersive soil clay particles are in MH seldom [3]. [13], indicated how to improve the engineering properties of selected soils of Al-Faw using cement and polymeric materials, the results of laboratory tests on sand soils treated with the proposed materials revealed increases in shear strength, internal friction and maximum dry density. [14], studied the swelling characteristics of the surface soils of selected sites of Faw, they showed that the soils of the region are clayey silt or silty clay, and the swelling effort in them ranges from medium to very high, which is an effort that negatively affects the stability of engineering facilities in the city. [15], explained in the study of the geotechnical properties of bearing strata in the Al-Faw city, that

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Al-Faw soils are divided into two types of cohesion from the surface to a depth of approximately 26.5m, representing clay and silt deposits, followed by non-cohesive soils extending from 26.5 to the end of borehole which represents the sand soils of the Dibddiba formation. The study of dispersive processes, the identification and classification of soils from specific tests and the identification of soils are the main objectives of this research.

2. Location of the study area

Faw city is located southeast of Basrah Governorate between longitudes 48˚ 30′ 00" and 48˚ 25′ 00″ east and latitudes 29˚ 56′ 36″ and 29˚ 56′ 97″ North. It overlooks the Shatt al-Arab banks of the eastern part and is bordered by the city of Umm Qasr to the west and the Sebh District to the north and Northeast coasts of the Arabian Gulf Fig.(1).

AL-Faw is characterized by a dry summer and cold climate wet winter, high temperature extremes ratio of solar radiation, lack of rain and high proportion, moisture compared to the rest of the country's neighborhood and proximity to the north and northwestern coasts of the Arabian Gulf, From November to April during the winter and spring, for the years 2004 to 2014, the evaporation rate was 308.1 mm, the annual rainfall rate was 15.3 mm, and the minimum temperature was around 23.7˚ degrees Celsius. The high temperature was approximately 39.4˚ degrees Celsius [16 and17].

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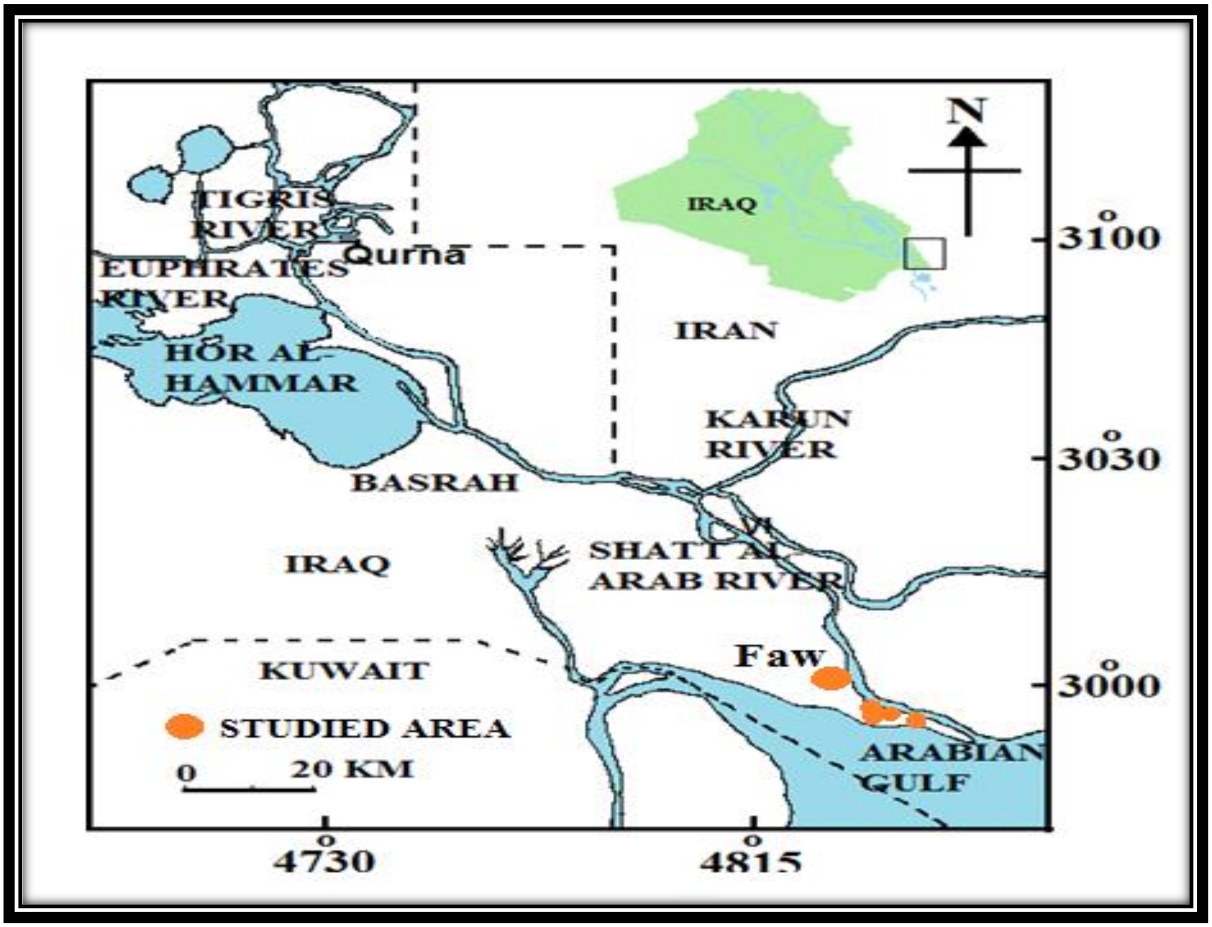

