



ISSN: 0067-2904

## Engineering Assessment of the Soils of Modern Residential Complexes (Bety, Yarmouk, and Al-Jawhara) in Tikrit/Salah Al-din/Iraq

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Received: 17/2/2021

Accepted: 24/5/2021

### Abstract

In this research, the geotechnical properties of soil for modern residential complexes in the city of Tikrit-Iraq were determined using six samples represented by three residential complexes (Bety, Yarmouk and Jawhara) and that these complexes built on gypsum soils suffer in the future from several engineering problems that appear in the form of cracks, inclination or subsidence in The buildings or the collapse of the facilities, the dilution of the roads and the breaking of the water and sewage networks due to the melting of the gypsum in the soil. One of the most important objectives for the research is that the residential complexes for the research area in Tikrit are not older than some years. With the urban expansion that all towns in Iraq are witnessing, including this region, the city of Tikrit represents the center of the province. Therefore most of the departments and institutions are present in this region, which necessitated the need to provide residential complexes and many of the constituencies' employees to occupy them in addition to its proximity to the University of Tikrit, so it is necessary to know the properties of soil, to point out the engineering problems in it and how to address them. As well, it is an important region from a geographical point of view because it is located directly on the main international road linking Baghdad - Tikrit – Mosul

The moisture content values of the soil samples range from (0.92 to 0.26%). The resultant values are low because one of the reasons is that the sampling process took place in the summer, specifically in July, and the reason is due to the low level of groundwater in the region, as well as the high temperature and the lack of rainfall, which causes the evaporation of the water in the soil, so the low moisture content gives a positive concerning the foundations of residential complexes in the study area because the presence of water causes the dissolution of gypsum as the soil under study contains a high percentage of gypsum.

The calculated specific gravity values of soil samples range from 2.42 to 2.46 with an average of 2.42, The average specific gravity is 2.42 in the Bety and Yarmouk, and it is 2.46 in Aljawhara.

The maximum dry density values of the soils of the residential complexes range between (1.611-1.663 gm/Cm<sup>3</sup>) and the highest dry bulk density value was recorded in the sample (Y1). On the other hand, the optimum moisture content values range between 15.2% and 16.8%, while the highest value is for the sample ( B2).

The consolidation test was performed on three selected samples (B2, J1, J2), ((A correction was made for the selection of samples to consolidation test based on the clay ratio, as was the case with the sieving analysis)) based on their clay content percentage compared to other samples which contain low or very clays, The compression index values (Cc) and the bulge index values (Cr) of these samples are (0.084,0.114,0.092) and (0.012,0.013,0.009) respectively.

The chemical analyses of the soil in the study area indicates that it contains a high percentage of gypsum that ranges between 43.05 and 69.27% . The gypsum content reaches the highest value in sample (B2) and lowest in sample J2. While the soluble

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salts percentage range from (73.13 to 85.21%), and the pH value ranges between 7.21 and 7.67.

Mineralogical tests of indicate that most samples have prismatic gypsum crystals with several clinker substances, carbonate and evaporites cement and organic materials. The gypsum crystals range in size from 0.02 to 0.7mm with an amount of clay.

**Keywords:** Residential complexes, Gypsum,  $\text{CaSO}_4(2\text{H}_2\text{O})$

## التقييم الهندسي لترب المجمعات السكنية الحديثة (بيتي، اليرموك، الجوهرة) في مدينة تكريت/ صلاح الدين/ العراق

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### الخلاصة

تم في هذا البحث ايجاد الخواص الجيوتكنيكية لترب للمجمعات السكنية الحديثة في مدينة تكريت وبواقع ستة نماذج ممثلة عن ثلاث مجمعات سكنية (بيتي، اليرموك والجوهرة) وان هذه المجمعات المقامة على التربة الجبسية تعاني مستقبلاً من عدة مشاكل هندسية تظهر على شكل تشققات او ميلان او هبوط في الابنية او انهيار المنشآت وتخسف الطرق وتكسر في شبكات الماء والمجاري بسبب حصول ذوبان للجبس الموجود في التربة.

من اهم اهداف البحث هو ان المجمعات الاستثمارية السكنية لمنطقة الدراسة في مدينة تكريت حديثة لا يتجاوز عمرها بعض سنوات بالتوسع العمراني الذي تشهده مدن العراق كافة، ومن ضمنها هذه المنطقة اذ تمثل مدينة تكريت مركز المحافظة وبالتالي فإن اغلب الدوائر والمؤسسات متواجدة في هذه المنطقة مما دعت الحاجة لتوفير المجمعات السكنية وإقدام العديد من منتسبي الدوائر لإشغالها بالاضافة لقربها من جامعة تكريت ، لذلك يجب معرفة خواص التربة للتنبؤ به إلى المشاكل الهندسية فيها وكيفية معالجتها فضلاً عن أنها منطقة مهمة من الناحية الجغرافية لوقوعها مباشرة على الطريق الدولي الرئيسي الرابط بين بغداد - تكريت - موصل. تراوحت قيم محتوى الرطوبة لنماذج التربة بين (0.92% - 0.26%)، اذ تكون هذه القيم منخفضة لكون احد الاسباب هو ان عملية النمذجة قد اجريت في فصل الصيف وتحديداً في شهر تموز، ويعود السبب إلى انخفاض مستوى المياه الجوفية في المنطقة، وكذلك ارتفاع درجة الحرارة وقلّة الساقط المطري مما يؤدي الى تبخر المياه الموجوده في التربة وتؤدي الى تبلور الجبسوم في نفس المكان. ويعطي انخفاض المحتوى الرطوبي انطباعاً إيجابياً فيما يتعلق بأسس المجمعات السكنية في منطقة الدراسة. لبيد ان وجود المياه في فترات المواسم الرطبة تؤدي الى إذابة الجبسوم المتواجد ضمن التربة والى حدوث مشاكل هندسية.

تراوحت قيم الوزن النوعي التي تم حسابها مختبرياً بين (2.42-2.46) وبمعدل 2.44، اذ بلغ معدل الوزن النوعي في مجعبي بيتي واليرموك السكنيين (2.42) بينما كان معدل الوزن النوعي في مجمع الجوهرة السكني (2.46).

