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Geotechnical Properties of Soil Slopes of the Great Musaiyab Project, Babylon, Middle of Iraq

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Abstract

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The research deals with the study of the geotechnical properties of the soil of the banks of the Great Musaiyab Project in the province of Babylon in central Iraq, as it includes the study of the physical, chemical, engineering, and mineral properties. The results of the physical tests showed that the grain size distribution of silt was higher than that of clay and sand at a rate of 36.91%, that of clay 30.9% and that of sand 31.06%, and the average of the maximum dry density values was 1.9125g/cm³. The average specific weight was 2.69, and the results of chemical tests showed that the percentage of carbonates (17.98%, percentage of gypsum 0.7075%, the percentage of sulfates 0.3282%, percentage of organic substances 2.7435%, and the percentage of total salts soluble 1.7193%. The results of the engineering tests indicated that the direct shear test showed that the cohesion value ranged between 0 and 50 KN/m², the internal friction angle ranged between 7 and 37, and the unconfined pressure resistance ratio ranged between 3 and 48 KN/m². While the results of the metal properties indicated using ray diffraction XRD, which showed the mineral content of the soil, as it consisted mainly of calcite, quartz, and feldspar, in addition to clay minerals.

Keywords: Great Al-Musaiyab; Soil slopes; Banks; Geotechnical; Mineralogy; Chemical properties

1. Introduction

The Great Musaiyab project is located in the north of Babylon Governorate between the Tigris and Euphrates rivers, 65 km south of the city of Baghdad, within the geographical coordinate's longitude 44°18'12"- 44°26'23" and latitude 32°47'14"- 32°48'50". Total area is 940 km² (Kaizal et al., 2022). The design drainage rate is 40 m³/sec, and is sufficient to irrigate an area of about 375,000 dunums (Fig. 1). There are many previous studies, such as Buringh (1960), who studied the soil of all of Iraq, including the study area and described the sediment of the river banks as silty loam. Al-Musawi (1989) studied geography and irrigation activities within the Babylon Governorate and analyzed soil samples taken from the banks of the irrigation canals. He found that the soil type is mainly silty loam, and there were differences in the nature and characteristics of the soil from place to place as well as in depth. Al-Ali (2016) studied the hydrogeochemistry of surface and groundwater and its effects on the soil of the Great Musaiyab Project. He showed that the soil in the study area is classified as sandy mud and mud.