Fig. (1) Map of the studied area after [18].

3. Stratigraphic and tectonic setting:

The sediments of the Quaternary period cover the Mesopotamia plain in Iraq [19], including the city of Al-Faw, climate oscillations and cyclical changes in sea level have affected during the Pleistocene period is very much in the nature of the sediments of this age [5] [20]. The Wadi Al-Rafidain Basin is filled with delta and river deposits characterized by the change and exchange of facies horizontally and vertically, The Dibddiba formation deposited, and then marine sediments represented by the formation of the Hammer and the lake sediments, and the upper part of the basin is a mixture of Alluvial deposits and flood river mud brought by the Tigris, Euphrates, Shatt al-Arab and Karun rivers [21]. The importance of these soils resides in the fact that they are the base which the shallow foundations of buildings and various engineering facilities are based in the city of Al-Faw.

Tectonically. the study area is part of the Mesopotamian plain controlled by a network of normal faults that is subsurface and tilts towards (NE-SW), the Mesopotamian plain is divided longitudinally into the following areas [22].

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1- The Tigris sub zone
2- The Euphrates subzone
3- The Zubair subzone

AL- Faw is located in the Zubair subzone, which represents the South part of the Mesopotamian plain and is characterized by a homogeneous synthetic pattern in which subsurface geological structures extend northwest to southeast. Deep faults extend on basement rocks from the pre-Cambrian period partition Iraq into five transverse blocks, each of which is composed of the following:

1- The Sinjar block
2- The Dier-Alzor-Arbil block
3- The Central Iraqi block
4- The Mesopotamian block
5- The Basra block

The study area is in the Basrah block, the basement rocks that are nearer to the surface and have a depth of less than 10 km, except for sections of the southwest that tilt northeast [20]. Fig.(2).

