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Geotechnical Study of Some Physical, Chemical and Mineral Properties of Selected Soils in Babel and Qadisiyah Governorates, Central Iraq.

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Abstract:
The research included conducting a geotechnical evaluation of some of the physical, chemical, and mineral properties of selected soils in the region between the provinces of Babel and Qadisiyah in central Iraq and within the quaternary era sediments of the sedimentary plain.
The research method included fieldwork for the study area, where eight digging sites were tested and samples were taken for every half meter. The soil was described in the field and the groundwater level was recorded. As for the second stage, it included physical, chemical and mineral laboratory tests.
Through the results obtained, it was found that the soil is Silty clay low to medium plasticity with fewer ratios of sand and it is oscillating in its other properties according to the volatility of the granular volumetric distribution, which is valid in most of its locations with simple treatments to establish the engineering origin.

Keywords: *geotechnical evaluation, selected soils, physical tests, chemical tests, mineral tests.*

Note: The research is improved from the thesis of the first researcher.

I. Introduction

Geotechnics is an important applied science in the field of geology, which studies the interrelationship between soil and the foundations of the engineering establishment [7] and it includes everything related to preparing the soil for engineering purposes [2]; [1].
The studies in this field are based on field observations to describe the soil and its structure and to take samples for testing purposes to find out their suitability for establishing the engineering origin, and they are variable in their durability due to their different physical, chemical and mineral properties [17].
One of the physical properties that have an effect and reflection of most properties is the property of the grain size distribution analysis because clay soils have some negative properties, such as consolidation and swelling, which are not present in sandy soil [12].
Also, the effect of humidity and the high levels of groundwater in the soil is one of the important things that must be studied and that affects the foundations of the facilities. Therefore, workers in the field of engineering geology must assess their

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damage on site for the purpose that engineers can benefit from [10].

As for the effect of the salts present in the soil, they have a great impact upon increasing them, and therefore they must be identified, and the treatments and

recommendations for building foundations and the use of building materials resistant to their impact must be determined [3].

In our research, we examined some of these properties of selected soils in the governorates of Babel and Qadisiyah, which are an extension of the sedimentary plain in Iraq, which is characterized by the predominance of clay at the expense of other components and knowing its suitability for engineering purposes.

II. SITE OF THE STUDY AREA

The study area is located in the middle of Iraq within the sedimentary plain region and is represented by the provinces of Babel and Qadisiyah, where it is confined between the latitude (31°14'8.83") and (33° 3'10.83") north, and longitude (43°55'2.31") and (44°30'2.78") east.

The study area crosses the Euphrates River, which branches into the Shatt Al-Hilla, which extends from its branch point from the Euphrates River to southeast, in line with the general slope of the surface in the provinces of Babel and Qadisiyah, Fig (1).

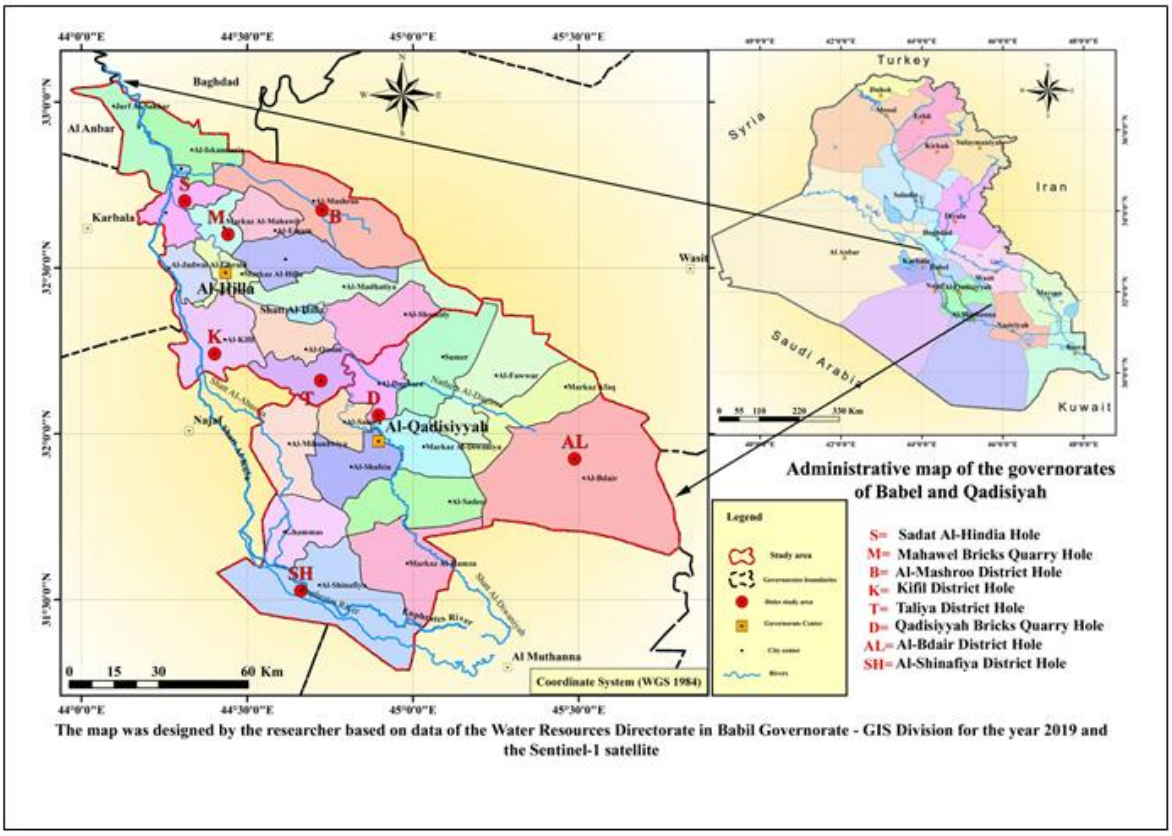

Fig 1: The administrative map of the governorates of Babel and Qadisiyah, illustrated by digging the study area.