وقد تراوحت قيم الكثافة الجافة العظمى لترب المجمعات السكنية بين  $1.611-1.663 \text{ gm/cm}^3$ ، اذ بلغت اعلى قيمة لها في النموذج Y1، بينما تراوحت قيم المحتوى الرطوبي المثالي بين 15.2-16.8%، وكانت اعلى قيمة لها في للنموذج B2).

اجري فحص الانضمام على ثلاثة عينات (J1، J2، B2) تم اختيارها بناءً على محتواها من نسبة من الطين مقارنة بالعينات الأخرى التي يكون فيها الطين قليل جداً، اذ بلغت قيم دليل الانضغاط (Cc) للنماذج نفسها (0.084, 0.114, 0.092) على التوالي، أما قيم دليل الانتفاخ (Cr) فقد بلغت (0.012, 0.013, 0.009) على التوالي.

بينت التحاليل الكيميائية لترتب منطقة الدراسة أن نسبة الجبس عالية وقد تراوحت بين 43.05-69.27%، إذ كانت أعلى قيمة لها في النموذج B2 وأقل قيمة في النموذج J2، بينما تراوحت النسبة المئوية للأملاح القابلة للذوبان بين (73.13-85.21%)، وتراوحت نسبة الأس الهيدروجيني بين (7.21-7.67). بينت الفحوصات المعدنية إن أغلب النماذج تكون فيها بلورات الجبس ذات هيئة بلورية موشورية فضلا عن تواجد المواد الفتاتية والمادة السمنتية (الكالسيوم والجبسوم) والمواد العضوية. وتتراوحت أحجام بلورات الجبسوم بين (0.7-0.02mm) مع وجود كمية من الاطيان.

### Introduction:

It is well known that the properties of the soil on which engineering projects and facilities are built, whether residential or industrial, keep pace with the population increases. Thus, the requirements of the age are necessary to know the extent to which the soil of the study area is bearing these facilities and its suitability for establishing projects or avoiding the matter if proven otherwise or finding appropriate engineering solutions such as replacing the site's soil or installing sulfate-resistant concrete foundations (Concrete resisting sulfate) and so on. Accordingly, it must be ensured that it does not fail under the influence of the imposed loads, the specialists in this field must deal carefully with the soil and carry out all the necessary checks and consider them while designing engineering projects, [1]

It has been proven that most countries worldwide spend exorbitant sums to deal with structural defects far exceed the sums paid on exchanging or conducting a necessary study of the soil before establishing facilities on it [2].

The city of Tikrit, the center of Salah al-Din Governorate, is witnessing the establishment of many modern residential complexes, coinciding with the increase in population density to accommodate them and cover their activities. These facilities are supposed to be located in stable areas with a high load capacity to stay away from the factors of cracking and collapse. It is known that increasing the percentage of gypsum in the soil plays a significant role in deteriorating the engineering properties of soil, which forms risks to the engineering facilities built on it.

### The location of the study area

Administratively, the study area is located within the city of Tikrit / Salah al-Din Governorate / Central Iraq, 175-km north of the capital Baghdad, it lies between 43°37'30"N and 43°39'30"N and 34°36'30"E and 34°38'30"E, Figure 1.

Structurally, the study area is located within the hazardous pavement area, which includes many surfaces and subsurface compositions due to the structural situation [3]. The study area is part of the plain sedimentary area, which declines with an asymmetric concave fold basin that allows continuous sedimentation due to the surface and non-surface tectonic movement [4].

