THE STUDY OF THE PHYSICAL PROPERTIES OF QUATERNARY SEDIMENTS IN THE MIDDLE PART OF ERBIL PLAIN, KURDISTAN REGION, NORTH IRAQ

Galawezh B. Bapeer*, Ali M. Surdashy and Karim M. Hassan*****

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ABSRTACT

This study deals with the physical properties of Quaternary sediments in the middle part of Erbil Plain, which is about 1670 Km²; Quaternary sediments, cover about 85% of the studied area. For consistency of soil and clay mineral tests, sixteen localities were selected in different parts of the studied area; GPS instrument was used for indicating the precise location.

The flow curve of Atterberg limits (liquid and plastic limits) indicated that generally the majority of the samples show low to medium plasticity index, between 6.7 – 19.1. However, some localities, particularly near the building of Construction Laboratories, have high plasticity index, which is 26.

The XRD analysis of the samples indicates that the samples contain quartz and calcite; the clay minerals are montmorillonite, illite and kaolinite. The percentage of these clay minerals was calculated and showed that in some areas like Hasarok, Daratu and Bestana the soil should be taken into consideration for any construction and might need soil improvement, because they include high percentage of montmorillonite and expansive clay, which are not suitable for heavy constructions and need soil improvement.

دراسة الصفات الفيزيائية للترسبات الحديثة في الجزء الأوسط من سهل أربيل، إقليم كوردستان، شمال العراق

كلاويز بكر بابير، علي محمود سورداشى و كريم محمود حسن

المستخلص

شملت هذه الدراسة تحديد أنواع المعادن الطينية لترسبات العصر الرباعي في الجزء الأوسط من سهل أربيل، التي تغطي مساحة قدرها حوالي 1670 كم^2، وإن 85% من المنطقة تقريباً مغطاة بترسبات العصر الرباعي. جمع 16 نموذج من مناطق مختلفة في منطقة الدراسة لغرض تحديد أنواع المعادن الطينية ودراسة قوام التربة، وتم استخدام جهاز الـ GPS لتحديد هذه المواقع.

دلت نتائج فحوصات حد السيولة وحد اللدونة ومنحنى الانسيابية للنماذج على إن معامل اللدونة في منطقة الدراسة واطئ الى متوسط، حيث يتراوح بين 6.7 – 19.1، ومع ذلك فإن بعض المناطق وخاصة قرب دائرة المختبرات الإنشائية فإن معامل اللدونة عالي ويصل الى 26. دلت منحنيات تحليل الأشعة السينية الحائدة للنماذج الملتقطة على وجود الكوارتز والكالسايت والمعادن الطينية مثل المونتموريلونايت، الإلايت والكاؤولينايت. وان النسبة المئوية لهذه الأطيان احتسبت في منطقة الدراسة، وتبين إن في بعض المناطق مثل: بيستانة، دارتو وحساروك يجب أن تأخذ التربة بنظر الاعتبار في بناء أي مشروع بسبب ارتفاع نسبة معدن المونتموريلونايت فى المنطقة وارتفاع نسبة الاطيان المنتفخة، حيث إن المونتموريلونايت يمتص المياه عند وجود الماء ويفقده عند الجفاف مما يدل على عدم صلاحيته للإنشاءات الضخمة.

* Department of Geotechnic, College of Engineering, University of Koya, Iraq
e-mail: galawezh.bakir@yahoo.com
** Assistant Professor, Dean of College of Engineering, University of Koya, Iraq
*** Assistant Professor, College of Science, University of Baghdad, Iraq

INTRODUCTION

The studied area is located in Erbil Plain, north Iraq and it is defined by UTM grids N 3960000 and 4014300, and E 384000 and 434200 (Fig.1). The area is surrounded by hills, mountains and valleys. Sharabout and Kasnazan hills bound the area from the north and northeast. At the southeast, Bestana hills exist, while Awana Mountain is in the southwestern part. The Dameer Dagh hills and Baranati Plateau bound the area from the northwest (Fig.2). It is worth to mention that the middle part of Arbil Plain is mostly covered by Quaternary sediments, which are accumulated under the effect of weathering and erosion of the surrounding elevated areas.

Identification of clay minerals helps in understanding the probable nature and mechanisms of active erosion processes (Kotoky *et al*., 2006). The amount and kind of the clay minerals greatly affect the physical condition of the soil that determines the ability of the soil to adsorb cations and to retain moisture. They influence shrink – swell potential and plasticity (Young and Mahyan, 2004).

PREVIOUS STUDIES

Many studies have been carried out in the studied area by several authors, some of which deal with hydrology; others deal with geophysics, among them are:

* Hassan (1981) dealt with hydrological conditions of the middle part of Erbil Plain.
* Al-Talabany and Aiub (1987) dealt with morphology and hydrology of Kaharez in Erbil basin.
* Al-Saigh *et al.* (1989) studied a regional gravity and magnetic traverse along the highway from Erbil to Shaqlawa.
* Hassan (1998) dealt with urban hydrology of Erbil city.
* Hamid (1995) carried out a regional gravity traverse between Mosul and Harrir, passing through Arbil area.
* Omar (1999) studied the morphometric analysis of some drainage basins in Erbil city.
* Ghaib (2001) executed a geophysical study for Erbil Plain.
* Chnaray (2003) studied the hydrogeology and hydrochemistry of Capran sub division.
* Nariman (2006) studied the performance of stone column in Erbil city.

METHODS OF WORK

The study includes both mineralogical and engineering analysis for the sediments of Erbil Plain. For mineralogical study, sixteen soil samples were collected from different localities in the studied area (Fig.2). The sampling was at different depths; ranging between (0.5 – 1.5) m. For studying the non clay minerals, bulk samples were prepared; 30 gm of the clay sample was taken, then acetone was added and placed in agate mortar to shake well, then the suspended part was spread on a clean glass slide and XRD pattern was recorded. For oriented samples, the soil sample was pre-treated with acetic acid to remove the carbonates. For treating the soil sample with sodium hexametaphosphate, samples were placed in a mixer to disperse the clay particles (Atkinson *et al*., 2004), then spread on a slide and were left to dry, and the XRD pattern was recorded. The test includes three stages (Fig.3):

- Testing of normal samples without treating with any material
- Treating the samples with Ethylene glycol
- Heating the samples to 550° C for about 2 hours

The easiest method for estimating the area measurements (of the XRD pattern) is to over lay the diffractogram on a grid pattern background and to count the whole partial squares.