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III. GEOLOGY OF THE STUDY AREA

The sediments that cover the study area date back to the Quaternary era that was formed by rivers, where the study area falls within the sedimentary plain, so the geology of this region, in general, does not differ from the geology of the sedimentary valley, where the valley of the sedimentary valley is distinguished by its exposure to periodic sequences of sedimentation and weathering As a result of climate changes during the period Pleistocene, Fig (2) represents a geological map of the study area [14].

Generally speaking, the area is characterized by being a flat land where there are some natural beams with few heights and covered with newly formed river sediments. From ancient geography, it appears to us that this region was forming the banks of rivers at a time when the process of formation and sedimentation continued in the area between the Tigris and Euphrates (called the island) [14].
As the recent deposits within the study area included the following:

- Sheet run-off deposits.
- Flood plain deposits.
- Depression fill deposits.
- Aeolian deposits [8].

IV. THE TOPOGRAPHY OF THE STUDY AREA

The area is generally low relative to the rest of the physiographic divisions of Iraq, and its average elevation above sea level is from 15 to 35 meters, Fig (3) and it descends mainly to the south and it has a wide extension of geomorphological units and it is generally river deposits, swamp deposits and erosion surface,(Almubarak and Jacob,1983).

V. RESEARCH METHODS

1. Field Work

Fieldwork included exploratory tours of the drilling sites and their suitability, after being evaluated for different purposes.

The second stage included drilling for eight sites chosen at a depth of (4 meters) and by relying on drilling by (auger).

The soil was described by field inspection of the samples, Fig(6) and for every half meter, as well as recording the water table.

1. Laboratory Work

Laboratory work included the following checks:

- Checking the moisture content according to the international standards organization [4].
- Considering the grain size analysis according to the specification (ASTM-D1140).
- The limits of atterberg according to [6], and the soil was classified according to the unified soil classification system (USCS).

2. Chemical Tests

Chemical analyzes include the following oxides (SiO2, CaO, MgO, Fe2O3, AL2O3, Organic Matter O.M., and Total Dissolved Salts -TSS) As well as chlorides, sulfates, and gypsum according to [13].

3. Mineral Examinations

Soil mineralization was identified through the use of (X-RAY) technology for all sites and with one examination for each site.

VI. RESULTS AND DISCUSSION

Through physical, chemical and mineral tests, it was found that:

1. Physical examinations

Physical tests were performed on samples brought from fieldwork in the drilling process after placing and storing them in bags, and the groundwater level ranged between (1.83-3.83m), Fig(4).

- **Water Content (W/C%)**

It was found from the calculation of the results of the water content of 64 samples distributed over the eight pits of the study area and compared with

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the groundwater level for each hole that the increase is proportional to the level of the underground water in a direct proportion, where the moisture content ratios for the examination samples ranged between (5,98-38,86)%, Table (1) illustrating these results.

- **Grain Size Analysis**

The granular size analysis of clay samples was carried out using dry and wet analysis [5].

Table (2) shows the results of the volumetric analysis of the study sample soil. The studied soil consisted of volumetric gradients distributed between sand (> 0.02 mm), silt (0.02-0,002 mm) and mud (<0,002 mm).

As it was found through looking at the results of Table No. 2 that the sand percentages ranged between (0-93%) and the rate (13%), and the silt rates ranged between (6-78%) and at a rate of (51%), while the clay ratios in the study area samples ranged between (1-71%) at the rate of (36%).

- **Atterberg Limits (LL, PL, PI)**

Table (3) shows the results of the atterberg limits, plastic limit, liquid limit, and plasticity index for clay model samples distributed and it's classification using Plasticity chart on (8) drilling pits Fig(5), where the results were as follows: Liquid limit ratio ranges between (26-57) At a rate of (35), and the plastic limit rate ranges between (21-35) and at the rate of (27) and the ratio of plasticity index ranges between (2-30) and at the rate of (8).

They conform with the specifications of the materials selected in the backfill works for aspects of engineering foundations, settlement works, or public service trenches, where the percentage (PI) does not exceed 35 [9].

- **Specific Gravity (Sp.gr.)**

The results of testing the specific gravity of Table (4) for eight samples of study pits, represented by one sample per hole, where most of them ranged from clay to Silty clay, which is identical to what was stated in the triangular classification of Folk.

The specific gravity values for the studied samples ranged between (2.43-2.67) and at the rate of (2.57).

Table 1: Shows the moisture content of the study area samples.

No.	**W/C %**	**No.**	**W/C %**	**No.**	**W/C %**	**No.**	**W/C %**
M1	10.40	D1	13.86	T1	23.97	B1	24.56
M2	6.23	D2	22.35	T2	11.59	B2	26.31
M3	5.98	D3	22.20	T3	23.53	B3	26.24
M4	8.64	D4	25.21	T4	38.86	B4	26.07
M5	10.50	D5	26.36	T5	27.32	B5	22.62
M6	24.87	D6	28.21	T6	31.97	B6	25.92
M7	21.01	D7	31.63	T7	33.30	B7	24.33
M8	20.50	D8	23.42	T8	33.68	B8	28.69
Ave.	13.52	Ave.	24.15	Ave.	28.03	Ave.	25.59
Min	5.98	Min	13.86	Min	11.59	Min	22.62
Max	24.87	Max	31.63	Max	38.86	Max	28.69
No.	**W/C %**	**No.**	**W/C %**	**No.**	**W/C %**	**No.**	**W/C %**
AL1	17.65	SH1	27.73	K1	18.33	S1	27.55
AL2	16.52	SH2	32.79	K2	28.99	S2	27.71
AL3	22.78	SH3	32.73	K3	29.45	S3	32.29
AL4	25.84	SH4	23.85	K4	31.11	S4	36.41
AL5	27.19	SH5	26.92	K5	27.95	S5	34.02
AL6	25.71	SH6	28.57	K6	30.46	S6	30.79
AL7	31.06	SH7	24.82	K7	36.29	S7	30.82
AL8	28.46	SH8	30.09	K8	35.46	S8	35.47
Ave.	24.40	Ave.	28.44	Ave.	29.76	Ave.	31.88
Min	16.52	Min	23.85	Min	18.33	Min	27.55
Max	31.06	Max	32.79	Max	36.29	Max	36.41