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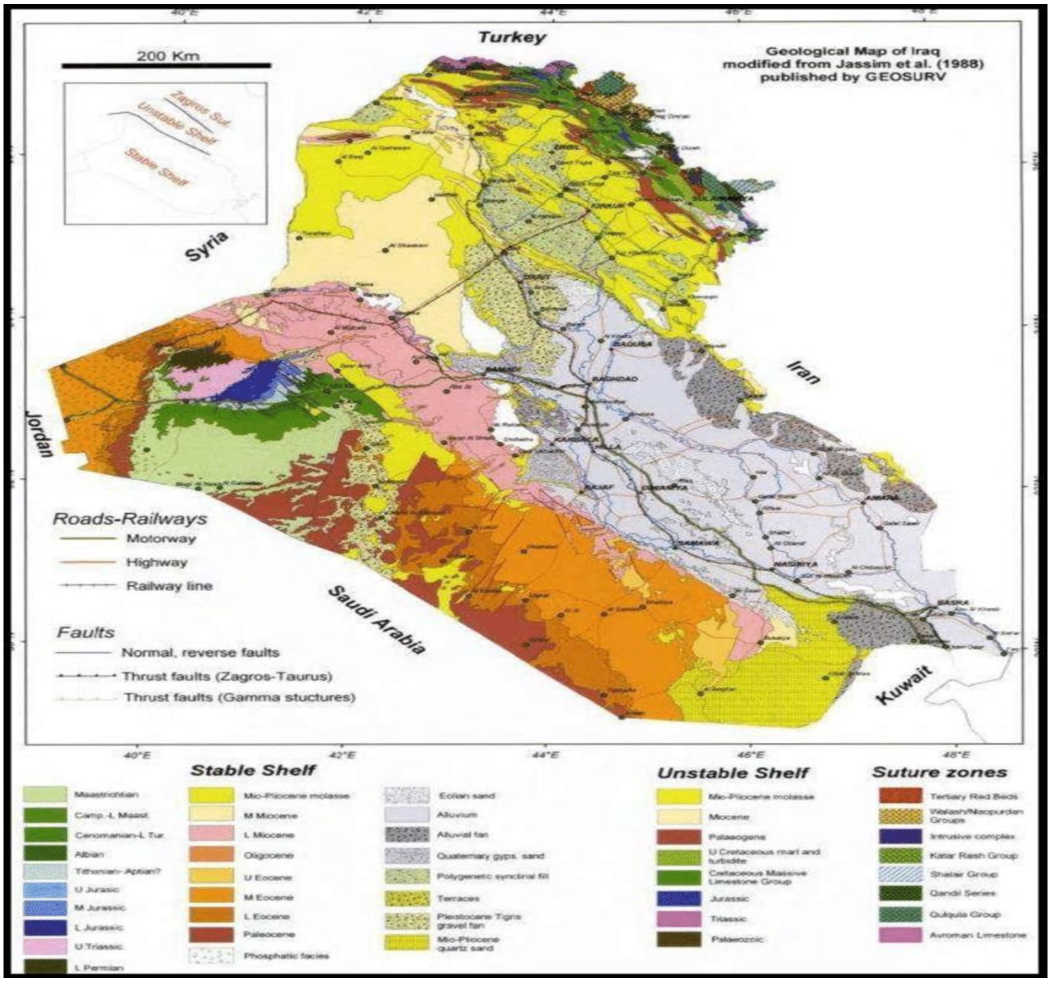

Fig. 2 : Geological map of Iraq after [23].

4. Materials and methods:

4.1 Field work

Four bore holes were excavated using a hand auger to a depth of two meters, and disturbed samples which were obtained from each borehole depths of 50 cm and 1.5 m Fig (1). According to British Standard 5930: 1981, the samples were labeled, then they were stored in plastic bags and sealed to maintain moisture.

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4.2 Laboratory work

4.2.1 Classification Test

4.2.1.1 Grain Size Analysis

The particle size analysis was set based on the method described in [24], its examination was conducted in the college of Science, Department of Geology.

4.2.1.2 Atterberg, s Limits

Based on [25], Atterberg limits (liquid limit, plastic limit, and plasticity index) were established .

The values of shear strength and unconfined compression strength depended on the data mentioned in [15].

4.2.2 Dispersive Test

4.2.2.1 Crumb test

Crumb test is a quick and easy field test that can now also be done in the laboratory to assess dispersive soil behavior. This test done according to D 4221 and D 4647. The test entails either producing a cubical specimen with a side measurement of approximately 15 mm at natural water content or choosing a soil crumb with a volume measurement of approximately the same natural water content. About 250 ml of distilled water is gently added to the specimen. Colloidal-sized particles have a propensity to deflocculate and move into suspension as the soil crumb starts to moisten. Results are classified as dispersive, intermediate dispersive, or non-dispersive at intervals of two hours. A reliable indicator of clay's potential erodibility is on the crumb test Table (1).

Table 1: **Table** (1) Description Of Crumb Grades [26].