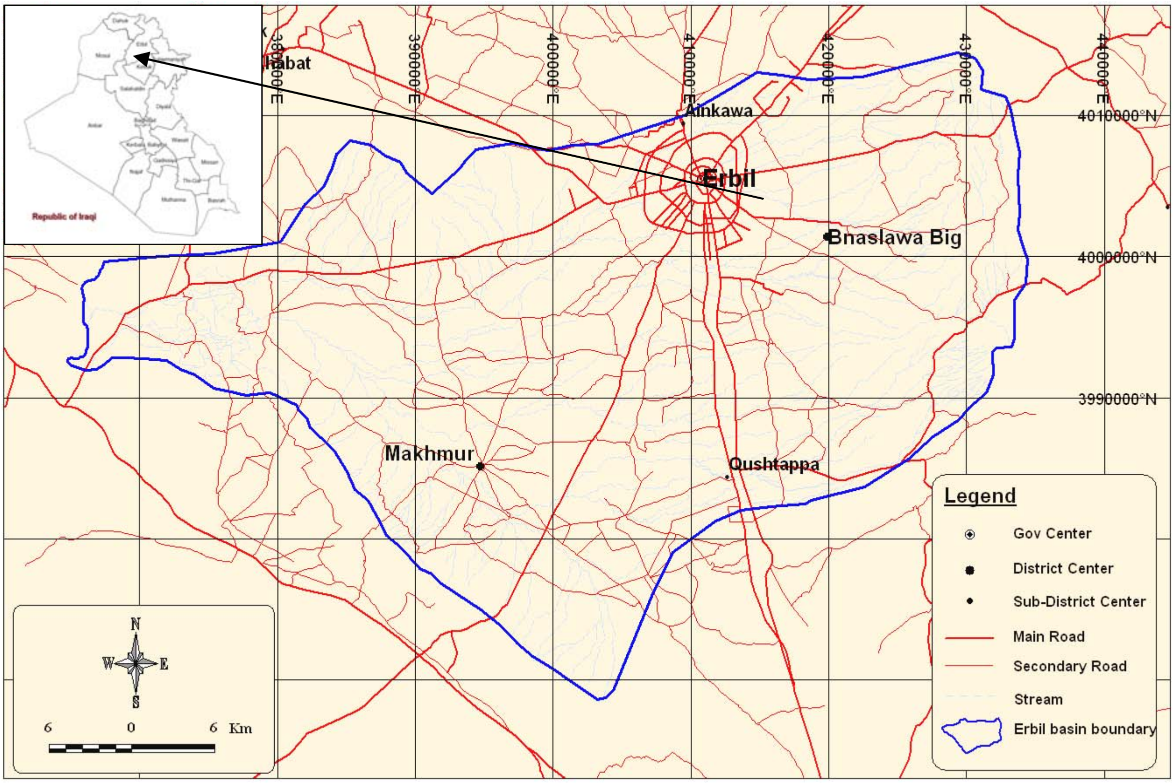


Fig.1: Location map of the middle part of Erbil Plain

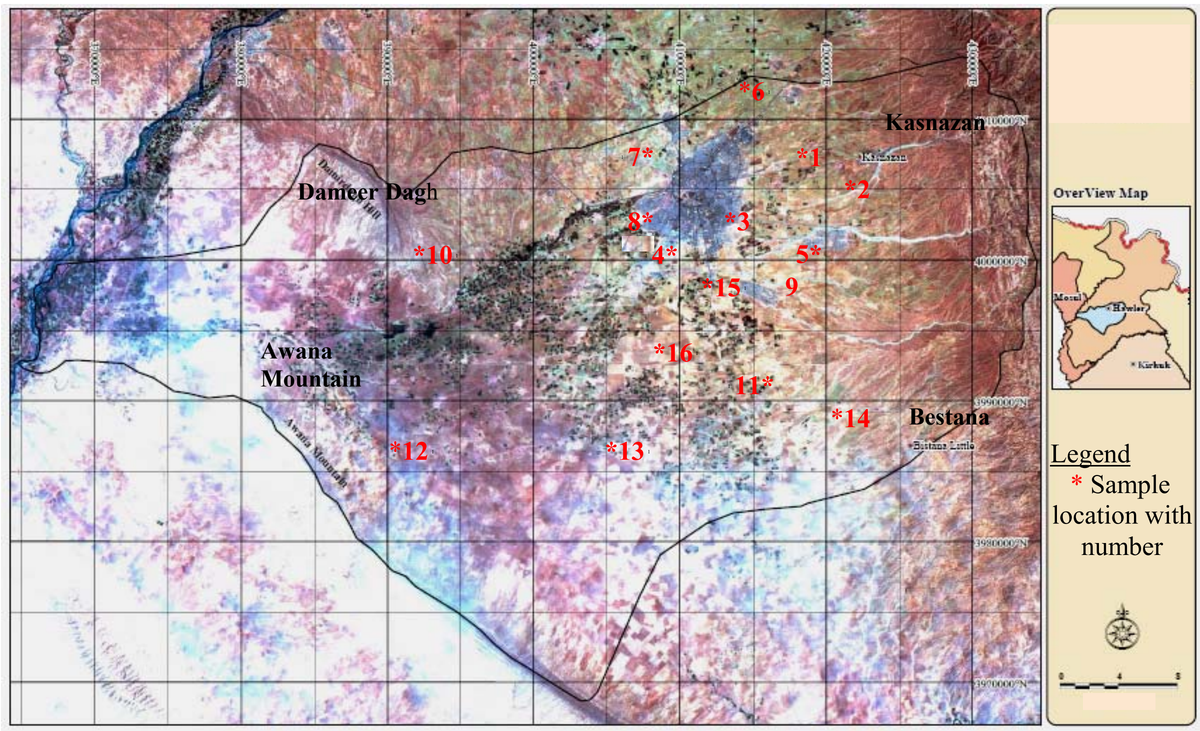
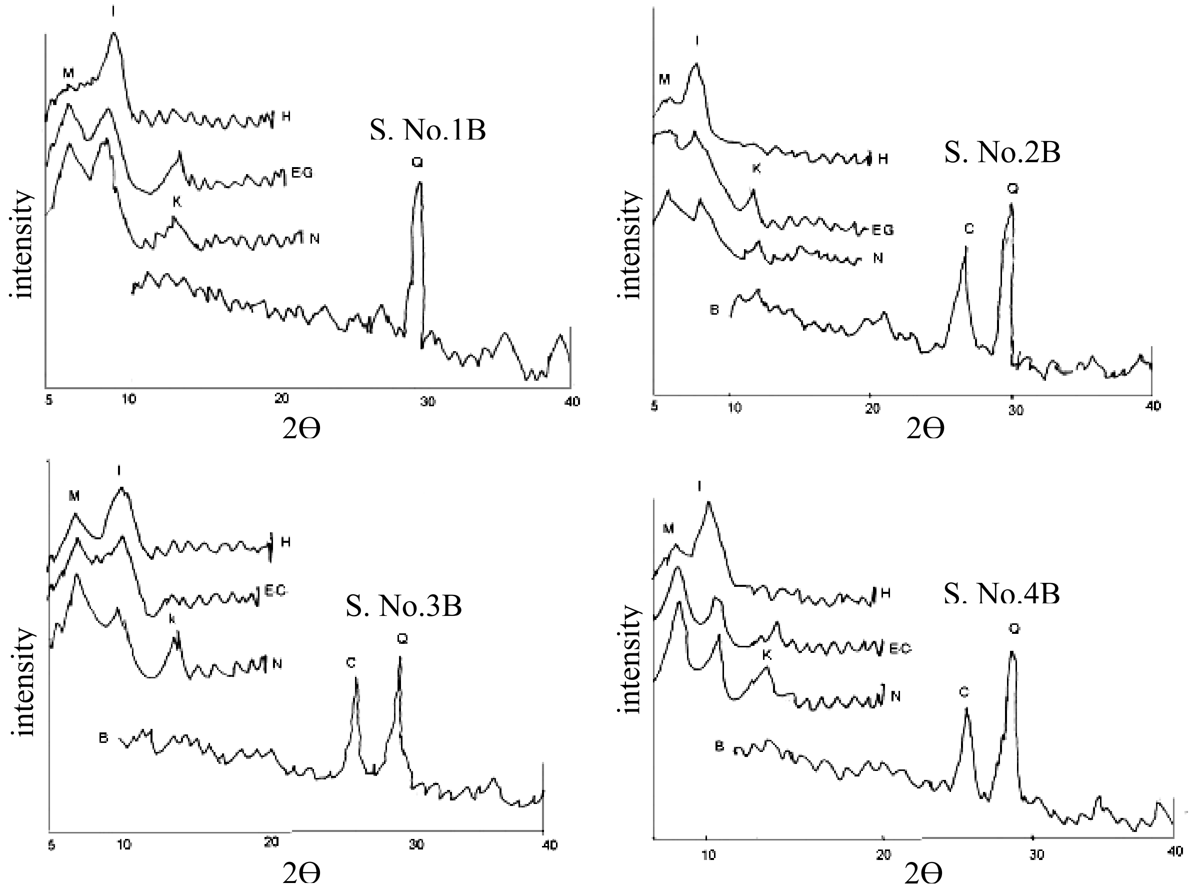