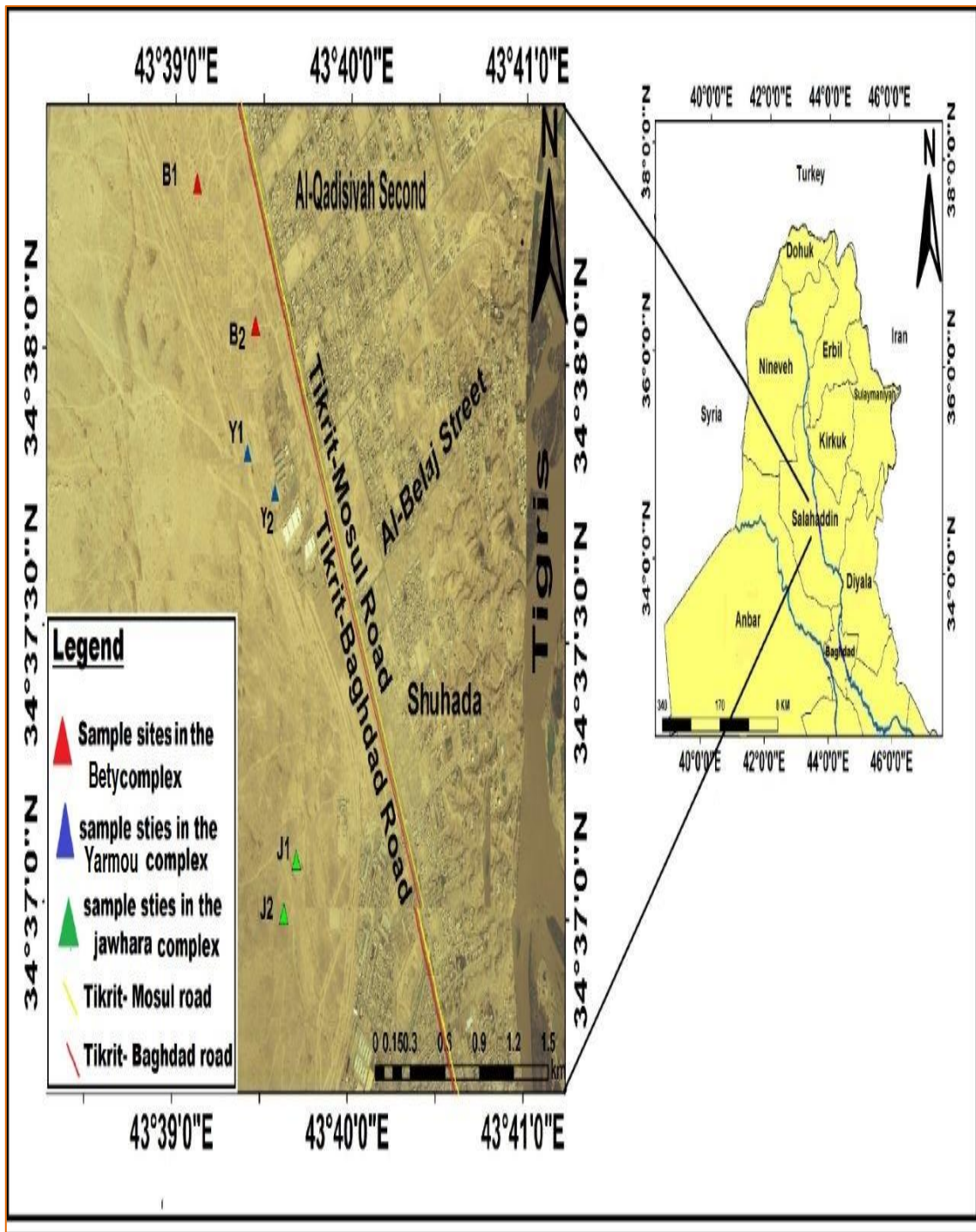


Figure 1-site map showing the locations samples of the study area

**Research methods**

- The information-gathering stage
- The fieldwork stage
- The laboratory work stage

The laboratory work stage included conducting some tests of soil samples collected from sites in the research area, including the following:

**1- Physical test**

**Grain size analysis :**this test was conducted according to American specifications ( ASTM, D 422-63, 2004)[5].

**Plasticity limits** This test was performed according to American specifications (ASTM-D4318, 00 -2004) [6]

**Specific Gravity** this test was conducted according to American specifications (ASTM, D 854-02., 2004) [7]

**Moisture content** this test was carried out according to American specifications (ASTM D2216-80-2004)[8].

## 2-Engineering tests

**Direct shear test** this test was conducted according to American specifications (ASTM D3080-11, 2004) [9] to find the coefficients of shear compaction (angle of internal friction, tenacity) and shear resistance.

**Consolidation test** this test was conducted according to American specifications (ASTM-D2435-2004) [10]. To find the compressibility coefficient, bulge coefficient, pre-join pressure and voids ratio.

**Compression test (Compaction)** this test was carried out according to the American standard (ASTM D-698) [11]

## 3- Soil chemical analyses

Chemical tests were performed on fifteen soil samples, according to specifications ( Handbook NO-60,1959) [12] included findings:

- Gypsum content.
- Total Soluble Salts (TSS).
- Organic Material Content (OMC).
- Measuring (pH) function.
- Chlorides Content (CL).
- Sulphate content.
- Carbonate content.

## 4 - Mineralogical tests of the Soil

The Mineral diagnosis was made for soil; the study area is by making glass slides (slides) to know the types of gypsum crystals, in addition to the available clay minerals. The test was conducted for six samples where the test was conducted in the Department of Geosciences/ College of Science/ Baghdad University, and the study also included a blurring X-ray diffraction (XRD) for six samples covering the entire study area to diagnose clay minerals, most of which are involved in the formation of the bonding material for gypsum crystals, in addition to the non-clay minerals, the test was conducted in the Ministry of Science and Technology - Department of Material Sciences.

### The office work stage

This stage included many works to prepare this research:

- Projecting sites on the administrative map using the program of ( Arc GIS).
- Perform calculations for tests performed and draw shapes and curves using a program (Excel. 2010).
- Interpretation of the results of geotechnical tests of the research area.
- Finally, writing search using the program (Word. v. 2010).

## Results and discussion

the results obtained from investigations geotechnical be essential and valuable in the design of engineering projects as well as it can be identified in which the future problems surrounding the project and to reach appropriate solutions to these problems ,as learned from the physical properties of the classification of soils for engineering purposes [13] [14].

### Physical Tests

#### Specific Gravity:

The values of the specific gravity that were laboratory calculated in the soil samples ranged between ( 2.42-2.46). At a rate of (2.44), the average specific gravity in the residential complex (B) and (Y) is ( 2.42) , while the average of specific gravity in the third residential complex (J) is ( 2.46) .Table (1), and it is known that the percentage of soft materials formed in the soil has a direct effect on the specific gravity values and that the presence of gypsum with a high rate in the grade leads to a decrease in the specific gravity values because it is considered one of the minerals that have a low specific gravity.

### Moisture Content

The moisture content was measured based on the materials test method (ASTM D2216-10, 2010). The values of moisture content of the soil of the research area ranged between- ( 0.92%,0.26) and through the results of the laboratory tests related to the moisture content. We note that these resulting values are low because one of the reasons is that the sampling process took place in the summer, specifically in July. The reason is due to the low level of groundwater in the area the high temperature and the lack of rainfall, which causes the evaporation of the water in the soil. The low moisture content gives a positive impression concerning the foundations of residential complexes in the research area because the presence of water causes the dissolution of the gypsum. Because the soil under study contains a high percentage of gypsum and the presence of water reduces. Elements of shear resistance, whose components are internal friction angle ( $\phi$ ) and cohesion (C) ,and the presence of water may cause soil swelling when there is a mineral of clay minerals that can swell like montmorillonite.

**Table 1-** The values of the specific gravity of the soils of the research area

Sample	Depth(M)	Specific Gravity
B1	1	2.42
B2	1.10	2.43
Y1	1.50	2.42
Y2	1.80	2.43
J1	2	2.46
J2	3	2.46

### Grain Size Analysis

The percentages of soil particles of different sizes were found by grain analysis by separating the sediments into coarse size groups represented by gravel and sand and smooth groups representing clay and silt. This is done in two stages of sieve analysis and wet analysis. The grain gradient curves were drawn for six samples as in Figures 2 to 7. Through the results obtained from testing the volumetric gradient, I show that sand and silt are prevalent in all stations, meaning that the soil is poorly graded and that the proportion of clays is tiny and almost non-existent in most stations. This is indicated by the results of other checks such as Atterbirk limits and others. Table 2 shows the proportions of soil components (gravel, sand, silt, and clay) for all station samples.