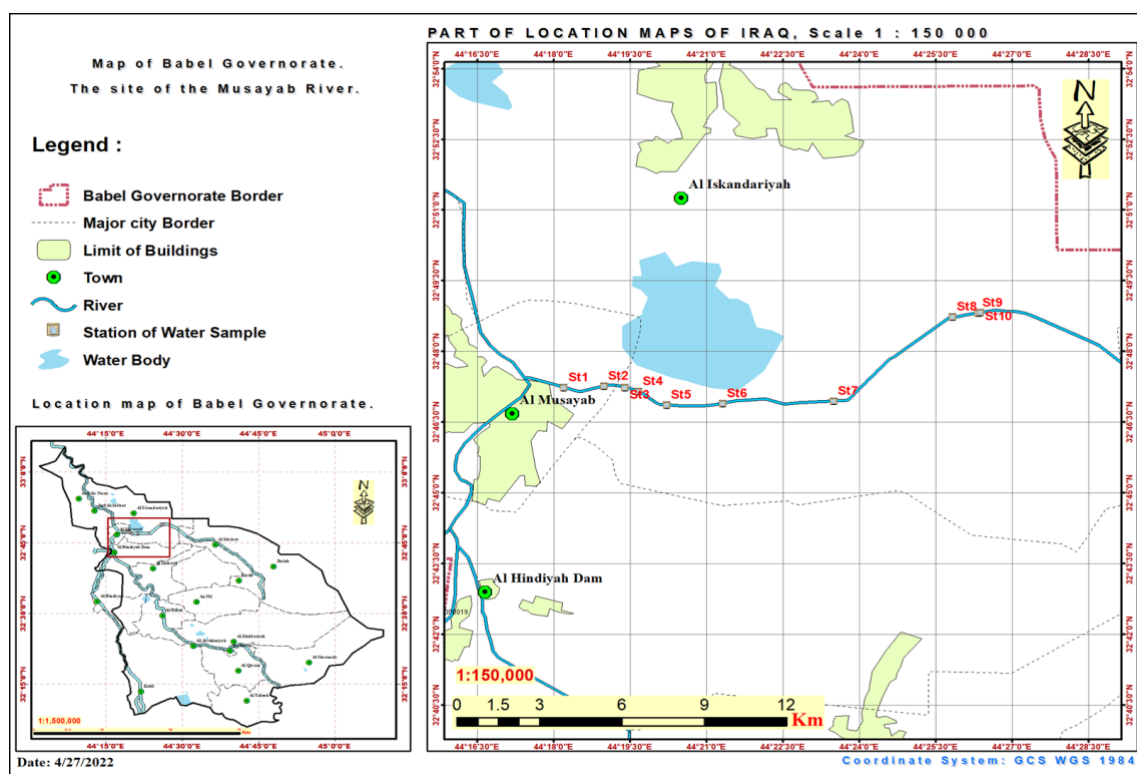


Fig. 1. A map of location of the study area and sampling sites.

The purpose of the study is to investigate the physical, chemical, engineering, and mineral properties of bank soil slopes and the mineral composition of the soil. In addition, the proposed remedial measures to protect the large banks of the Musaiyab project and its stability ensure the river's optimized investment in water quality and quantity.

2. Geology of the Study Area

Mesopotamian sediments cover the central part of syncline depression. Geologically, the study area mainly includes Quaternary sediments from the Pliocene to the Miocene (Khalaf and Issa, 2021). The province of Babylon within the study area is characterized by a gentle surface with a slope of approximately 22 cm/km. The general orientation of the slopes in the study area is from northwest to east and southeast parts (Al-Jubori, 2002).

The sediments of the study area mainly consist of the deposits of the Tigris and Euphrates rivers and their branches, in addition to the aeolian deposits (Mrzah et al., 2021). The rivers carry high rates of suspended sediment; 95% of these sediment deposits are in the southern floodplain, while 5% reach the Arabian Gulf (Buringh, 1960). The most important formations in the study area are the Euphrates Formation (Lower Miocene), Fatha Formation (Middle Miocene), Injana Formation (Upper Miocene), Dibdibba Formation (Pliocene-Pleistocene), and Quaternary Deposit (Al-Rubaiee and Al-Owaidi, 2022).

3. Materials and Methods

Ten soil samples were collected from the river banks along the study area and put it in storage bags to estimate their physical, chemical, engineering, and mineral properties; the sampling sites are shown in Table 1. After the fieldwork, the soil samples were transferred to the laboratories of the National Laboratory and Center for Structural Research (Babylon Division) and to the laboratories of the Earth Science Department in the College of Science, University of Babylon, to conduct the

following tests: the physical tests include grain size analysis, density, Atterberg limits, and specific gravity. The engineering tests include uniaxial compressive strength and direct shear tests. The chemical tests of the soil samples at these sites include SO_3 , gypsum, carbonates (CaCO_3), organic matter, and total dissolved salts (TSS), and mineralogical tests to identify the mineral components of soil.

Table. 1 The coordinates of the water and sampling sites

Number of samples	Longitude E	Latitude N
St1	44° 18' 12"	32° 47' 14"
St2	44° 18' 59"	32° 47' 16"
St3	44° 19' 24 "	32° 47' 14"
St4	44° 19' 40"	32° 47' 09"
St5	44° 20' 13"	32° 46' 52"
St6	44° 21' 19"	32° 46' 54"
St7	44° 23' 30"	32° 46' 57"
St8	44° 25' 50"	32° 48' 44"
St9	44° 26' 20"	32° 48' 49"
St10	44° 26' 23"	32° 48' 50"

3.1. Physical tests of soil

3.1.1. Grain size distribution

The samples are tested according to the standard ASTM-D422-63, 2014. To find the grain gradient distribution curves using the sieve analysis method and to determine the percentage of fine granules through the method of wet analysis (hydrometer).