Fig.2: Satellite image of the middle part of Erbil Plain showing the location of the samples for XRD, PL and LL tests



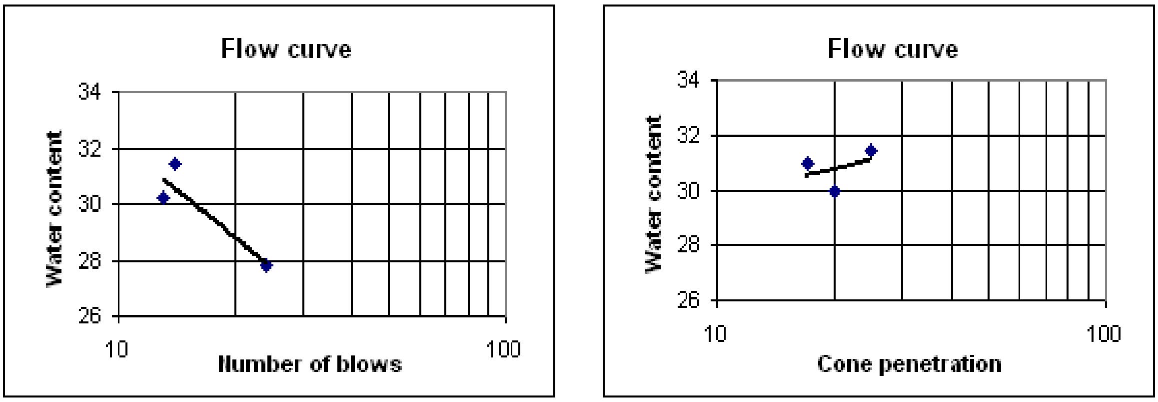
Legend

Q: Quartz
C: Calcite
M: Montmorilonite
I: Illite
K: Kaolinite
N: Normal
E.G.: Ethelene glycol
H: Heating
B: Balk

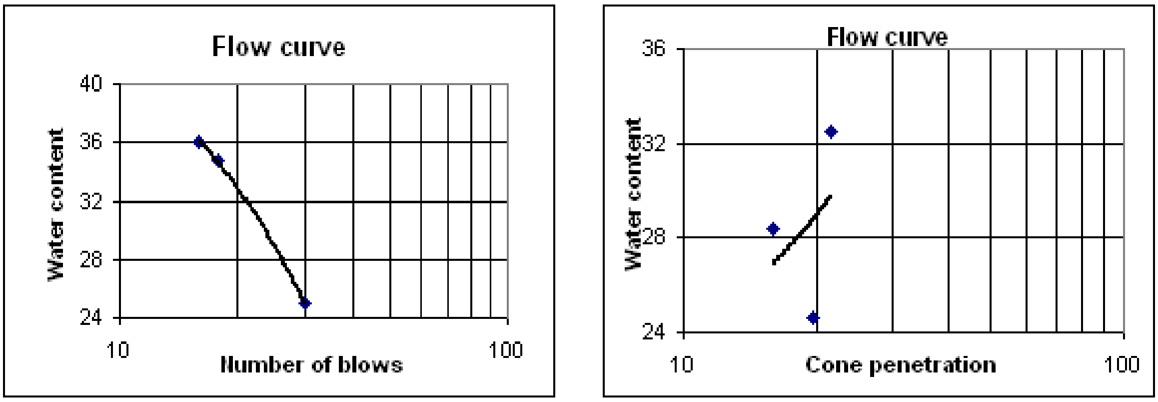
Fig.3: X-ray diffractograms of samples No.1B, 2B and 3B

The Engineering analysis includes soil consistency and grain size distribution of the sediments. For studying the soil consistency, the same samples were used, which depend on Casagrande and Cone Penetration Test methods. To start the Casagrande test, about 250 gm of the sample passing through sieve number 40 (0.425 mm diameter) was taken, distilled water was added and mixed to form a uniform soil paste, a portion of the paste was placed in the cup of liquid limit device and leveled by spatula, using groove tools to cut the sample in the cup, the cup was given blows. The number of blows required to close the groove of a distance of 13 mm was recorded, part of the sample; where the grooves have closed was taken for water content determination. About three sets of blow numbers and water content were recorded, after that a flow curve was plotted, for water content values; on natural scale against number of blows; on log scale to obtain a straight line. Liquid limit values were determined in the intersection of the water content values corresponding to 25 blows (Fig.4).