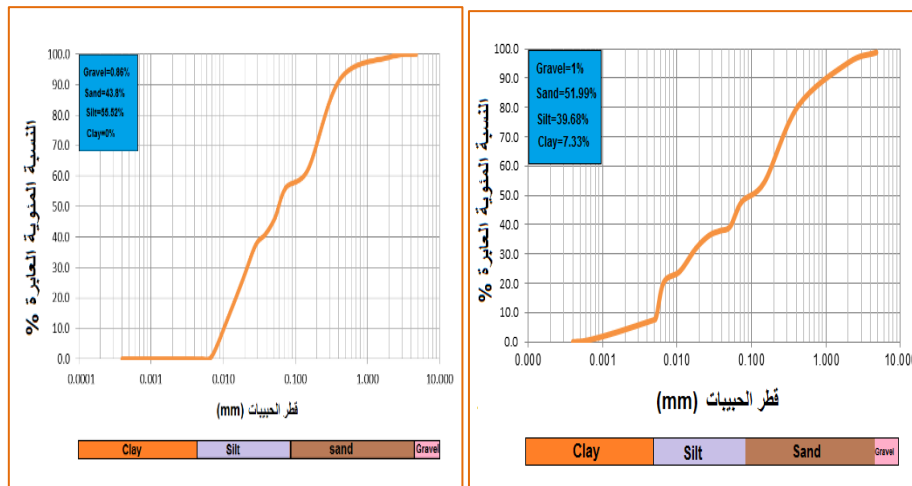


Figure 2- shows the scalar curve for sample B1 Figure 3- shows the gradient curve for sample B2

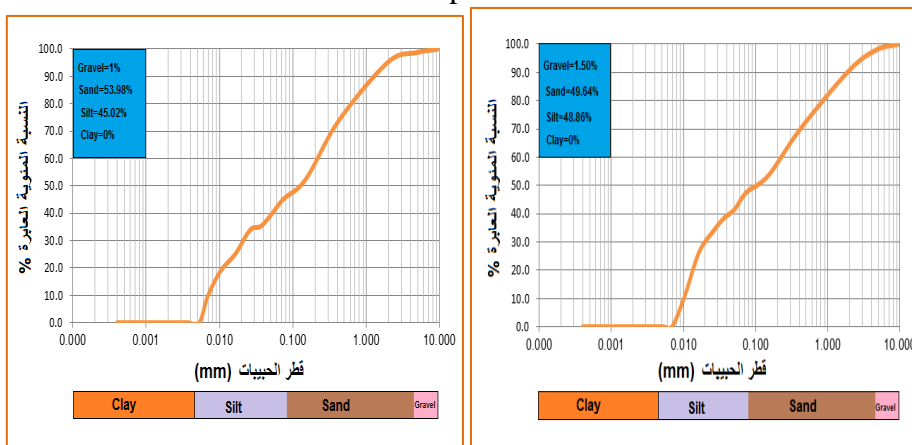


Figure 4- shows the scalar curve for sample Y1 Figure 5- shows the gradient curve for sample Y2

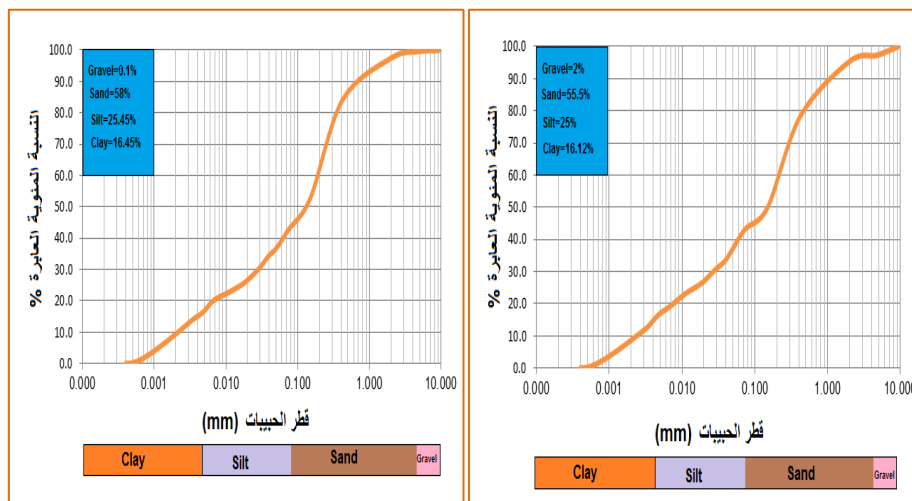


Figure 6- shows the scalar curve for sample J1 Figure 7- shows the gradient curve for sample J2.

The proportions of mud, silts, sand and gravel were determined for the stations of each complex. Both sand and silt in the soils of these residential complexes constitute the most significant proportion, as the percentage of sand in the Bety residential complex in (B1, B2) (43.8-51.99%) in the order. While the proportion of silt for the same complex (55.52-

39.68%) as for the Yarmouk residential complex, the sand percent in (Y1, Y2) (53.98-49.64%) in the order. While the proportion of silt for the same complex (45.02-48.86%), as for the Al-Jawhara residential complex, the sand ratios in (J1, J2) (58-55.5%), and the proportion of silt (25.45-26.38) it is evident from the above that the soil is silt sandy ,as the soil of the study area was classified according to the unified soil classification system based on the coefficient of concavity and the symmetry of the analysis curves for the size and plasticity of the soil, as in Table 2.