Grade	Reaction	Description
1	No reaction	Crumbs may slake, but no sign of cloudiness cause by colloids in suspension.
2	Sight reaction	Bare hint of cloudiness in water at surface of crumb.
3	Moderate reaction	Easily recognizable cloud of colloids in suspension, usually spreading out in thin streaks on bottom of beakers.
4	Strong reaction	Colloid cloud covers nearly the whole bottom of the beaker, usually as a thick skin

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4.2.3 Chemical Test

4.2.3.1 Total Dissolved Salts (TDS)

The most reliable methods for determining soil dispersivity appears to be the chemical analysis of soil pore water. Since the phenomenon of dispersivity was caused by the presence of dissolved sodium in the pore water, it's percent is determined by estimating the total concentration of dissolved cations (Na, K, Ca and Mg) in the soil pore water. The ETDA titration technique (for Ca and Mg) and the flame photometer were used to test this extracted pore water (for Na and K) according [27], chemical analysis was conducted at the College of Agriculture.

The definition of the sodium percentage is

$$Na\% = \frac{Na+}{Na+K+Ca^2+Mg^2} *100 \text{ -- } (1)$$

expressing each unit in meq /l of saturation extract

4.2.3.2 Sodium absorption Ratio (SAR)

A (SAR) is a further parameter that is frequently examined to assess the contribution of sodium to disperse in the presence of free salts.

The equation defines Sodium an absorption ratio as follows:

$$SAR = Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{0.5} \text{ ------------------------------------- } (2)$$

If there are no free salts, the SAR technique is not relevant [7]. There is a relationship between the exchangeable ions in the clay adsorbed layer and the electrolyte content of the soil pore water.

4.2.4 X-Ray Diffraction (XRD)

The most popular X-ray analytical method for characterizing materials is probably X-ray diffraction analysis (XRD). The types of minerals contained in soil samples are identified via X-ray analysis.

When an X-ray beam strikes a sample and is diffracted, we can calculate the distances between the planes of the atoms that make up the sample by using Bragg's Law: n = 2d sin, where the integer n is the order of the diffracted beam, the number is the wavelength of the incident X-ray beam, the number is the distance between adjacent planes of atoms (the d-spacings), and the angle of incidence is the X.

5. Results and Discussion

5.1 Classification tests

Table (2) and figure (3) indicate that the soil of the study area is silty clay or clayey silt , with the percentage of clay ranging from 59 to 73%, the percentage of silt ranged from 26 to 39%, the liquid limit changes slightly and the plasticity index ranged from 10 to 13%, and the soil was classified by Unified Standard Classification System (USCS) to CL, indicating that the soil of the area is dispersed as pointed by [3], dispersive clays typically have low- medium plasticity and are categorized as CL in the Unifined soil classification system.

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Table (2) Results of Classification Test of Study Area

Borehole NO.	Depth(m)	Clay%	Silt%	Sand%	Unifined Classification (USCS)	Liquid limit(LL)%	Plasticity Index(PI) %
1	0.5	73	26	60	CL	33	12
	1.5	70	29	64	CL	40	13
2	0.5	69	30	66	CL	36	11
	1.5	65	35	60	CL	35	13
3	0.5	59	39	64	CL	41	12
4	1.5	60	38	66	CL	38	12
	0.5	64	35	60	CL	37	10
	1.5	66	32	64	CL	40	13