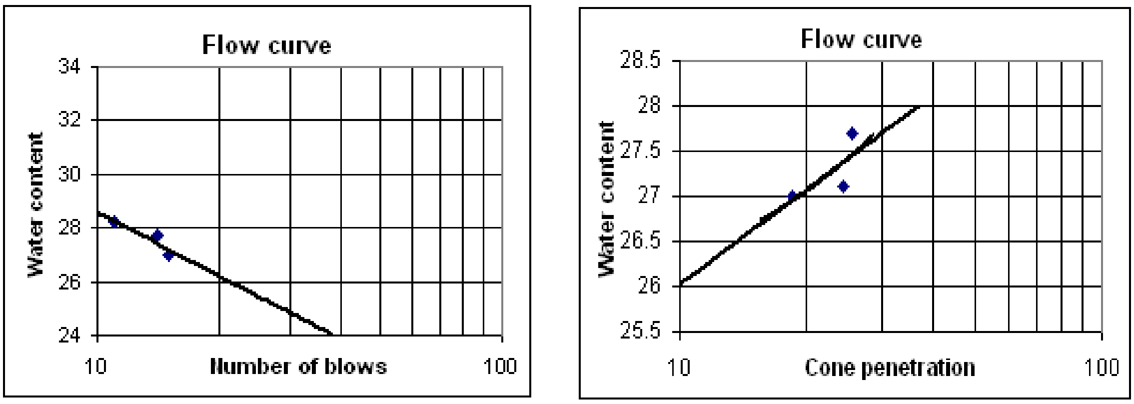
The Cone Penetration Test method is based on the relationship between moisture content and the penetration of the cone into the soil sample under controlled condition. The penetrometer is fitted with a stainless steel cone about 35 mm long with cone angle 30°. A soil paste was filled in the metal cup kept under the cone, the penetration of the cone at various water contents was noted, a graph between cone penetration and water content values



S.No.1B



S.No.2B



S.No.3B

Fig.4: Liquid limit test by Casagrande and cone penetration method
(S.No.1B, 2B and 3B)

was plotted, the cone penetration on log scale, whereas the water content values on natural scale. Liquid limit values were determined in the intersection of the water content values corresponding to 20 mm penetration (Fig.4).

To find the percentage of the fine materials and grain size distribution, twenty two samples were collected from the studied area. They were selected from different locations to cover the whole area (Fig.5). Sieve analysis and wet analysis were applied. The textural composition of the soil was determined by sieving the soil through a series of sieves of various sizes and weighing the materials retained by each sieve. The following calculation was applied:

$$\text{Percentage of retained on any sieve} = \frac{\text{Weight of the retained soil}}{\text{Total soil weight}} \times 100$$

Cumulative percentage retained on any sieve = Sum of percentage retained on all coarser sieves.

Percentage of fine materials = 100 – cumulative of retained materials on the sieves

The results are usually represented on a semi-log paper. Fine materials are represented on normal scale and the particle diameter on a log scale (Fig.6) (Pettijohn, 1975 and Murthy, 2002). Soils consisting of materials smaller than 0.002 mm are considered as clay. Following the Unified Soil Classification System (USCS), if more than half of the materials are larger than sieve No. 200, then the soil is considered as coarse grained soil.

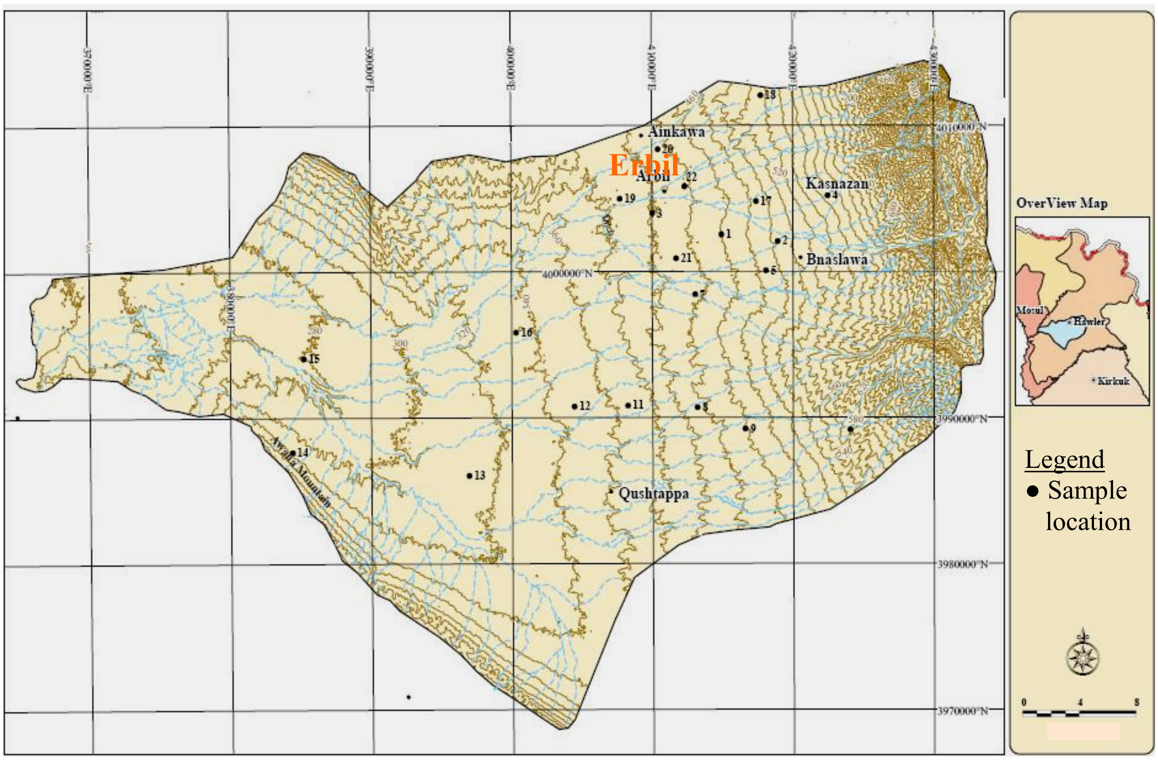


Fig.5: Topographic map showing the location of samples for grain size analysis test

RESULTS

The XRD analysis results show that the montmorillonite, illite and kaolinite are present in all samples (Table 1). The amount of each mineral in the examined sample is determined approximately in percent. X-ray diffractograms of samples 1B, 2B, 3B and 4B are shown in Fig. (3).