**Table 2-** Classification of soil in the research area according to the standardized classification.

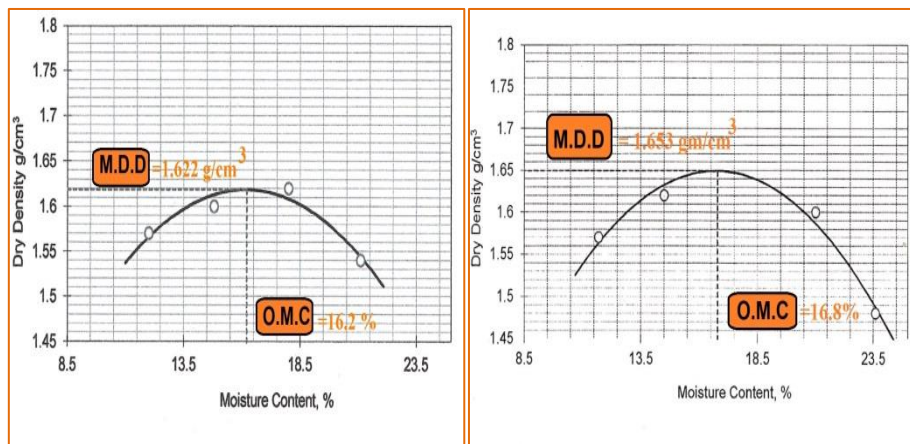
Sample	Depth (m)	(%)Clay	Silt (%)	Sand (m)	(%)Gravel
B1	1	0	55.52	43.8	0.68
B2	1.10	7.33	39.68	51.99	1
Y1	1.50	0	45.02	53.98	1
Y2	1.80	0	48.86	49.64	1.50
J1	2	16.45	25.45	58	0.1
J2	3	16.12	26.38	55.5	2

**Soil engineering Tests**

Some engineering tests were carried out on the soil of the study area, and the most important of these tests are:

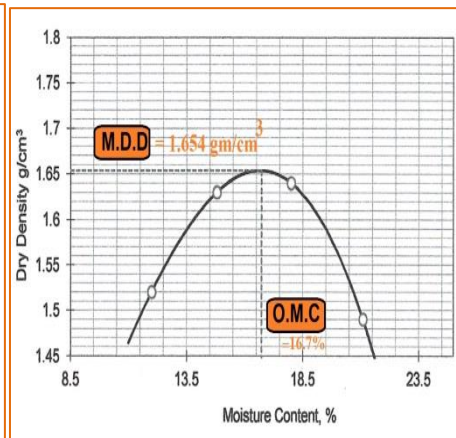
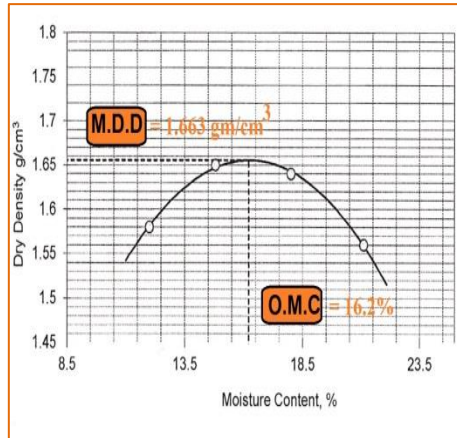
**Compaction Teste**

The limit test was performed on six samples from the research area. The values of the maximum dry density of the soils of residential complexes ranged between (1.611-1.663 gm/Cm<sup>3</sup>). As the highest dry bulk density value was in the sample (Y1) . As for the values of the Optimum Moisture Content (O.M.C), it ranged between15.2 and 16.8%) while the highest value is for the sample(B2), Figures from 8 to 13.

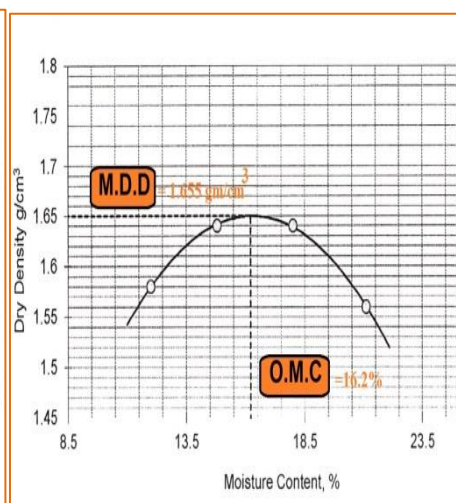
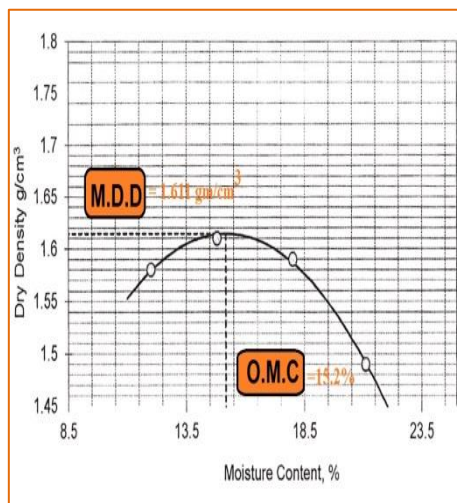


**Figure 8-** Compaction Teste of the sample B1 **Figure 9-** Compaction Teste of the sample B2





**Figure 10-** Compaction Teste of the sample Y1 **Figure 11-** Compaction Teste of the sample Y2



**Figure 12-** Compaction Teste of the sample J **Figure 13-** Compaction Teste of the sample J2

**Direct Shear Test**

The direct shear test was performed as the cohesion values were obtained (C) which ranged in Betty residential complex between (55-57 KN / m<sup>2</sup>) As for the Yarmouk residential complex, the cohesion values ranged between 56 and 59 KN/m<sup>2</sup> ,while the angle of internal friction ranged from (32-35°), Either in the Jawhara residential complex it ranged in which cohesion between the values(51-53 KN / m<sup>2</sup>) While the angle of internal friction ranged (29-30°) As in Figures 14, 15 and 16 and in Table 3 which shows the values of cohesion and the internal angle of friction for the samples.