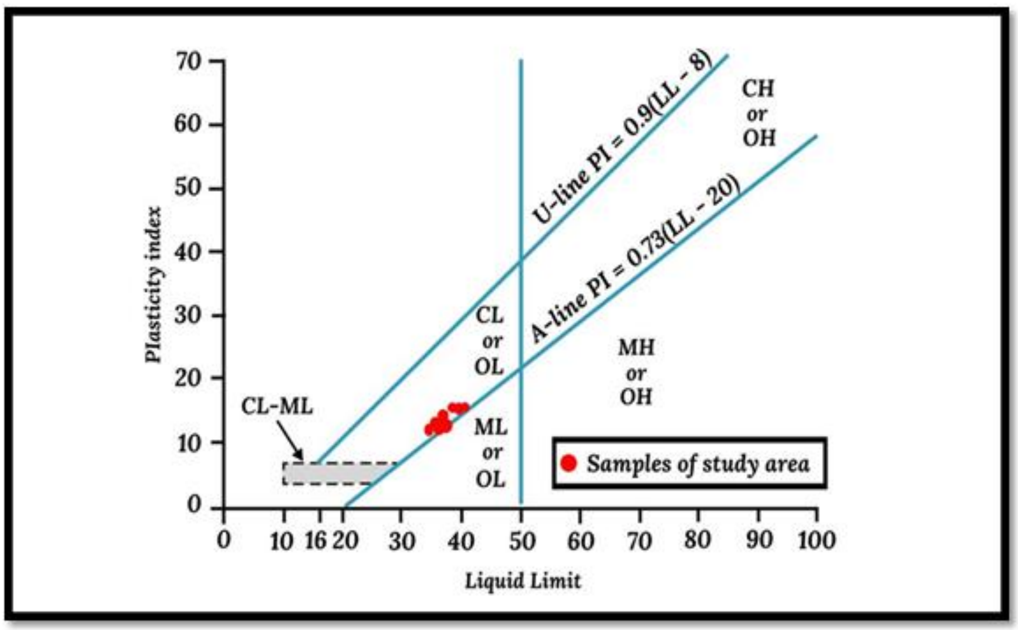

Fig. (3) Classification of study area samples according to plasticity chart

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5.2 Mechanical Test

The average of shear strength (Su) of soil in the study area is 46 KN/m^2 at the first to second meter, and the average of the Unconfined compressive strength (qu) is 89 KN/m^2 [15]. The values of shear strength and confined compressive strength are a low due to the high level of groundwater and the high concentration of dissolved sodium salts in the groundwater that weakens the soil and increase the degree of depressive, which causes collapse in the structures built on this soil

5.3 Dispersive Tests

- Crumb test

All 8 samples were put through the crumb test because the preliminary findings were not very conclusive. The crumb was air dried, and observations were conducted over 10 minutes, an hour and two hours. The samples then were graded according to the system. The results of the crumb analysis are shown in Table (3). After two hours of testing, discoloration in the solution was discovered by observation. The test can be quite vulnerable because it simply measures depressiveness visually. A non-dispersive soil could be considered depressive because of the staining in the solution rather than the fines in suspension.

Table (3) Results of Crumb Test

Borehole No.	Depth(m)	Grade of Reaction	Reaction	Inference
1	0.5-1	11	Some cloudiness in the water near the surface of the crumb.	Intermediate
	1.5-2			
2	0.5-1	11	Some cloudiness in the water near the surface of the crumb.	Intermediate
	1.5-2			
3	0.5-1	11	Some cloudiness in the water near the surface of the crumb.	Intermediate
	1.5-2			
4	0.5-1	1	Crumbs may be slake, but there is no indication that they caused the suspension to become cloudy	No dispersive
	1.5-2			

- **Chemical Test**

The values of sodium percent (Na) %, total solid salts (TDS) and sodium adsorption ratio (SAR) are calculated in the unit of a milliequivalent per liter (meq) Table (4), these values and Fig.(4), which show the classification of soil based on the total salts dissolved in the pore water and the ratio of sodium percent, the results showed that the soil of these site in the four borehole ׳s within the C zone representing the Intermediate dispersive soil, and the results from SAR values showed that the soil in the area is dispersed, according to [7] a SAR value greater than 6 indicates

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that the soil is susceptible to leaching, while, according to [8], dispersive soil occurs when the SAR is more than 10 Table (4). SAR increases depend on precipitated calcium and magnesium carbonates during soil drying [28]. The salt increases

the thickness of the diffused double water layer surrounding the individual clay particles in dispersive soils, when there is water present, the particles easily get into suspension because the repulsive forces outweigh the attractive forces. On the clay's surface the sodium ions are adsorbed, it has a big, weak charge and is an ion, they appear to be stable, moderately resistant to erosion clays like other clays, yet they can really be very erosive and vulnerable to severe damage or collapse [5]. It is worthy to mention that the classification of dispersive soils uses the phrases slightly and moderately dispersive, What is the main purpose behind having these classes? Dispersive or problematic soils might exist. Dispersive soil concerns cannot be considered as minor or moderate. It is not necessary to define it in this way because there is no evidence in the literature that the level of depressiveness justifies a distinct therapeutic strategy, there is no purpose in continuing if the classification is either dispersive or non-dispersive, and no alternatives for interim treatment are offered.