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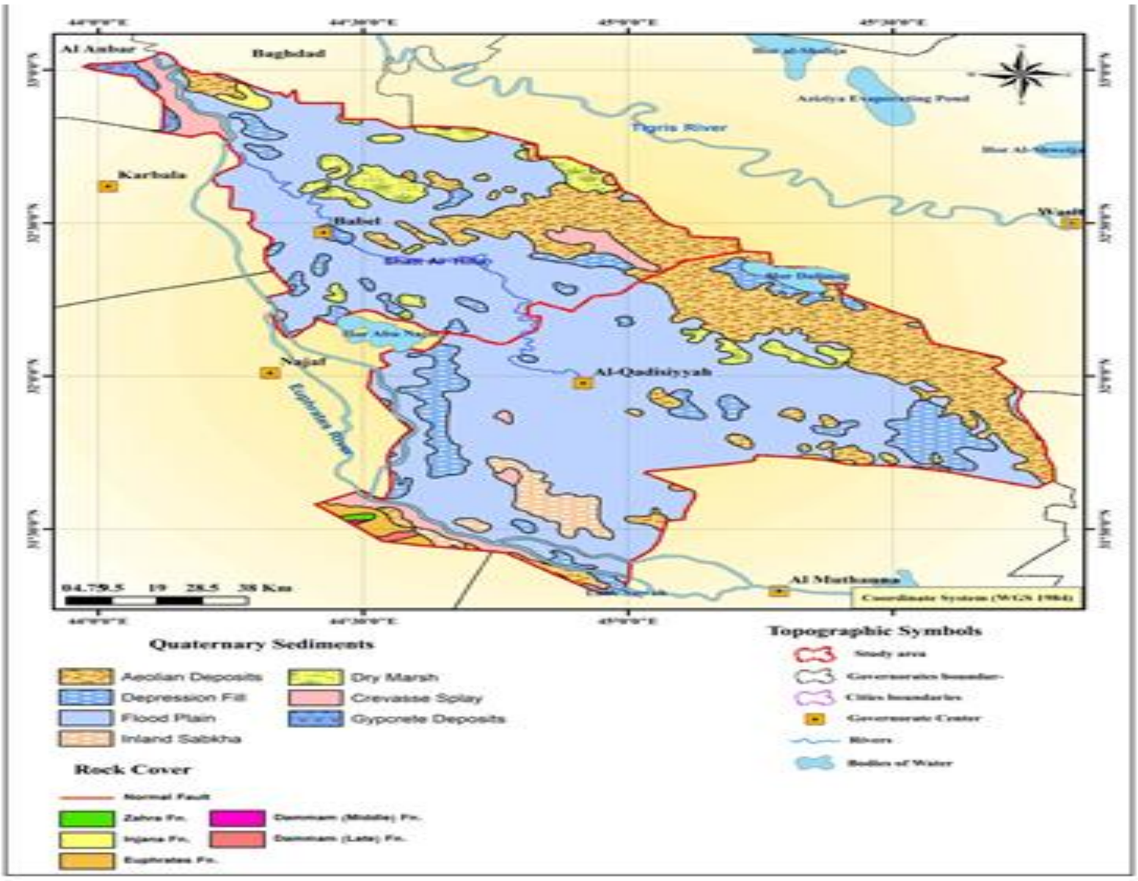

Fig 2 :Represents the geological map of Babil and Qadisiyah governorates.

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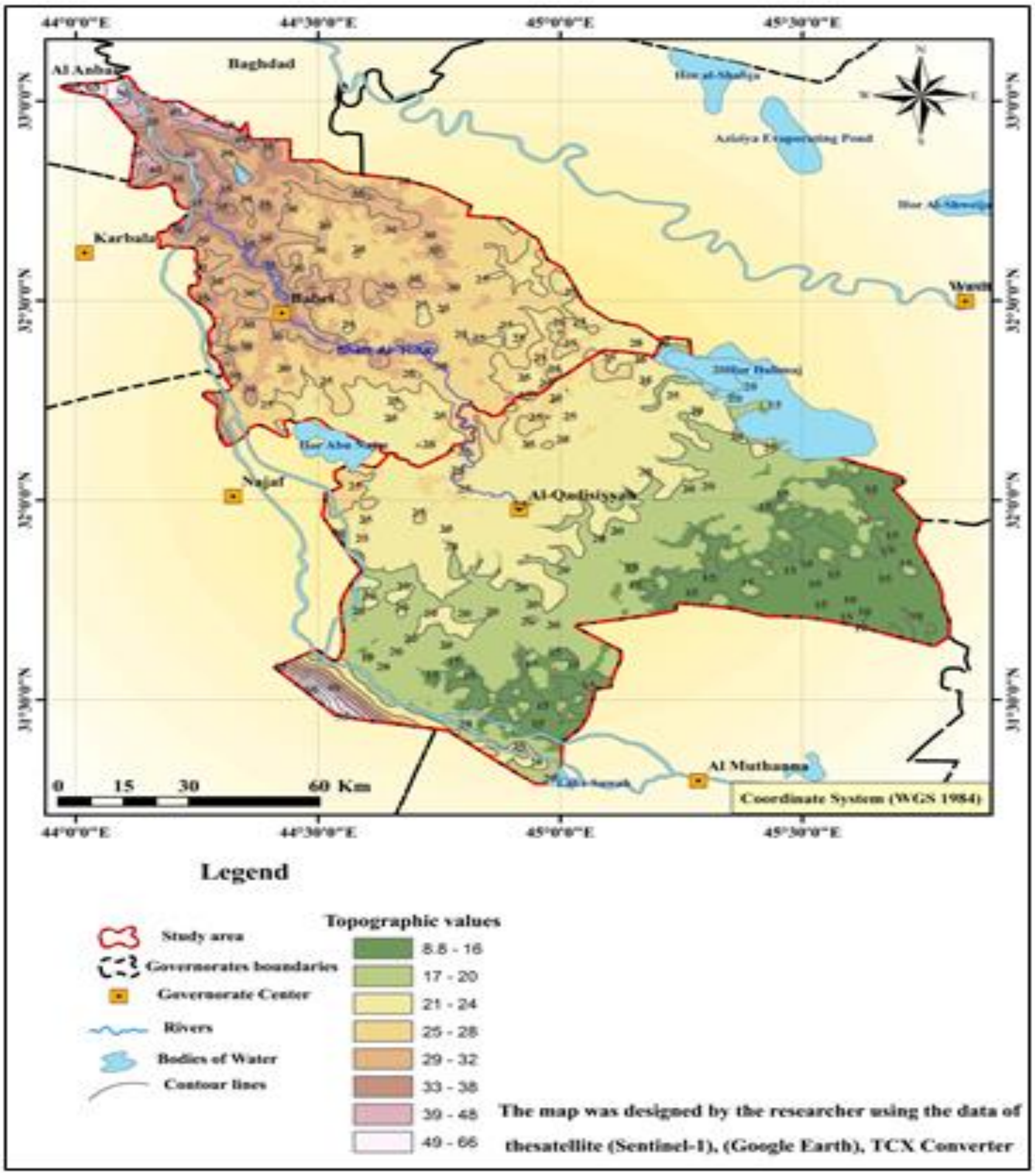