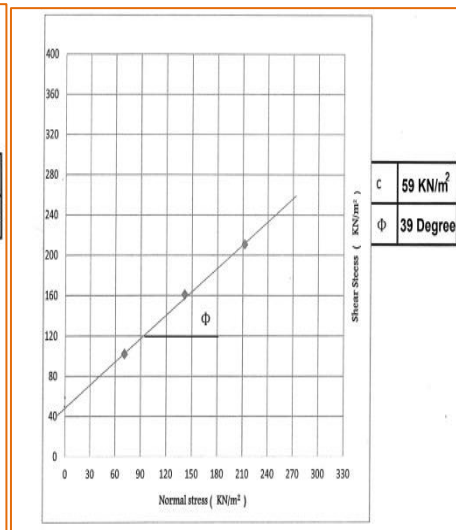
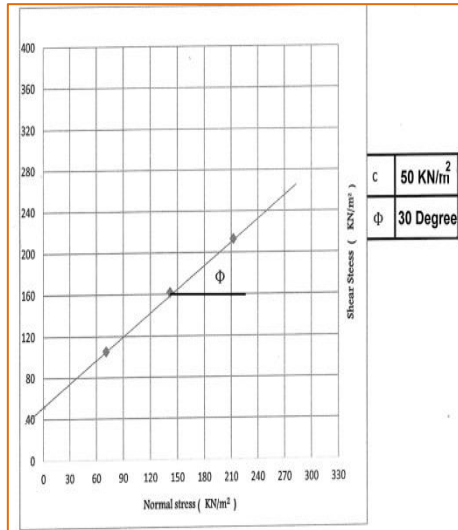


Figure 14-direct shear test of the Sample J2

Figure 15-direct shear test of the Sample Y2

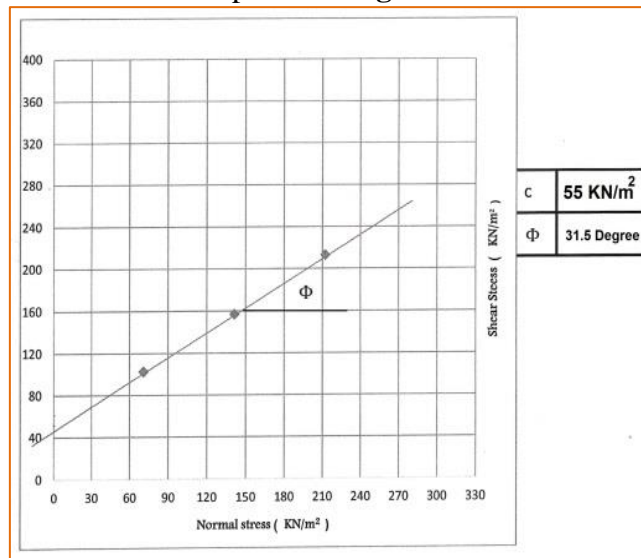


Figure 16-direct shear test of the Sample B2

Table 3- shows the values of cohesion (c) and the angle of internal ( $\phi$ ) For area samples

Sample	Depth(m)	C (KN / m <sup>2</sup> )	( $\phi$ )°
B1	1.5	57	32
B2	1.75	55	31.5
Y1	1.2	56	35
Y2	1.4	59	32
J1	2	51	29
J2	3	50	30

**Consolidation test**

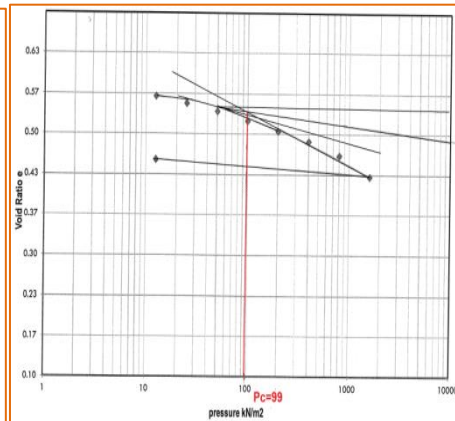
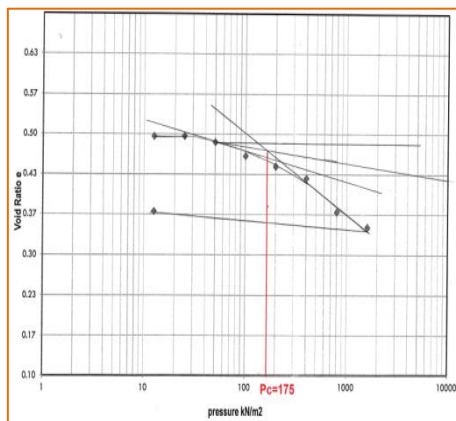
The consolidation test was performed according to the American standard (ASTM, D 2435-11,2011) for three soil samples from the stations of the study area, namely (B2, J1, J2), where these samples were selected based on their content of a percentage of clays compared to other samples in which the clays are very few.

Through the consolidation tests conducted on soil samples, the percentage of voids was found that depends on the size of the grains, as this percentage gradually decreases as the pressure exerted. The excess water seepage from the soil, and the percentage of gypsum has a great effect on the percentage of voids, the dissolution of gypsum leads to an increase in the percentage of voids. Consequently, soils containing a high percentage of gypsum are subject to collapse or subsidence given that the research area samples have a high percentage of gypsum.

Thus it poses a significant risk to residential complexes built on this soil in the event of water penetration and the melting of the gypsum present in the soil, the percentage of voids reached for the samples checked (B2, J1, J2) (0.432,0.501,0.391) Respectively, Table 4 and the compression index values (Cc) were reached for the samples themselves (0.084, 0.114, and 0.092) respectively, as for the bulge index values (Cr) it has 0.012, 0.013, and 0.009 accordingly, Table (5), Figures(17 to 19), and that the most critical factor affecting the values of the index of swelling is the quality of the clays present in the soil, meaning that the presence of bulging minerals increases the voids and thus leads to an increase in the index of swelling.