Table (4) Results of Total Dissolved Salts in Pore Water

Remarks	Dispersive zone	SAR	Na%	(Mg+Ca+k+Na) (meq/l)	Na+ Meq/L	K+ Meq/L	Ca+2 Meq/L	Mg+2 Meq/L	Depth(m)	Borehole No.
					mlliequivalent /liter(meq/l)					
Intermediate dispersive	C	30.376	53.633	699.2	375	5.2	164	155	0.5-1	1
Intermediate dispersive	C	25.238	51.779	592.9	307	1.9	136	148	1.5-2	
Intermediate dispersive	C	29.842	54.7335	696.1	301	5.1	158	152	0.5-1	2
Intermediate dispersive	C	26.854	52.796	606.1	320	2.1	138	146	1.5-2	
Intermediate dispersive	C	29.629	53. 563	700.1	375	3.1	165	157	0.5-1	3
Intermediate dispersive	C	26.976	53.51	586.8	312	1.8	127	144	1.5-2	
Intermediate dispersive	C	23.917	47.736	649.4	310	3.4	167	169	0.5-1	4
Intermediate dispersive	C	23.409	50.027	534.7	272	1.7	128	142	1.5-2	

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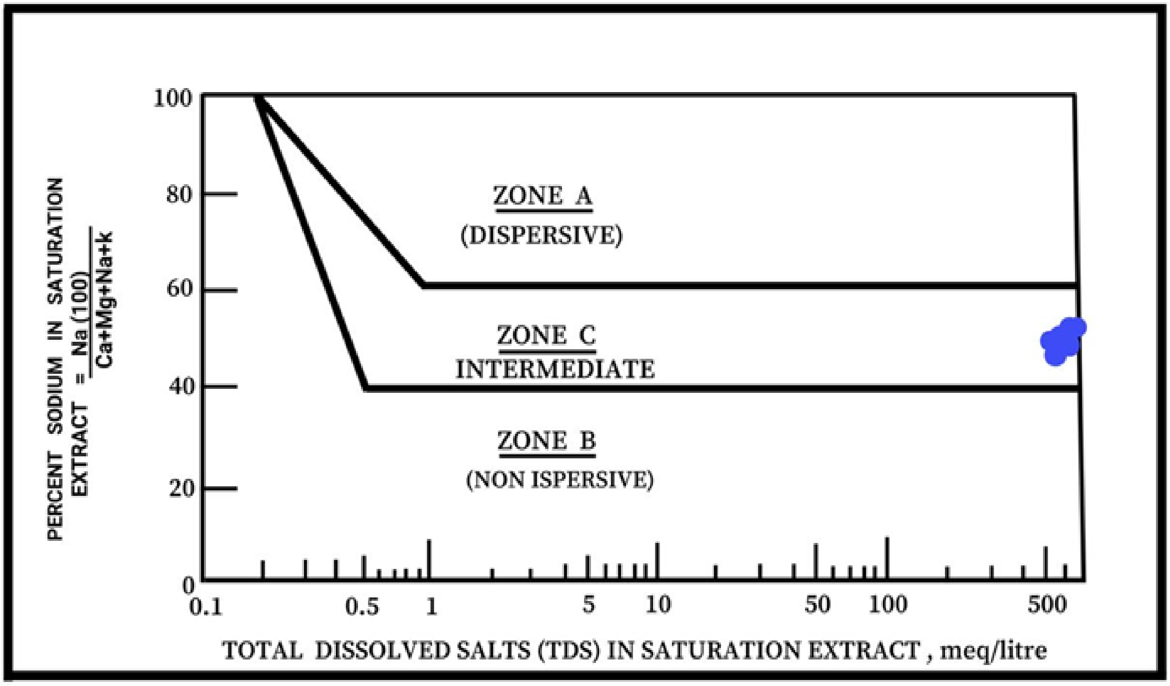

Fig. (4) Classification of study area soil by total dissolved salts in pore water By [2].