Fig 3 :Represents the Topographic map of Babil and Qadisiyah governorates.

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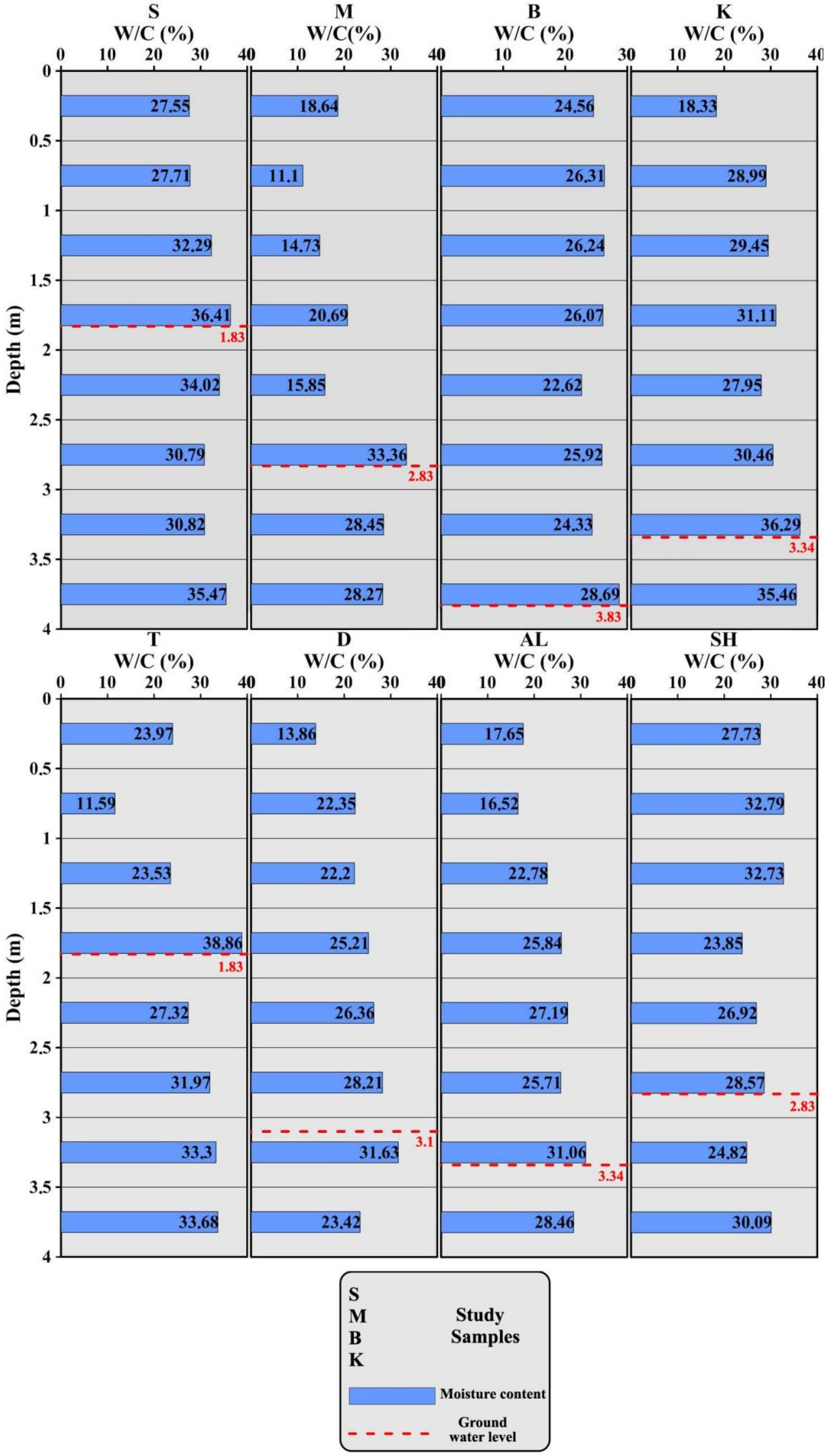

Fig 4 :Shows the fluctuation of the water content of the study samples and the groundwater level of the studied pits.

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Table 2:Shown the grain size distribution analysis of the study samples.