**Table 4**-shows the values of join index, bulge index, and gap ratio for the studied samples

Sample	Pc KN/m <sup>2</sup>	Po KN/m <sup>2</sup>	Void ratio e	Bulge guide (Cr)	Compression index (Cc)	Depth (M)	O.C.R
B2	175	20.28	0.432	0.012	0.084	2	8.62
J1	99	40.25	0.501	0.013	0.114	2.5	2.45
J2	163	29.41	0.391	0.009	0.092	1.5	5.54



**Figure 17** -Consolidation test of sample **B2** **Figure 18**- Consolidation test of sample **J1**

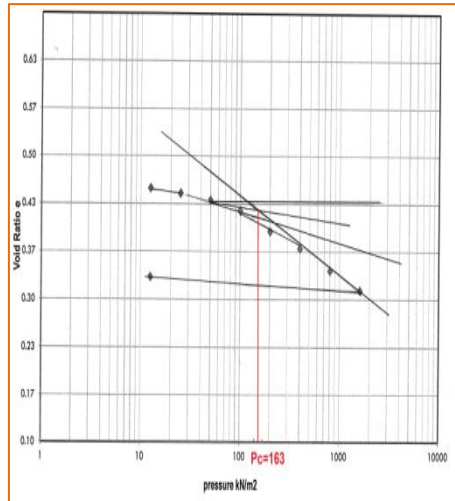


Figure 19- Consolidation test of sample J2

**Chemical analyses of the soil**

The chemical properties of the soil are a significant factor in knowing the chemical behavior of the soil and the extent of the soil's tolerance to external factors affecting it, such as erosion and weathering processes. (Handbook No.60.1959).Table(5).

Table 5- shows the results of the chemical tests for the soil in the study area

No.	Sample	Gypsum	Carbonate	Ph	Organic Materials	Total Soluble Salts	Sulfates	Chlorides
		%	%		%	%	%	%
1	B1	67.31	12.36	7.21	0.16	82.03	1.13	0.21
2	B2	69.27	12.18	7.25	0.18	85.21	2.06	0.92
3	Y1	65.83	11.81	7.37	0.12	80.31	1.06	0.33
4	Y2	63.08	16.13	7.36	0.13	80.69	1.03	0.31
5	J1	46.19	27.61	7.57	0.13	76.09	0.82	0.31
6	J2	43.05	26.75	7.67	2.50	73.13	0.79	0.27

**Petrography of the study area**

**Thin section under Polarized Microscope**

**Sample B1 :** It mainly consists of a prismatic gypsum crystals with clay minerals, and the cement material is of the type of carbonate and evaporators .As for the sedimentary description is between the sizes of the gypsum crystals ranging from (0.05 -0.7mm). The degree of screening is poor due to the difference in the size of the crystals and the chemical texture interconnected with the presence of crumb materials (Figure 20a).

**Sample B2 :** It was found that the gypsum crystals have an incomplete prismatic shape with the presence of rocky pieces of carbonates and the presence of gaps due to dissolution and the bonding material are carbonates and evaporators. While the sedimentary description indicates

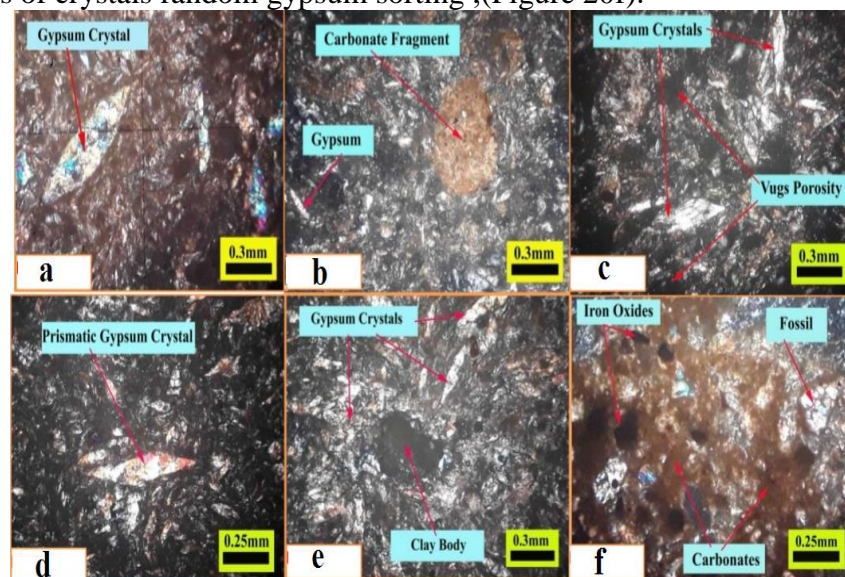
that the sizes of the gypsum crystals are smooth, ranging from (0.02-0.1mm). The sizes of gypsum crystals are similar due to their small sizes and chemical texture (Figure 20b).

**Sample Y1 :**Between the petrographic description of the sample, gypsum crystals with crystalline body prismatic with a quantity of clastic material and crumbs material are the type of carbonate and evaporite also with the presence of organic materials. On the one hand, the description found that the precipitation sizes ranged from crystals gypsum (0.02 - 0.5mm). The degree of sorting is poor due to different crystal sizes and randomly arranged crystals (Figure 20c).

**Sample Y2 :** It was shown that gypsum crystals have a full-face prismatic shape with the presence of rocky pieces of carbonates and the presence of gaps due to dissolution, and the bond materials are carbonates and evaporates with the presence of clay bodies, while the sedimentary description indicates that the sizes of the gypsum crystals are smooth, ranging from ( 0.01-0.4mm )Sorting is not good because different sizes (Figure 20d).

**Sample J1 :** It was found that the gypsum crystals are colorless and have a prismatic crystalline form with the presence of a number of clay minerals. The cement material is of the type of carbonate and also evaporators and the crystals are directional and arranged, as for the sedimentary description between the sizes of the gypsum crystals ranging from ) 0.02-0.3mmThe degree of sorting is poor due to the difference in the size of the crystals and the chemical fabric interconnected with the presence of clinker materials (Figure 20e).

**Sample J2 :**It was found through the petrographic description of the sample that the predominant texture is a clay containing clays with a number of crumbs and includes fragments of fossils with crystals of gypsum granular in form and the bonding material are clays with carbonates and the presence of organic materials, as for the sedimentary description it was found that the sizes of the gypsum crystals Soft ranging from) 0.01-0.1mm ,(Sizes of crystals random gypsum sorting ,(Figure 20f).