- **X-Ray Diffraction**

The XRD data Fig.(5) and Fig.(6) show that the minerals quartz, calcite, dolomite,feldspar and clay make up the majority of the soil samples. The percentage of feldspar mineral is low due to the nonstability of this mineral, so it transformed into clay minerals [29]. The principal clay minerals include smectite, palygorskite and kaolinite, according to calculations of clay and non-clay mineral percentages Table (5). Clay active minerals like montmorillonite, low electrolyte concentrations and the presence of exchangeable sodium all contribute to emergent dispersive behavior [9], on the other hand, the layered structure of kaolinite is comprised of alternating silicon and oxygen sheets linked to create a single electrically neutral unit cell. The strong bonding between the various sheets prevents hydration and adsorption from happening in the interstices.

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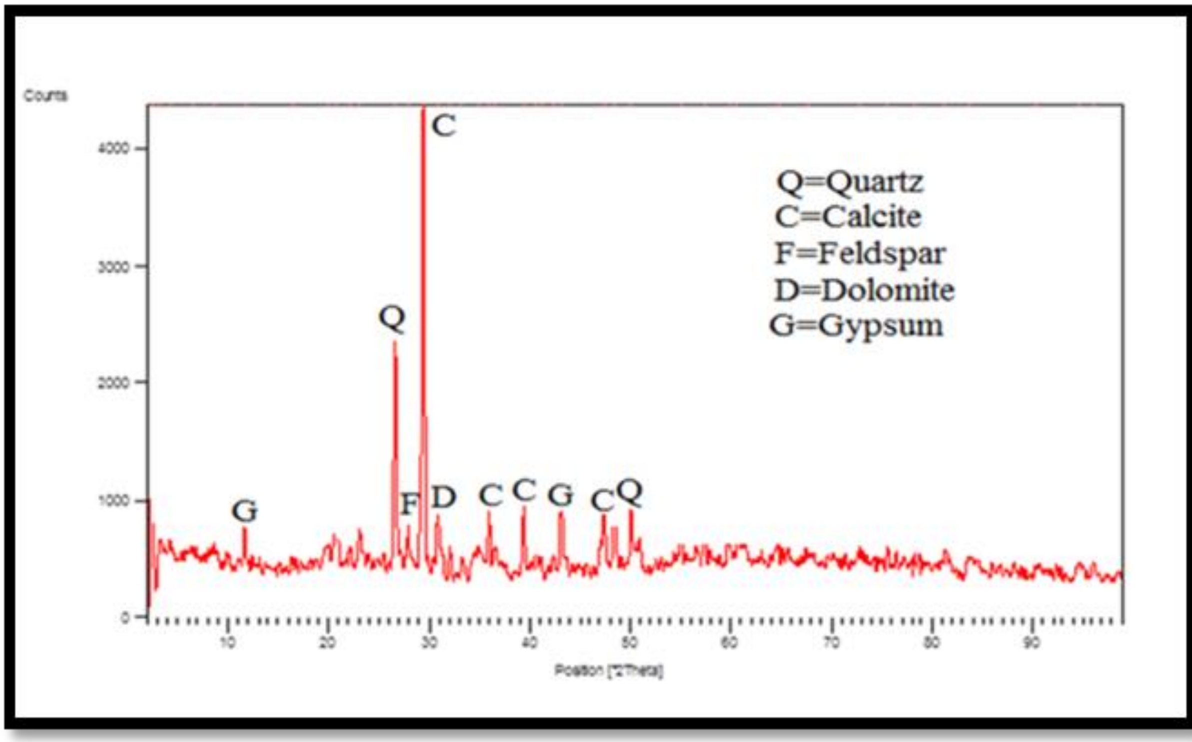