No.	**Sand %**	**Silt %**	**Clay %**	**No.**	**Sand %**	**Silt %**	**Clay %**	**No.**	**Sand %**	**Silt %**	**Clay %**	**No.**	**Sand %**	**Silt %**	**Clay %**
M1	4	49	47	D1	2	68	30	T1	4	64	32	B1	3	49	48
M2	5	56	39	D2	1	56	43	T2	39	41	20	B2	3	48	49
M3	15	50	35	D3	2	72	26	T3	73	20	7	B3	3	48	49
M4	27	46	27	D4	1	52	47	T4	1	45	54	B4	2	48	50
M5	60	26	14	D5	0	54	46	T5	5	51	44	B5	14	38	48
M6	9	60	31	D6	0	47	53	T6	2	56	42	B6	2	41	57
M7	93	6	1	D7	1	40	59	T7	12	55	33	B7	1	46	53
M8	3	43	54	D8	16	42	42	T8	3	55	42	B8	2	39	59
Ave.	27	42	31	**Ave.**	3	54	43	**Ave.**	17	48	34	**Ave.**	4	45	52
Min	3	6	1	**Min**	0	40	26	**Min**	1	20	7	**Min**	1	38	48
Max	93	60	54	**Max**	16	72	59	**Max**	73	64	54	**Max**	14	49	59

No.	**Sand %**	**Silt %**	**Clay %**	**No.**	**Sand %**	**Silt %**	**Clay %**	**No.**	**Sand %**	**Silt %**	**Clay %**	**No.**	**Sand %**	**Silt %**	**Clay %**
AL1	4	60	36	SH1	32	54	14	K1	4	50	46	S1	4	40	56
AL2	5	70	25	SH2	20	61	19	K2	1	43	56	S2	3	33	64
AL3	9	77	14	SH3	18	62	20	K3	2	27	71	S3	3	60	37
AL4	10	67	23	SH4	30	60	10	K4	2	43	55	S4	8	66	26
AL5	5	78	17	SH5	27	64	9	K5	3	40	57	S5	7	63	30
AL6	3	34	63	SH6	20	68	12	K6	26	49	25	S6	16	59	25
AL7	3	40	57	SH7	26	67	7	K7	36	41	23	S7	12	49	39
AL8	2	48	50	SH8	60	33	7	K8	27	66	7	S8	6	54	40
Ave.	5	59	36	**Ave.**	29	59	12	**Ave.**	13	45	43	**Ave.**	7	53	40
Min	2	34	14	**Min**	18	33	7	**Min**	1	27	7	**Min**	3	33	25
Max	10	78	63	**Max**	60	68	20	**Max**	36	66	71	**Max**	16	66	64

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Table 3: Shows the results of Atterberg limits for study samples.

No.	LL	PL	PI	USCS Class	No.	LL	PL	PI	USCS Class
M1	40	29	11	ML	D1	31	24	6	ML
M2	36	27	9	ML	D2	32	26	6	ML
M3	37	25	12	ML	D3	32	25	7	ML
M4	26	23	3	ML	D4	40	29	11	ML
M5	-	-	-	SP	D5	53	35	18	MH
M6	33	26	7	ML	D6	57	26	30	CH
M7	-	-	-	SP	D7	52	26	26	CH
M8	54	34	19	MH	D8	44	27	17	ML
Ave.	38	27	10			43	27	15	
T1	33	24	9	ML	B1	41	33	8	ML
T2	-	-	-	SW	B2	40	29	11	ML
T3	-	-	-	SW	B3	42	31	11	ML
T4	28	25	4	ML	B4	44	29	15	ML
T5	33	27	6	ML	B5	33	26	7	ML
T6	42	31	11	ML	B6	32	28	4	ML
T7	32	26	6	ML	B7	31	26	5	ML
T8	41	31	10	ML	B8	30	28	2	ML
Ave.	35	27	8			37	29	8	
AL1	33	27	6	ML	SH1	-	-	-	SW
AL2	32	26	6	ML	SH2	33	25	8	ML
AL3	27	23	4	ML	SH3	31	26	5	ML
AL4	29	21	8	ML	SH4	34	27	7	ML
AL5	31	27	4	ML	SH5	-	-	-	SW
AL6	27	24	3	ML	SH6	30	26	4	ML
AL7	28	24	4	ML	SH7	-	-	-	SW
AL8	41	32	9	ML	SH8	-	-	-	SW
Ave.	31	26	6			32	26	6	
K1	31	26	5	ML	S1	32	26	6	ML
K2	33	24	9	ML	S2	32	27	5	ML
K3	32	27	5	ML	S3	30	28	2	ML
K4	31	25	6	ML	S4	-	-	-	SW
K5	31	25	6	ML	S5	29	24	5	ML
K6	-	-	-	SW	S6	28	25	3	ML
K7	-	-	-	SW	S7	28	25	3	ML
K8	-	-	-	SW	S8	32	27	5	ML
Ave.	32	25	6			30	26	4	