**Figure-20-**etrographic description of soil samples

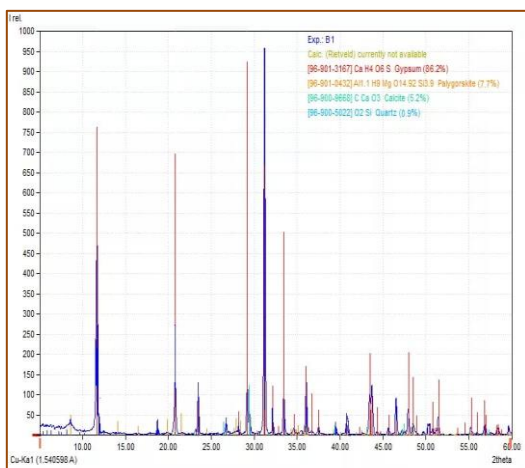
### XRD TEST

The main mineral in the samples studied is gypsum, with a small amount of carbonates represented by the mineral calcite in addition to the presence of the mineral quartz in small quantities. These minerals represent the non-clay minerals in the sample, while the clay minerals represented by the mineral palygorskite, which is considered a mineral accompanying gypsum, is often crystallized. From a hot and dry climate (Table 6 and Figures 21-26).

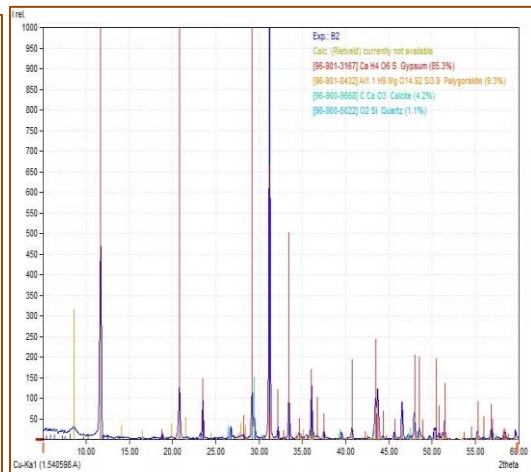


**Table 6-**The percentages of minerals in the study area by XRD

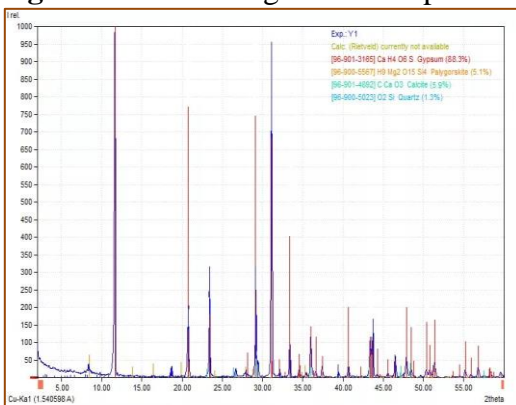
Sample	Quartz %	Calcite %	Gypsum %	<u>Paligorskite</u>
B1	0.9	5.2	86.2	7.7
B2	1.1	4.2	85.3	9.3
Y1	1.3	5.9	88.3	5.1
Y2	0.9	5.3	87.6	6.2
J1	1.6	5.0	85.9	7.6
J2	1.0	4.7	84.5	9.8



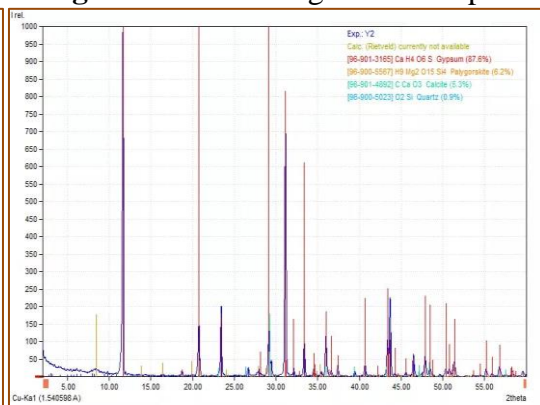
**Figure 21-** XRD diagram of sample B1



**Figure 22-** XRD diagram of sample B2

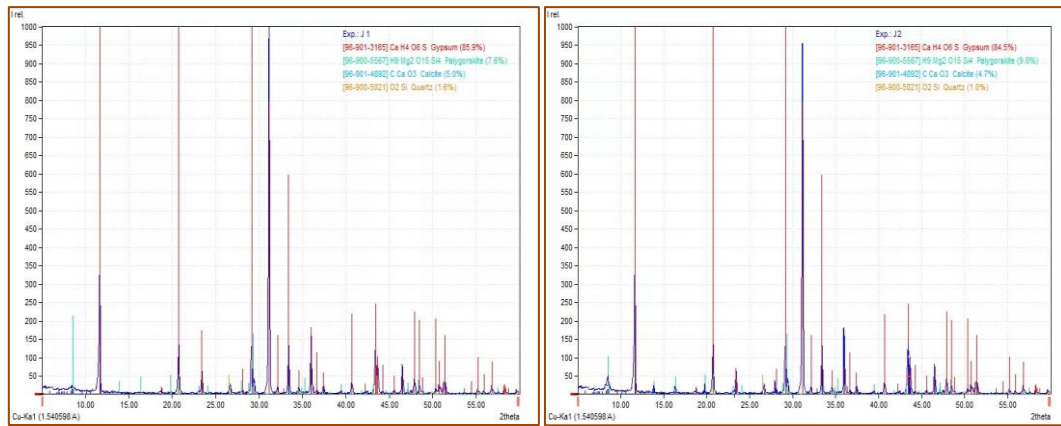


**Figure 23-** XRD diagram of sample Y1



**Figure 24-** XRD diagram of sample Y2





**Figure25-** XRD diagram of sample J1

**Figure26-** XRD diagram of sample J2

### Recommendations:

Replace the top of the soil according to the level specified for the base of the facilities with an insulating layer of clay soil free from salts using Sulphate resisting cement and with a thickness as determined by the founding engineer.

Reduce the surface layer of soil to increase its relative density, make it more homogeneous, and reduce permeability and compressibility.

The possibility of using mats foundations when constructing residential complexes on these sites to avoid uneven subsidence resulting from melting gypsum.

### Conclusion:

Through the values obtained from the engineering tests conducted for the various sites of the study area. With the possibility of engineering problems that would happen due to water. In addition to that, the dissolution of the gypsum reached to 86% this leads to soil subsidence and slope of the foundations and collapse of buildings.

There should be solutions to these obstacles before starting the design of residential complexes and engineering facilities.

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