Fig.(5) The XRD diffractogram for non -clay bulk sample

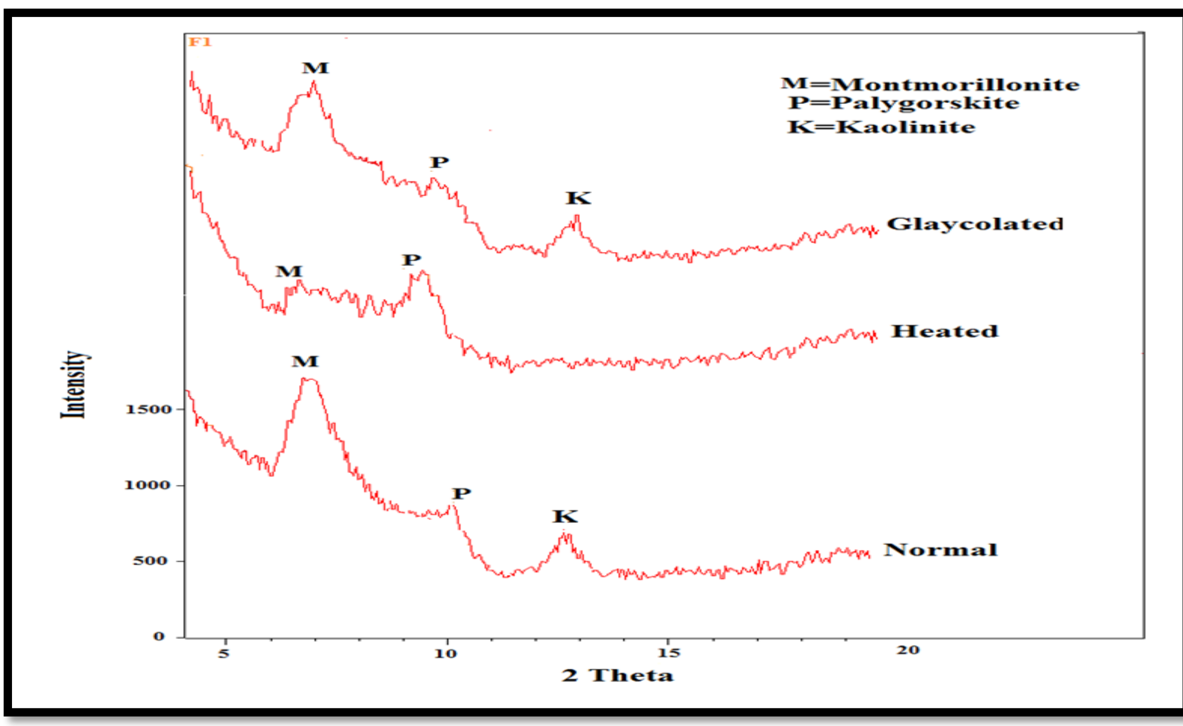

Fig. (6) The XRD Diffractogram for Clay Sample

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Table (5) The average percentages % of non- clay and clay minerals in AL- Faw city

Sample	Non- clay minerals				
	Quartz	Calcite	Dolomite	Gypsum	Feldspar
Faw (Bulk sample)	28.5	35	3.2	4	2
Faw (Clay sample)	Clay minerals				
	Montmorillonite		Palygorskite	Kaolinite	
	39.769		35.191	25.04	

6. Conclusions

The conclusions of several analyses performed on each of the four borehole samples.

- Tests used to identify dispersive soil should not rely on subjective methods, but rather, concrete data. For instance, the results of a crumb test should indicate if colloidal suspension is present or not. There is no advantage to making the test more difficult by specifying a light, moderate, or heavy suspension.
- The results of the Total dissolved salts test showed a variety of the Crumb test for a difference in the soil content of mineral and chemical components.
- The values of shear strength and confined compressive strength are a low duo to the high level of groundwater and the high concentration of dissolved sodium salts in the groundwater that weakens the soil and increase the degree of depressive, which causes collapse in the structures built on this soil.
- The XRD data show that the minerals quartz, calcite, dolomite, and clay make up the majority of the soil samples. The principal clay minerals include smectite (Montmorillonite), palygorskite, and kaolinite.
- It is necessary to conduct further research on the XRD analysis with detailed interpretation of the minerals present, the importance of clay mineral types like smectite should be assessed.
- For classification purposes, a soil is consider sodic if SAR levels are 13 or more, however, these all values are more than 13 refer to a sodic soils in the study area.
- The phenomenon of soil dispersive is influenced by the values of plasticity index.

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Conflict of interests.

There are non-conflicts of interest.

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