3.1.2. Atterberg Limits

The limits of Atterberg of the soil of the study area were examined according to the standard ASTM D 4318-2017, where the limit of fluidity was known by taking a sample of the transient dry soil from the sieve No. 40 and treating it with water to be homogeneous, and placing it in the Casagrande device (Lambe, 1951). The plasticity index was calculated using the following equation:

$$PI = LL - PL \quad (1)$$

3.1.3. Maximum dry density

The purpose of the maximum dry density is to determine the maximum dry density and optimal moisture content of the soil (Al-Zubaidi, 2006); the test was done according to ASTM D 698-2012.

3.1.4. specific Gravity

The specific gravity of soil is the ratio of the weight of a specific volume of material to the weight of an equal volume of distilled water (Boweles, 1984; Sivakugan, 2021). The test was carried out according to ASTM D 845-2010.

3.2. Engineering Tests of Soil

3.2.1. Direct shear test

The direct shear strength of soil samples was measured according to ASTM D 3080-98, 2000. In this test, the following soil properties (cohesion and internal friction angle) were calculated.

3.2.2. Uniaxial compressive strength

The uniaxial compressive strength is a special case of the triaxial test, which measures resistance when the cell pressure is equal to zero (Al-Adili, 1998). The uniaxial compressive strength of soil models was measured according to the American standard ASTM D2166-00, 2003.

3.3. Chemical Analyses of Soil

The chemical analyses were carried out for soil samples taken from the study area to know the chemical properties of the soil according to British Standard (BS1377-2).

3.4. Mineralogical Study of Soil

Mineral analysis of soil samples was carried out for three samples (station 1, station 5, and station 9). X-ray diffraction (XRD) analysis was performed on the samples after sieving them in sieve No. 200 with an amount of 2g for each sample. This XRD examination was conducted at Babylon University, College of Materials Engineering.

4. Results and Discussion

The maximum value of dry density was recorded 1.974 g/cm³ at station 6, and the lowest value of 1.868 g/cm³ at station 7 (Table 2).

Table 2. The result of some physical test of soil in the Musaiyab water project.

St. No.	Pericles size distribution & hydrometer analysis			Index properties			Sym USCS	S. G.	Density g/cm ³
	Clay%	Silt%	Sand%	LL %	PL %	PI%			
1	45.2	35.1	19.7	31	19	12	CL	2.74	1.92
2	17.1	31.3	51.6	25.5	18.2	7.3	SP	2.66	1.896
3	43.3	38.4	18.3	30.1	19.5	10.6	CL	2.73	1.89
4	28.1	54	18.1	23.4	18.4	5	CL&ML	2.69	1.873
5	38.2	35.7	26.1	25.4	19.1	6.3	CL&ML	2.71	1.985
6	28.1	46.1	25.8	25.5	19.5	6	CL&ML	2.69	1.974
7	41.1	24.7	34.2	29.2	18.4	10.8	CL	2.74	1.868
8	13.7	36.3	49.7	23.4	18	5.4	SP	2.65	1.912
9	42.2	39.9	16.4	30	19	11	CL	2.73	1.888
10	22	27.3	50.7	26.6	19.7	6.9	SP	2.65	1.919
Min.	13.7	24.7	16.4	23.4	18	5		2.65	1.868
Max.	45.2	54	51.6	31	19.7	12		2.74	1.985
Average	29.9	36.88	31.06	27.01	17.06	8.1		2.69	1.912

The highest specific weight value was 2.74 at locations 1 and 7, and the lowest value was 2.65 at stations 8 and 10. Through a direct shear experiment, the highest value of cohesion was 50 KN/m² at station 9, and the lowest value was 0.0 at station 8, where the value of cohesion, increased with the increase of the percentage of the clay. The internal friction angle recorded the highest value of 37 at

station 8 and the lowest value of 8 at station 1. The angle value decreased with an increasing plasticity index. According to the USCS, the soil is classified as low plasticity clay (CL) soils in the following stations: 1, 3, 7, and 9; silty alluvial soils with little plasticity (CL-ML) in stations 4, 5, and 6, and sandy soils of poor grading (SP) at stations 2, 8, and 10 (Figs. 2, 3, and 4).