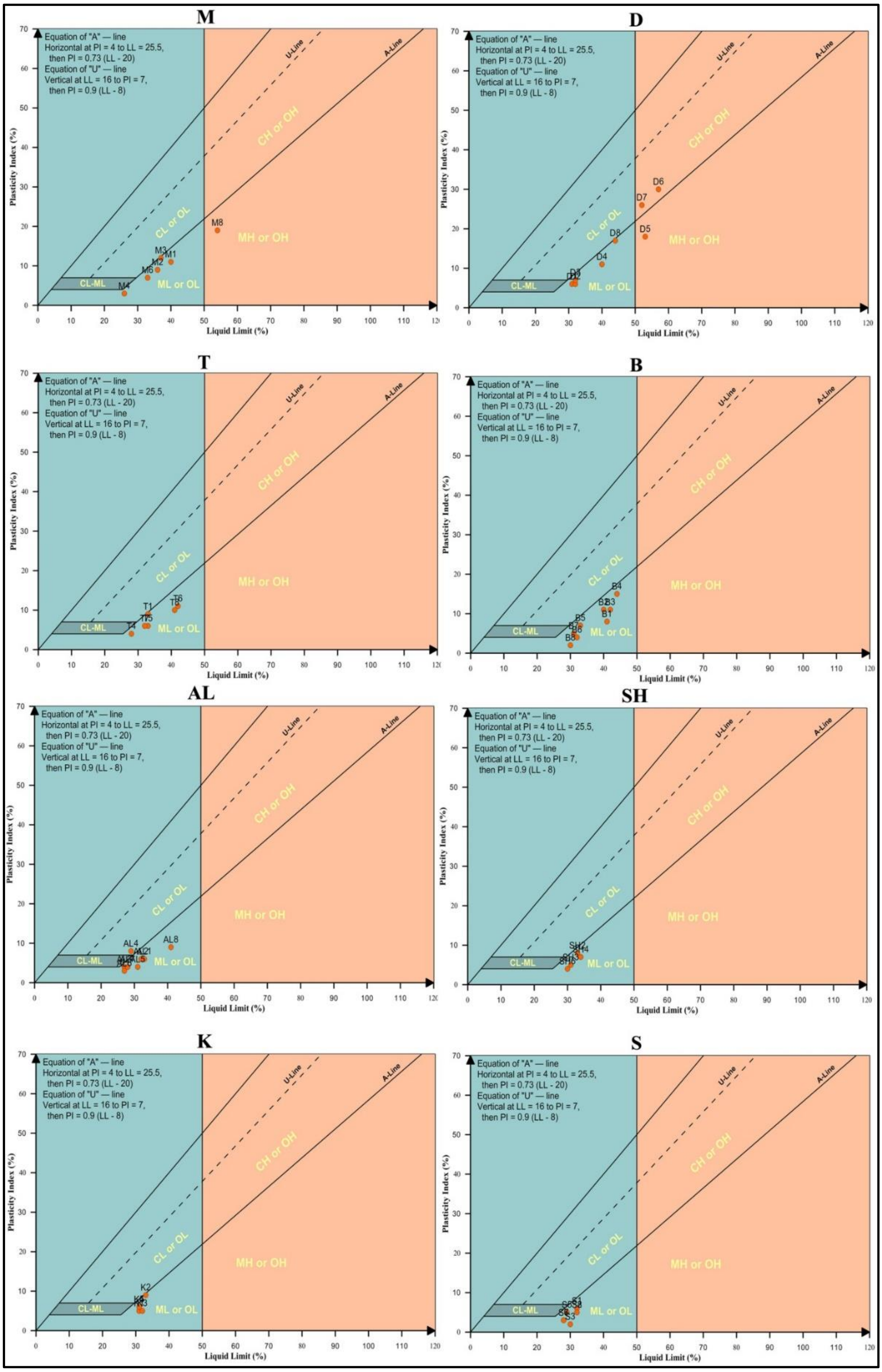

Fig 5: Demonstrates the use of the plasticity chart on soil of Study area.

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Table 4:The results show the specific gravity of the eight pits soil.

Samples No.	Specific Gravity(Sp.gr.)
M	2.66
D	2.59
T	2.67
B	2.54
AL	2.43
SH	2.60
K	2.49
S	2.60

2. Chemical Tests

The chemical examination method has been divided into studied samples at the rate of one sample for every two meters, equivalent to two samples per hole, one sample at a depth of two meters and the other at a depth of 4 meters, The results of the samples at a depth of 2 and 4 meters are shown in Table (5).

Silicate Oxide (SiO2)

In considering the percentage of silicon oxide, the ratios in the samples at a depth of (2 meters) ranged between (42.09-56.86)% and at a rate of (52.88)%, while the ratios of the samples at a depth of (4 meters) were close to the previous ones, as they ranged between (48.95-56.52)% At the rate of (52.52)%.

- **Calcium Oxide (CaO)**

In considering the percentage of calcium oxide, the ratios in the samples at a depth of (2 meters) ranged between (11.37-14.92)% at a rate of (12.54)%, and the ratios for the samples at a depth of 4 meters were also close to where they were between (9.86-14.35)% and at an average rate (12.38)%.

- **Magnesium Oxide (MgO)**

In considering the percentage of magnesium oxide, the ratios in the samples at a depth of (2 meters) ranged between (3.27-3.93)% and at a rate of (3.68)%, while the ratios for the samples at a depth of 4 meters ranged between (3.10-3.65)% and a rate of (3.47) %.

- **Iron Oxide (Fe_2O_3)**

In considering the iron oxide ratio, the ratios in the samples at a depth of (2 meters) ranged between (4.08-6.96)% at a rate of (5.92)%, while the ratios for the samples at a depth of (4 meters) ranged between (4.76-6.90)% and at a rate of (6.04) %.

- **Aluminum Oxide (Al_2O_3)**

In considering the percentage of aluminum oxide, the proportions in the samples at a depth of (2 meters) ranged between (2.51-3.90)% at a rate of (3.29)%, while the ratios for the samples at a depth of (4 meters) ranged between (2.06-4.00)% and at a rate of (3.34) %.

- **Organic Matter (O.M.)**

In considering the percentage of organic matter, the ratios in the samples at a depth of (2 meters) ranged between (0.11-0.56)% and at a rate of (0.32)%, while the ratios for the samples at a depth of (4 meters) ranged between (0.18-0.78)% and at a rate

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of (0.41) %. Oxidation of organic matter results in sulfuric acid, thereby reducing soil resistance [15].

- **Total Dissolved Salts (TSS)**

In considering the percentage of total dissolved salts, the ratios in the samples at a depth of (2 meters) ranged between (0.55-5.86)% and at a rate of (2.17)%, while the ratios of the samples at a depth of (4 meters) ranged between (0.73-2.52)% and the rate of (1.47)%.
Immersion of saline soil, runoff of surface water in it, or penetration of groundwater and its movement between the soil layers causes the gypsum to dissolve and the salts present in the soil between the layers, which causes damage to the foundations of the engineering establishment [16].

- **Chlorides (Cl^-)**

In considering the percentage of chlorides, the ratios in the samples at a depth of (2 meters) ranged between (0.06-0.85)% at a rate of (0.38)%, while the ratios for the samples at a depth of 4 meters ranged between (0.04-0.74)% and at a rate of (0.22)%, the danger of an increase in his rate lies in his interaction with the armature of engineering installations Where it should not exceed 10 percent [9].

- **Sulfur Trioxide (SO_3)**

In considering the percentage of sulfur trioxide, the ratios in the samples at a depth of (2 meters) ranged between (0.15-3.13)% and at a rate of (1.15)%, while the ratios for the samples at a depth of 4 meters ranged between (0.22-1.83)% and a rate of (0.76) %.