The activity of the clay, in the studied samples was determined by applying a relationship between the plasticity index and the percentage of clay sizes finer than 2 micron, following Skemption (1953) in Cernica (1995), as shown in the following equation:

$$\text{Activity of clay} = \frac{\text{PI}}{\text{\% finer than 2 micron}}$$

According to the classification of Skemption (1953) (Table 2), the samples 2B (Hassarok), 9B (Daratu) and 14B (Bestana) are considered as active clay (Table 3 and Fig.7). This means that these samples are characterized by high percentage of montmorillionite and with high percentage of clay size finer than 2 micron?. Non clay minerals like quartz and calcite are also present in the samples.

The plasticity index classification is based on plasticity index chart (Das, 2002) (Table 4). Plasticity index indicates the range of moisture, when the plasticity index increases; then the soil contains high moisture content, and it has great effect on engineering projects due to swelling of the clayey soil.

The liquid limit and plastic limit values in the studied samples, according to Casagrande and Cone Penetration Test methods are shown in Table (5). The results show that samples No.2B (Hassarok), 3A and 3B (Taajel), 13A and 13B (Qush Tapa) and 16B (Kirkuk road) are with low plasticity, sample No.8B; near the building of Construction Laboratories is with high plasticity, whereas the other samples are with medium plasticity (Figs.8 and 9).

Table 1: Approximate percentage of clay minerals in the soil samples in the studied area

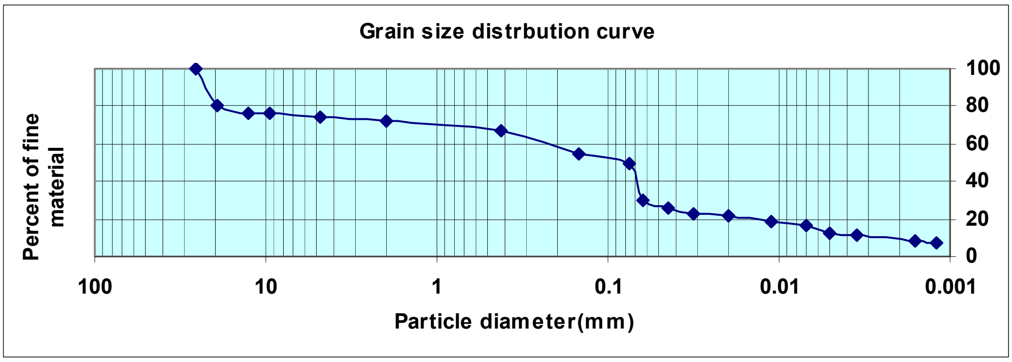
S.No.	Location	Montmorilonite	Illite	Kaollinite	Percentage of clay in the soil
		(%)			
1B	Kasnazan	47	43	10	23.2
2B	Hassarok	57	28	15	28.2
3B	Taajel	43	42	15	18.0
4B	Arbil park	50	40	10	12.16
5B	Science College	50	35	15	28
6B	Shawes	45	35	20	27
7B	Ain Kawa	45	35	20	12.6
8B	Construction Laboratories	65	20	15	12.0
9B	Daratu	55	30	15	15.0
10B	Jmka	45	30	25	1.0
11B	Quarry along Guair road	45	45	10	38.0
12B	Mastawa	40	36	8	20
13B	QushTapa	40	27	33	33
14B	Bestana	55	30	15	18
15B	60 meter street	50	35	15	18
16B	Kirkuk road	42	38	20	18

Table 2: Activity of clay (Skemption, 1953)

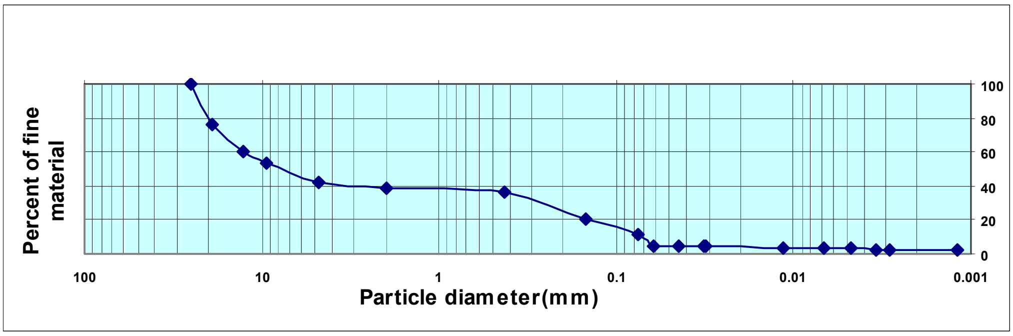
Activity (A)	Classification
< 0.7	Inactive clay
0.7< A< 1.20	Normal clay
>1.20	Active clay

Table 3: Activity of the clay in the studied samples

S.No.	Location	Plasticity index (PL)	% Clay < 2 (micron)	Activity (A)	Type of clay
1B	Kasnazan	11.5	10	1.15	Normal
2B	Hassarok	7.3	4	---	Active
3B	Taajel	8.7	14	0.62	Inactive
4B	Arbil park	10.9	26	0.41	Inactive
5B	Science College	16	18	0.88	Normal
6B	Shawes	14.85	17.2	0.86	Normal
7B	Ain Kawa	15.6	35	0.44	Inactive
8B	Construction Laboratories	26	27	0.96	Normal
9B	Daratu	17.7	5	3.5	Active
10B	Jmka	11.4	10	1.11	Normal
11B	Quarry along Guair road	13.1	18	0.72	Normal
12B	Mastawa	15	13	1.15	Normal
13B	Qush Tapa	7.8	21.5	0.36	Inactive
14B	Bestana	16	4.2	3.8	Active
15B	60 meter street	16.2	23	0.68	Inactive
16B	Kirkuk road	6.7	33	0.2	Inactive



S.No.1



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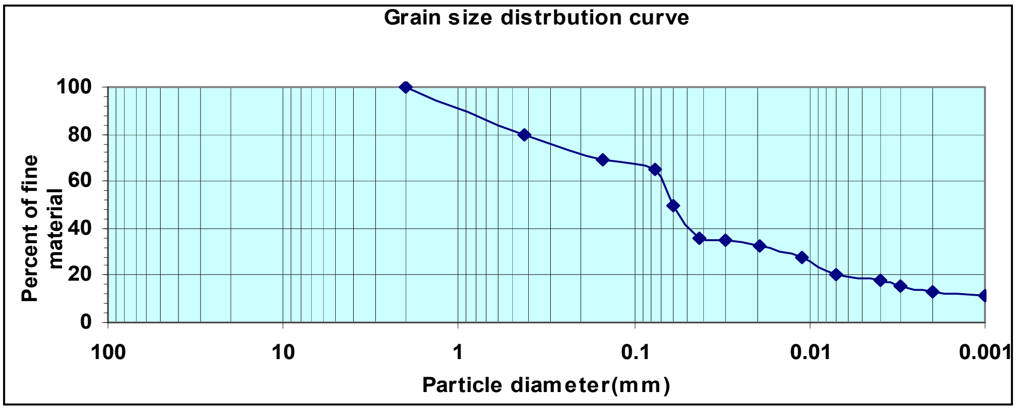