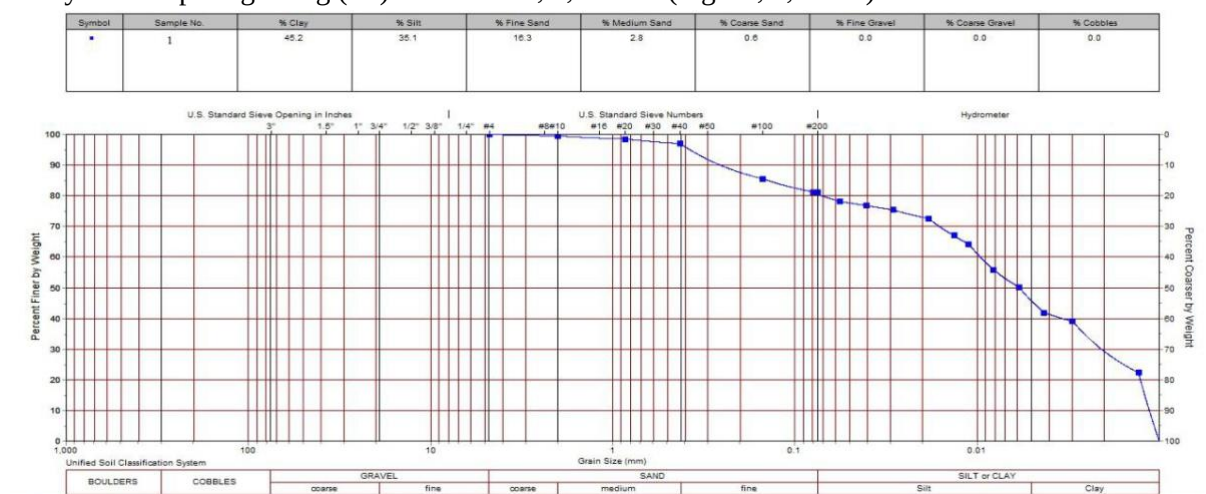


Fig. 2. The results of grain size analysis in station (1)

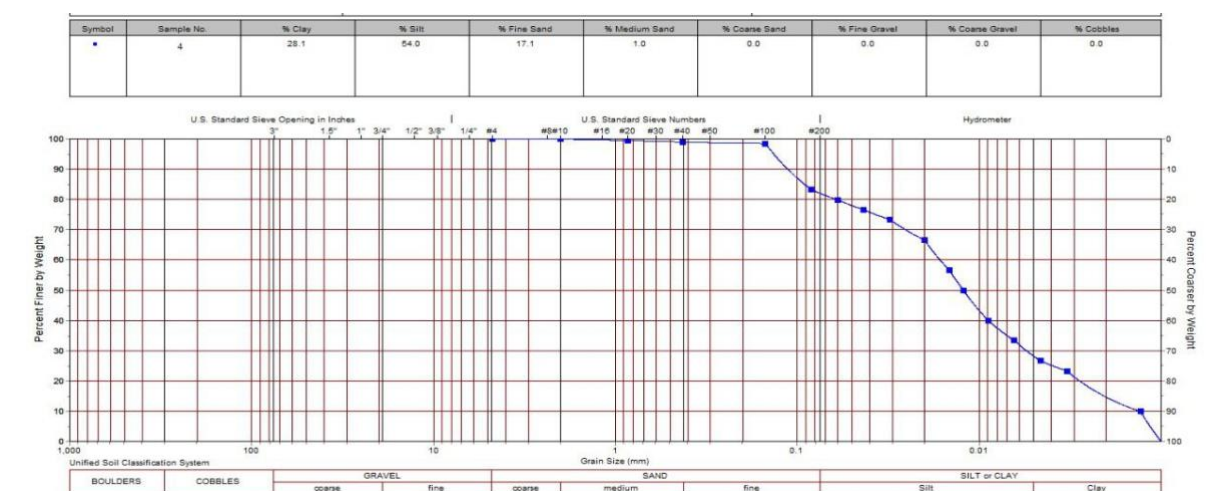


Fig. 3. The results of grain size analysis in station (4)