- **Gypsum**

In considering the proportion of gypsum, the proportions in the samples at a depth of (2 meters) ranged between (0.32-6.73)% and at a rate of (2.47)%, while the ratios for the samples at a depth of (4 meters) ranged between (0.47-3.93)% and at a rate of (1.63) %.
Water acts as a catalyst for the reaction of gypsum with tri-calcium aluminates, and it creates a chemical compound called tri-calcium aluminate, causing stresses generated in the concrete to break it down [11].

Table 5:Shows the results of chemical tests for study samples at a depth of 2 and 4 meters.

Depth of Sample 2 meters									
No.	SiO2%	CaO%	MgO%	Fe2O3%	Al2O3%	O.M%	TSS%	Cl-%	SO3%
M	56.07	12.01	3.93	6.08	3.22	0.289	0.551	0.153	0.15
D	54.35	11.65	3.81	5.92	2.93	0.108	1.920	0.848	0.47
T	54.78	11.37	3.68	6.24	3.90	0.541	3.273	0.142	2.98
B	52.67	11.74	3.73	6.72	3.71	0.559	1.048	0.060	0.65
AL	51.61	13.93	3.88	5.39	3.60	0.325	1.522	0.816	0.39
SH	42.09	14.92	3.33	4.08	3.11	0.325	5.856	0.440	3.13
K	54.63	12.66	3.27	6.96	3.30	0.253	1.288	0.227	0.58
S	56.86	12.00	3.80	6.00	2.51	0.162	1.917	0.333	0.84
Ave.	52.88	12.54	3.68	5.92	3.29	0.32	2.17	0.38	1.15
Min	42.09	11.37	3.27	4.08	2.51	0.11	0.55	0.06	0.15
Max	56.86	14.92	3.93	6.96	3.90	0.56	5.86	0.85	3.13
Depth of Sample 4 meters									
No.	SiO2%	CaO%	MgO%	Fe2O3%	Al2O3%	O.M%	TSS%	Cl-%	SO3%
M	53.43	11.83	3.46	6.51	2.66	0.343	0.766	0.156	0.36
D	52.71	11.68	3.58	6.13	3.00	0.776	1.700	0.738	0.52
T	53.20	12.18	3.33	6.30	4.00	0.397	1.811	0.057	1.31
B	48.95	13.69	3.42	6.20	3.80	0.433	0.837	0.043	0.30
AL	49.78	13.59	3.62	5.20	3.73	0.253	1.738	0.280	0.53
SH	49.32	14.35	3.60	4.76	3.20	0.180	2.521	0.280	1.83
K	56.27	9.86	3.10	6.30	3.70	0.433	0.731	0.078	0.22
S	56.52	11.87	3.65	6.90	2.60	0.433	1.631	0.121	0.98
Ave.	52.52	12.38	3.47	6.04	3.34	0.41	1.47	0.22	0.76

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Min	48.95	9.86	3.10	4.76	2.60	0.18	0.73	0.04	0.22
Max	56.52	14.35	3.65	6.90	4.00	0.78	2.52	0.74	1.83

O.M = Organic Matter ,G = Gypsum ,Cl^- = Chlorides.