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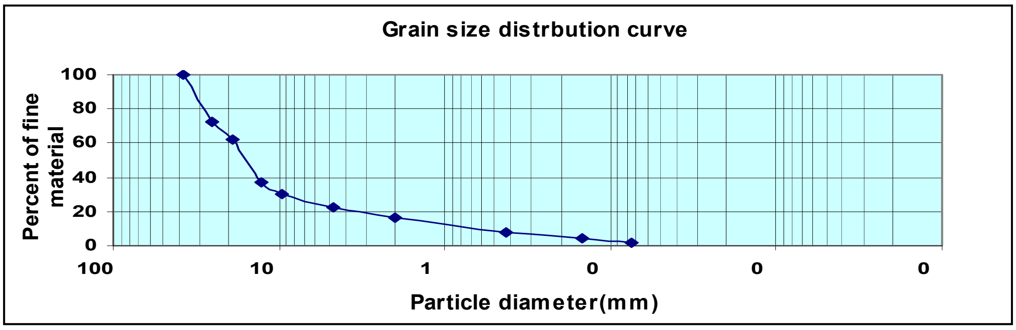


S.No.4

Fig.6: Grain size distribution curves of samples No.1, 2, 3 and 4

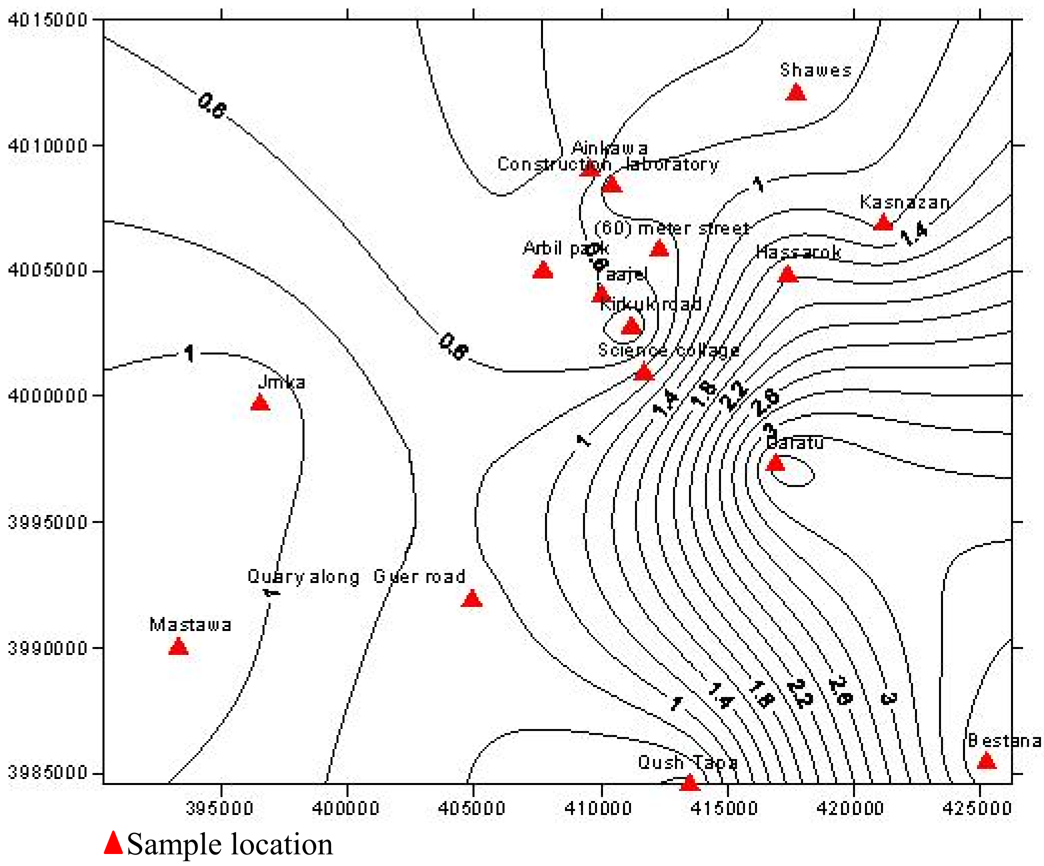


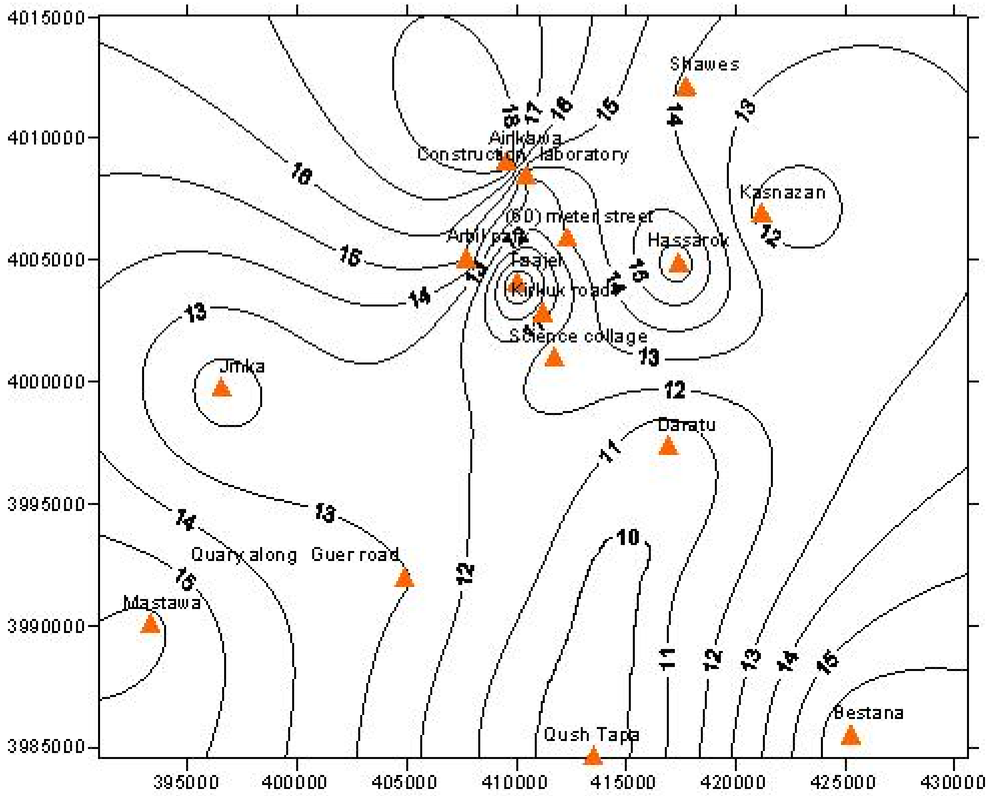
Fig.7: Map of clay activity at a depth of 1 m for the middle part of Erbil Plain