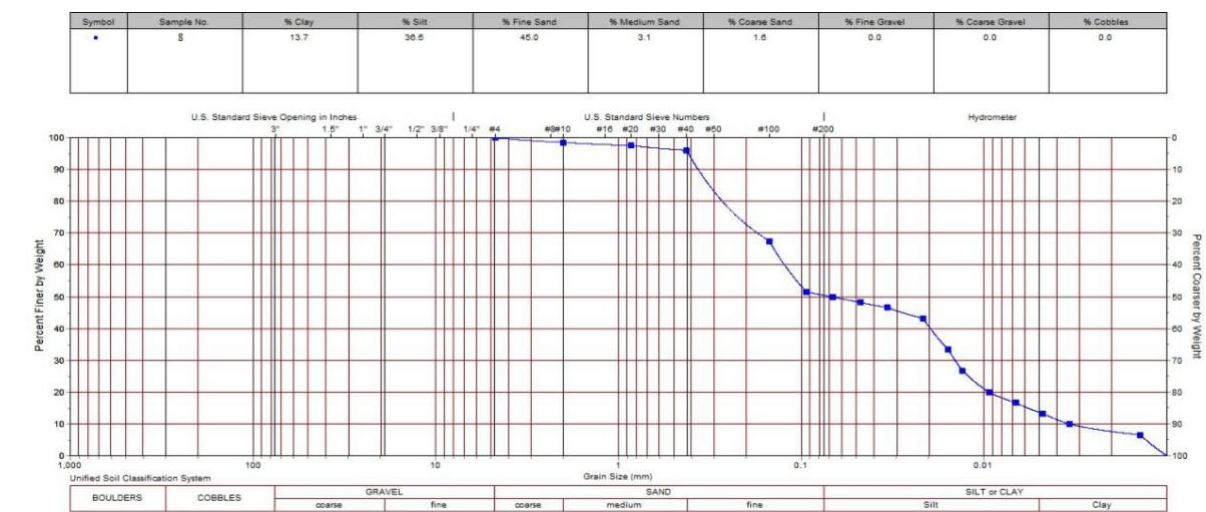


Fig. 4. The results of grain size analysis in station (8)

By analyzing the grain size distribution, the proportion of silt was higher than that of clay and sand at a rate of 36.91%, that of clay 30.9% and that of sand 31.06%. Through the USCS system, it was found that the soft soils are mostly clay with low plasticity (CL) and silty clay with little plasticity (CL-ML). The coarse soil was sandy, with poor gradation SP (Table 3).

Table 3. Compression and shear strength values and soil type

ST. No.	Type of sample	Type of Sample	Uniaxial compressive strength (KN/m ²)	Shear strength parameters	
				θ	C(KN/m ²)
1	Disturbed (Remolded)	CL	27	8	25
2		SP	6	27.5	5
3		CL	3	27.5	5
4		CL&ML	30	30	20
5		CL&ML	11	26	3
6		CL&ML	27	17	30
7		CL	9	27.5	5
8		SP	16	37	0
9		CL	48	7	50
10		SP	19	20	5
Min.			3	7	0
Max.			48	37	50
Average			19.6	22.75	14.8

The liquidity limit values ranged between 23 and 31, at a rate of 27.01. Plasticity limit values ranged between 18.0 and 19.7 at a rate of 17.06, while the plasticity index ranged between 5 and 12 at a rate of 17.06. The average value of the maximum dry density was 1.9125 g/cm³ which falls within the ideal density values. Specific weight values ranged between 2.65 and 2.74, with an average of 2.69 (Table 3), as the difference in specific weight values was small due to soil formation in the same sedimentary area.