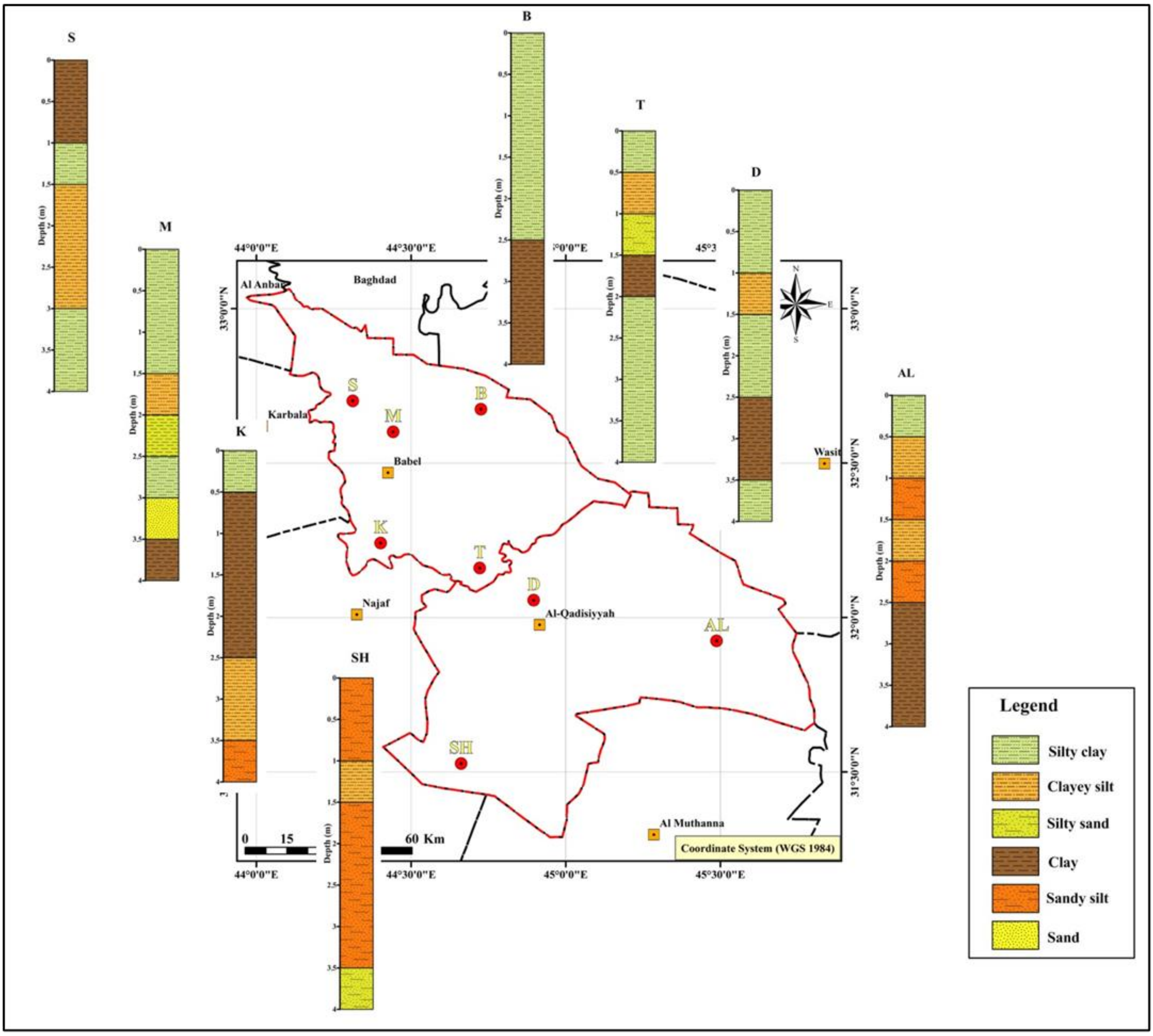

Fig 6:Shows the lithological description of the soil of the study area.

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Mineral Examinations

Mineral X-ray diffraction examination (XRD) of eight samples at a rate of one sample per hole showed the dominance of non-clay minerals quartz, calcite, and feldspar while the proportions of clay minerals such as montmorillonite were very few and illite and kaolinite, Fig (7).

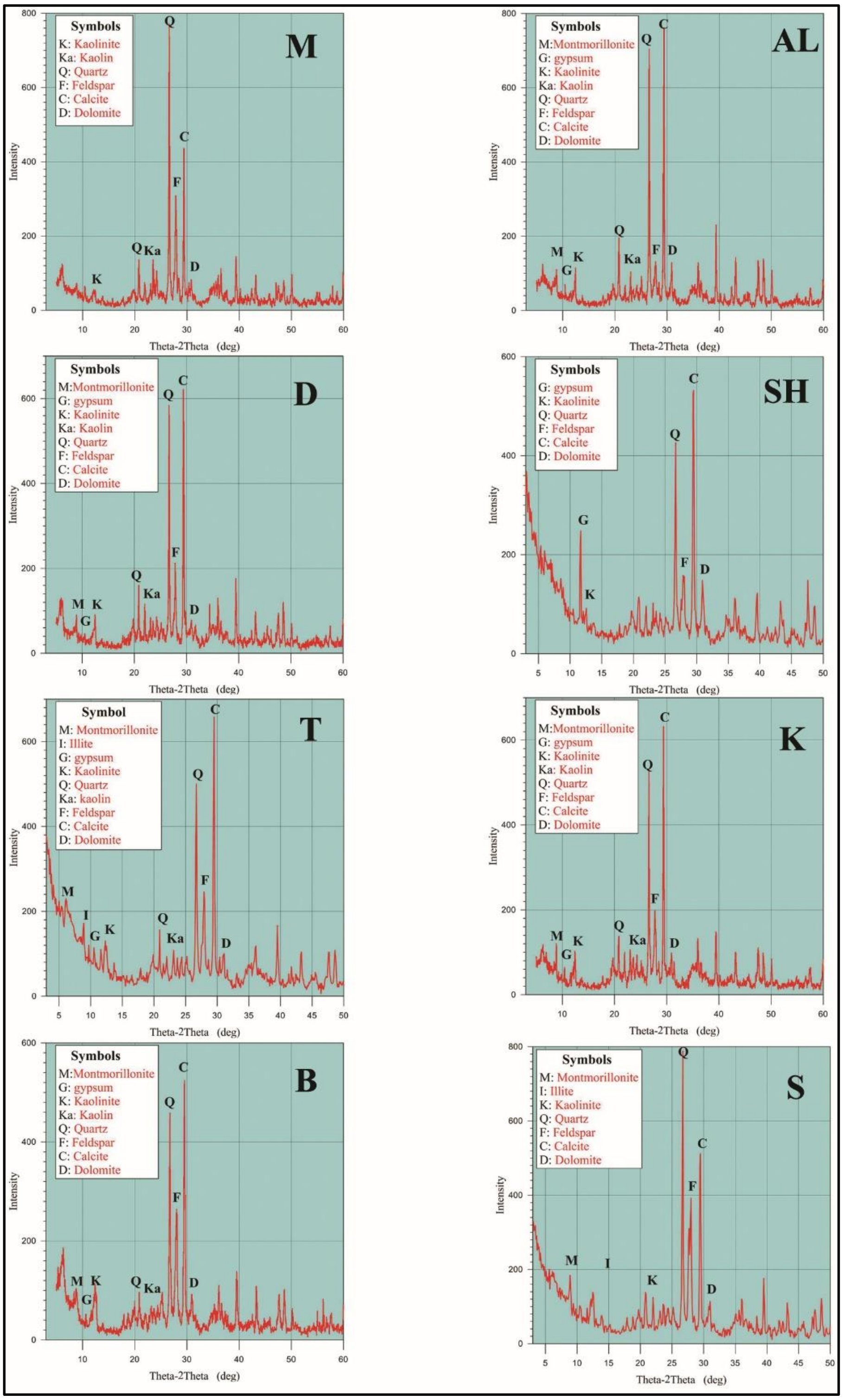

Fig 7: X-ray diffraction sketch (XRD) for study samples.

VII. Conclusions And Recommendations

1. Conclusions

- It was found through the results of the physical tests that the soil represented by the deposits of the quaternary age are Silty clay soils with a few ratios of sand and of plasticity (low to medium) free of gaps and non-influential quantities of gypsum and organic materials and it is suitable for this engineering construction or need simple treatments Especially since the groundwater level.
- The soil is volatile in terms of grain size distribution and volatile according to its physical properties accordingly.
- The ratios of SO3 are generally not effective and exist for some depths with influential content. Therefore, sulfate-resistant cement must be used in some locations where it is abundant to resist this type of soil salt.
- For soil with a higher percentage of clay, a higher strength appears when compressed at a certain moisture content, thus giving an ideal fixation to the engineering foundations. Activities include:

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