Table 4: Plasticity index chart (Das, 2002)

Plasticity index (PI)	Description
0	Non plastic
1 – 5	Slightly plastic
5 – 10	Low plasticity
10 – 20	Medium plasticity
20 – 40	High plasticity
>40	Very high plasticity

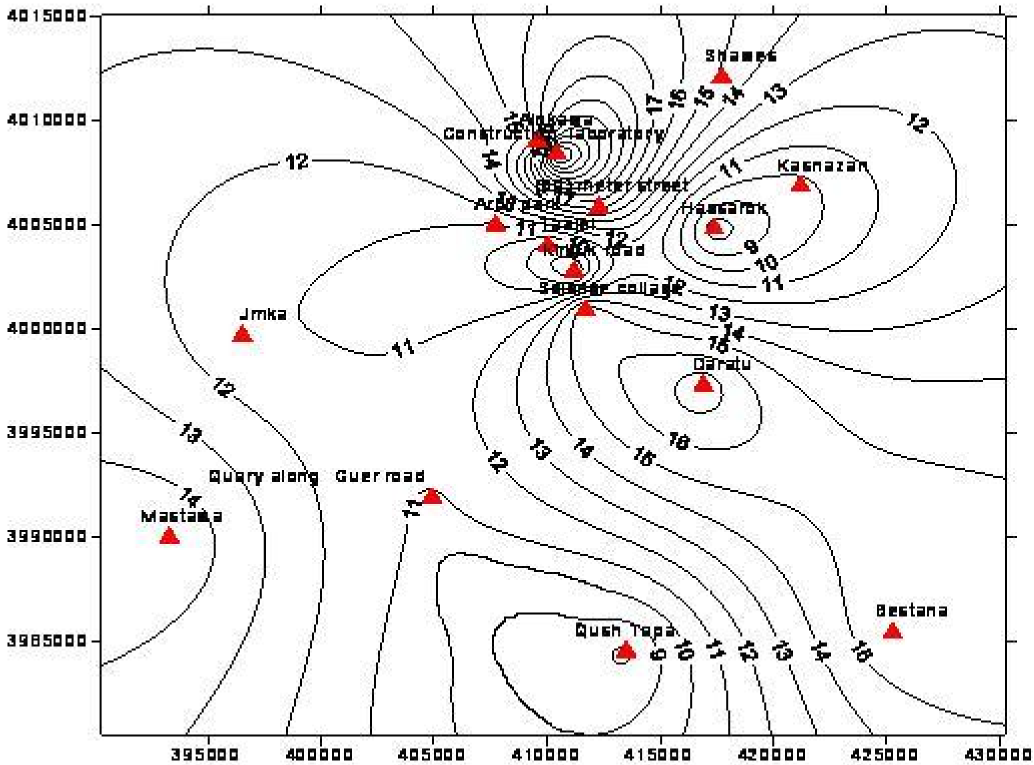
Table 5: Liquid limit and plastic limit values indicated by Casagrande and Cone Penetration Test methods (Ramamurthy, 2005)

S.No.	Location	Depth (m)	Casagrande method			Cone Penetration method		
			LL (%)	PL (%)	Pl	LL (%)	PL (%)	PI
1A	Kasnazan	0.0 – 1.0	29	17.5	11.5	31.5	17.5	14
1B	Kasnazan	1.0 – 1.5	27.8	18.1	9.7	30.8	18.1	12.7
2A	Hassarok	0.0 – 1.0	36.8	20	16.8	33.4	20	13.4
2B	Hassarok	1.0 – 1.5	28.2	20.9	7.3	29	20.9	9.9
3A	Taajel	0.0 – 1.0	29.2	21.8	7.4	29.6	21.8	7.8
3B	Taajel	.0 – 1.5	25.7	17	8.7	27	17	10
4A	Arbil park	0.0 – 1.0	33	17.94	15.06	32	17.94	14.06
4B	Arbil park	1.0 – 1.5	27.4	16.5	10.9	26.8	16.5	10.3
5A	Science College	0.0 – 1.0	24.2	11.4	12.8	24.5	11.4	13.1
5B	Science College	1.0 – 1.5	33.8	17.8	16	31	17.8	13.2
6A	Shawes	0.0 – 1.0	29.3	15.5	13.8	26.8	15.5	11.3
6B	Shawes	1.0 – 1.5	38.6	23.15	14.85	36.2	23.15	13.05
7A	Ain Kawa	0.0 – 1.0	44.3	25.2	19.1	42.2	25.2	17
7B	Ain Kawa	1.0 – 1.5	33	17.4	15.6	31.2	17.4	13.8
8A	Construction Laboratories	0.0 – 1.0	31	18.2	12.8	28.5	18.2	10.3
8B	Construction Laboratories	1.0 – 1.5	46	20	26	42.5	20	22.5
9A	Daratu	0.0 – 1.0	29.2	19.2	10	30	19.2	10.8
9B	Daratu	1.0 – 1.5	38.2	20.5	17.7	36	20.5	15.5
10A	Jmka	0.0 – 1.0	32.2	20.83	11.37	35.2	20.83	14.37
10B	Jmka	1.0 – 1.5	31.8	20.66	11.14	34.2	20.66	13.54
11A	Quarry along Guair road	0.0 – 1.0	35.2	22.1	13.1	32.5	22.1	10.4
11B	Quarry along Guair road	1.0 – 1.5	35.4	24.5	10.9	34.4	24.5	9.9
12A	Mastawa	0.0 – 1.0	30.5	14.2	16.3	30.5	14.2	16.6
12B	Mastawa	1.0 – 1.5	29	14	15	29	14	14.8
13A	Qush Tapa	0.0 – 1.0	27.5	18.5	9	28	18.5	9.5
13B	Qush Tapa	1.0 – 1.5	27	19.2	7.8	27.6	19.2	8.4
14A	Bestana	0.0 – 1.0	27	10	17	25	10	15
14B	Bestana	1.0 – 1.5	26.2	10.2	16	29.6	10.2	19.4
15A	60 meter street	0.0 – 1.0	31.2	18.2	13.1	28	18.1	9.9
15B	60 meter street	1.0 – 1.5	37	20.8	16.2	36.8	20.5	16.3
16A	Kirkuk road	0.0 – 1.0	28	17.64	10.76	28	17.64	10.76
16B	Kirkuk road	1.0 – 1.5	30.8	24.1	6.7	28	22	6