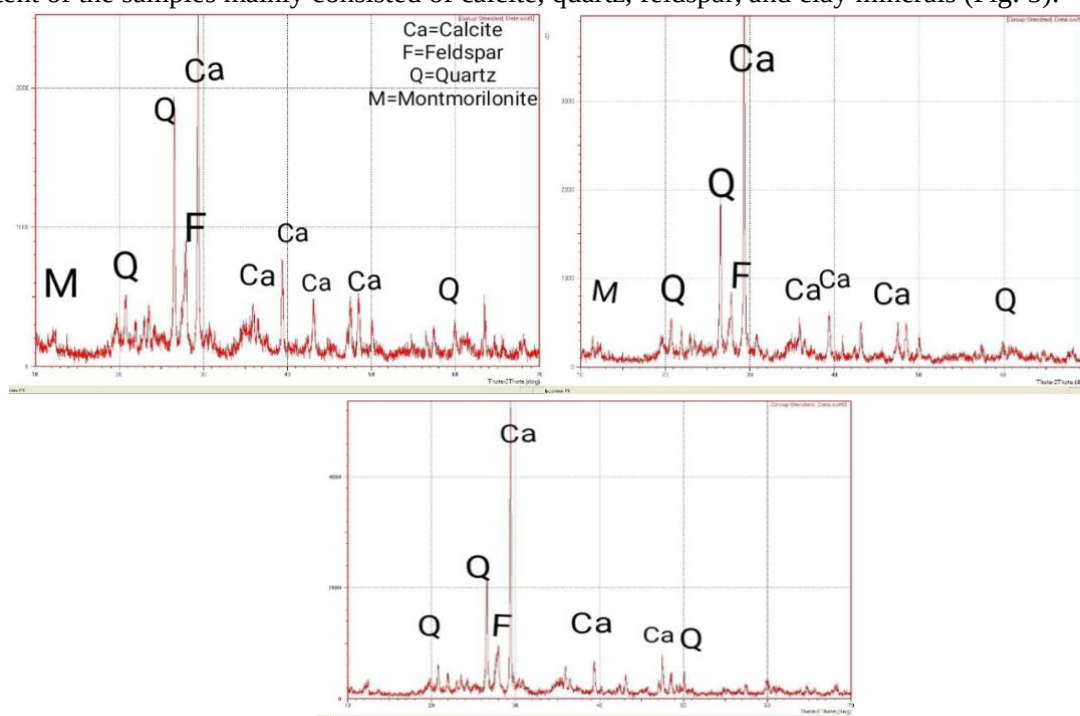
Through the direct shear examination, the cohesion value ratios ranged between 0 and 50 KN/m² (Table 3), as the high values are due to the high proportions of clay and silt. As for the internal friction angle, it ranged between 7 and 37, as it depends on the plasticity index, which decreases with increase in the plasticity index. The uniaxial pressure resistance ratio ranged between 3 and 48 KN/m² (Table 3).

The percentage of sulfate SO₃ ranged between 0.085 and 0.698%, with a rate of 0.3282 %. The carbonate ratio (CaCO₃) ranged between 8 and 35 %, with a rate of 17.98 %. The percentage of gypsum ranged between 0.184 and 1.5007%, with an average of 0.7075 %. The percentage of organic matter (OM) ranged between 1.407 and 3.869 %, with an average of 2.7435 %. The percentages of total dissolved salts (TSS) ranged between 0.295 and 3.90 %, with an average of 1.7193 %. The results of the chemical analyses are shown in Table 4.

Table 4. Results of the chemical properties of soil

Station	CaCO ₃	Gypsum	SO ₃	O.M.	TSS
1	8	1.345	0.625	1.407	2.475
2	19	0.789	0.367	3.869	1.865
3	10.8	1.500	0.698	2.814	3.243
4	16.6	0.320	0.149	2.462	0.679
5	19.4	0.523	0.243	3.517	0.936
6	9.4	0.855	0.397	2.462	2.132
7	12.2	0.305	0.142	3.517	0.873
8	26.4	0.538	0.250	2.814	0.814
9	23	0.715	0.332	2.814	3.9
10	35	0.184	0.085	1.758	0.295
Min.	8	0.184	0.085	1.407	0.295
Max.	35	1.5	0.698	3.869	3.9
Average	17.98	0.707	0.328	2.743	1.719

Using X-ray diffraction, it was found that the soil consists of the following minerals: calcite, quartz, and feldspar, in addition to clay minerals. The X-ray diffraction results showed that the mineral content of the samples mainly consisted of calcite, quartz, feldspar, and clay minerals (Fig. 5).

**Fig.5.** XRD Chart for the Musaiyib Project station 1, 5, and 9

5. Conclusions

- The results of the study showed that most of the soils are clayey with low plasticity (CL), silty clay with little plasticity (CL-ML), and sandy poor grade (SP), respectively.
- The soil contains low percentages of sulfate SO₃, ranging between 0.085 and 0.698%, and a low content of gypsum. It ranged between 0.184 and 1.5007%. The average percentage of carbonate (CaCO₃) ranged between 8 and 35%. The content of little organic matter ranged between 1.407 and 3.869%. The percentage of total soluble salts (TSS) ranged between 0.295 and 3.9%.