▲ Sample location

Fig.8: Map of plasticity index at a depth of 1 m for the middle part of Erbil Plain



▲ Sample location

Fig.9: Map of plasticity index at a depth of 1.5 m for the middle part of Erbil Plain

The grain size analysis results are represented in Fig. (6) and Table (6). The grain size distribution curves suggest that the northeast, southeast, southwest and northwestern parts are characterized by coarse grain sediments, as in samples No.2, 4, 6, 10 and 14. The central and southern parts are characterized by fine grain sediments.

Following Unified Soil Classification System (USCS) the soil of the study area can be divided into two groups:

Group A includes the samples No.2, 4, 6, 10 and 14, which can be considered as coarse grained soil, because more than 50% of the soil retained on sieve No.200. Sample No.2 consists of well graded gravel, silty gravel (GW and GM); because coarse grained particles are more than 50% and the gravels form more than 50% of the coarse particles. The Coefficient of Uniformity (CU) is more than 4; present fines are more than 5. Sample No.4 is well graded gravel (GW), because more than 50% of the soil is gravel, present fines are less than 5, which are negligible, and CU is more than 4. Samples No.10, 14 and 6 are classified as well graded gravel, silty gravel (GW and GM), because more than 50% of the soil is gravel and CU is more than 4 (Table 7), present fines are between (5 – 12) %.

Group B includes samples No.3, 5, 7, 8, 9, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21 and 22, which are considered as fine grained soils, because more than 50% pass through sieve No.200 (Tables 6 and 7).

Table 6: Percentage of gravel, sand, silt and clay size particles in the studied samples

Sample No.	Clay	Silt	Sand	Gravel
	(%)			
1	10	40	23.75	26.25
2	3	8	31	58
3	13	51.94	35.06	0
4	0	0	20	80
5	18	53.54	28.46	0
6	1	7	27	65
7	8	40	16	16
8	0	55.89	31.49	12.62
9	34	51.59	14.44	0
10	12	20	13	55
11	33	51.05	15.95	0
12	38	48	14	0
13	20	66.02	13.98	0
14	1.2	7.14	26.66	65
14	18	51.22	10.78	20
16	16	64.96	19	0
17	23.2	57	19.8	0
18	17.2	49.6	25.06	8.14
19	12.16	73.73	14.11	0
20	37	51.33	11.67	0
21	18	56.74	25.26	0
22	28	51.15	20.85	0

Table 7: Values of CU, D60 and D10 are obtained from the grain size distribution curves

Sample No.	D10	D60	CU
2	0.075	13	173
4	0.65	20	30.7
10	0.002	12	600
14	0.2	14	70
6	0.2	13.5	67.5

SOIL IMPROVMENTS

Some methods for soil improvement techniques are available, which could be used to improve the soft soil, among them are:

- Compaction
- Soil replacement
- Soil stabilization by cement
- Stone columns

The authors suggest using stone columns for the soil improvement, in the studied area. Bowles (1996) mentioned that stone columns are commonly used in soft soils.

Vibro-stone column method is a modern technique for forming stone columns. Generally, it consists of sinking the vibroflote into the soil layer to make a circular hole. In this method, air or water flows out of the bottom of the device; under pressure. Then the cavity is backfilled with stone, and while raising and lowering the vibroflote, additional stones are added. The stones in the hole are gradually compacted as the vibroflote is withdrawn. The result is a densely compacted stone column. The used gravel for stone column has a size range of (6 – 40) mm. Stone columns usually have diameter of (0.5 – 0.75) m (Das, 2004). This technique was proved, in general, to reduce settlements within (30 – 80) % (Zakariya, 2001).

The constructions of stone column by vibro-system are performed by two methods:

- **Vibro-displacement method (dry method)**

The term displacement means that most of the soil is displaced laterally as the vibrator penetrates under own wet and power of vibration. The main condition in this method is the absence of jetting water during initial formation of the hole (the soil do not washed out) and instead of water a compressed air is used (Barksdal and Bechus, 1983). The dry method is employed only when the hole remains stable and there is no risk of ground water running into the hole. It is most effective in partially saturated clay and fully saturated soils having undrained shear strength of 20 KN/m^2, which are unlikely to collapse into the hole (Bell, 1993).

- **Vibro-replacement method (wet method)**

The term replacement means that the soil is more replaced than displaced. In this method, jetting water is used to remove soft material, stabilize the hole and ensure that the stone back fall reaches the tip of the vibrator. The technique is suitable in very soft soils having undrained shear strength less than 20 KN/m^2 (Bell, 1993).

CONCLUSIONS, DISCUSSION AND RECOMMENDATION

The flow curve of Atterberg limits (liquid and plastic limits) indicate that the surface and near surface sediments down to 1.5 m has low to medium plasticity indices ranging between (6.7 – 19.1). However, some localities, like the area near the building of Construction Laboratories show high plasticity index of 26. Areas like Hassarok, Daratu and Bestana are characterized by active clay, which has great effect on building construction.

The results of the XRD indicated that the studied soils contain quartz, calcite and clay minerals like montmorillonite, illite and kaolinite. The first two types of the clay minerals, which are dominant in the all samples with different percentages, have great effect on engineering projects, due to swelling; when the soil absorbs water and shrinks when it loses water. It might need soil improvement because it is characterized by high percentage of montmorillonite with high plasticity index and with active clay. Areas like Hasarok, Daratu and Bestana should be taken into consideration for any construction; they might need soil improvement, because they are characterized by high percentage of montmorillonite and with active clay.

The study of the grain size distribution indicated that the source of the sediments is Bai Hassan Formation, where the sediments are carried by valleys and deposited in Erbil Plain. The northeast, southeast, southwest and northwestern parts are characterized by coarse grained sediments, as in samples No.2, 4, 10, 6 and 14. The southern and central parts of the studied area are characterized by fine grained sediments. Areas with only coarse grained sediments are not suitable for construction purposes, due to low shear strength. But, they form very good aquifer for ground water accumulation and are considered as a good recharge area for Erbil city and surroundings, so it is recommended not to use these areas for heavy construction projects.

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