- The mineral content of the soil was mainly composed of calcite, quartz, feldspar and clay minerals.

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References

- Adili, A.S., 1998. Geotechnical Evaluation of soil and Treatment of Baghdad, Ph.D. Thesis, College of Science, University of Baghdad.
- Al-Jubori, 2002. The Geotectonic Evaluation for the Soil in Babylon Governorates, M.Sc. Thesis Collage of Science, University of Baghdad.
- Al-Ali, I.A., 2016. Hydrogeochemistry of surface and Ground water and Their Effects on the soil of the Greater Musaiyab Project - central Iraq. M.Sc. Thesis, Collage of Science, University of Baghdad.
- Al-Musawi, H.K.A., 1997. The nomadic stratification of Al-Araqib in the Iraqi alluvial plain, Al-Musayyab Al-Kabeer Project, Ph.D. Thesis, College of Agriculture, University of Baghdad, Iraq.
- Al-Rubaiee, A.H., Al-Owaidi, M.R.A., 2022. Assessment of heavy metal contamination in urban soils of selected areas in Hilla City, Babylon, Iraq. *Iraqi Journal of Science*, 63(4), 1627-1641.
- Al-Zubaydi, J.H.A., 2006. Geotechnical Study for Selected Soil Between Hilla And Kut Cites (Middle of Iraq). Ph.D. Thesis, Baghdad University, Iraq.
- ASTM D 2166, 2003. Standard test method for Unconfirmed Compressive Strength of Cohesive soil (D 2166-00), American Society for material (ASTM).
- ASTM D 3080-98, 2000. Designation: Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions. Annual Book of Standards, Vol. 04.08, Soil and Rock; Dimension Stone; Geosynthetics, American Society for Testing Material (ASTM).
- ASTM D-422-63, 2014. Standard Test Methods for Particle-size Analysis of Soils. Annual Book of ASTM Standards, ASTM international, West Conshohocken, PA.
- ASTM D4318-10, 2010. Standard test methods for liquid limit, plastic limit, and plasticity index of soils. American Society for Testing Materials, West Conshohocken, Pennsylvania, PA 19428, USA.
- ASTM D698, 2012. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (600KNm/m³, Reprinted from the Annual Book of ASTM Standards. Copyright ASTM, Vol.4, No.8.
- ASTM D854, 2010. Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer. Annual Book of ASTM Standards, Vol.04.08, Philadelphia, P&A, ASTM, USA. Copyright, ASTM International, 10&0 Barr Harbor Drive, PO Box C700, West Conshohocken.
- Bowles, J.E., 1984. Physical and Geotechnical Properties of soil, 2nd Ed., Mc Graw HILLM Japan Ltd.
- BS 1377 - 2 (British Standard Institution) 1990. Method of test for soils for civil engineering purposes" British Standard Institution, London, UK.
- Buringh, P., 1960. Soils and soil conditions of Iraq. Ministry of Agriculture Directorate, General of Agricultural Research and Projects, Baghdad.
- Kaizal, A.F., Salman, J.M., Kot, P., 2022. Evaluation of some heavy metals, their fate and transportation in water, sediment, and some biota within Al-Musayyib River, Babylon Governorate, Iraq. *Baghdad Science Journal*, 20(2), 436- 451.
- Khalaf, M.O., Issa, B.M.A., 2021. Study of the relationship between some physical properties of selected soils in Babylon, Central Iraq. *Iraqi Geological Journal*, 54 (2D), 155-164.
- Lambe, T.W., 1951. Soil Testing for Engineers. John-Wiley& Sons. New York.
- Mrzah, W.N., Mahmod, R.A., Lafta A.A., 2021. Geotechnical properties study of soil bank slopes for Shatt Al-Hilla, Middle of Iraq. *Iraqi Geological Journal*, 54 (2F), 97-109.
- Sivakugan, N., 2021. Soil Mechanics and Foundation Engineering: Fundamentals and Applications. McGraw Hill, USA.