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Assessment of Some Geotechnical Properties for Soils of Euphrates River Banks (Kufa- Mishkhab), Middle of Iraq

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Abstract

Twelve stations in the cities of Kufa and Mishkhab were selected for studying the geotechnical, including physical, engineering, chemical and mineralogical, properties of soils in the river banks along the Euphrates River. Grain size distribution of the bank soils showed higher silt than clay and sand percentages. Soil samples from the 12 stations were classified according to the USCS standards. Silt with low plasticity constituted 91% of the silt fraction, whereas that with high plasticity composed 9%. The saturated density values ranged between 1.75-2.073 g/cm^3 with an average of 1.953 g/cm^3, while the dry density values ranged between 1.307-1.740 g/cm^3 with an average of 1.553 g/cm^3. The values of the dry and saturated density are within the permissible limits. Direct shear test showed cohesion values (C) that ranged between 15-55 kN/m^2 with an average value of 34.8 kN/m^2. The values of the internal friction angle (Ø°) of the clay type of soil with low plasticity ranged between 8.5°-17° with an average of 9.91°. The Ø° values of the other soil types ranged between 9°-17° with an average of 25°. Therefore, clay with high plasticity had higher Ø° values than the permissible limits. The results of unconfined compression test showed a range of 22.802-58.587 kN/m^2 with an average of 38.173 kN/m^2, with water percentage of 30%. The mineralogical tests of the bank soil performed using XRD analysis showed that the analyzed soil samples are composed mainly of quartz, calcite, chlorite, palygorskite, and montmorillonites. The pH value ranged between 6.4-7.55 with an average of 7.10, indicating low basicity. Gypsum concentrations ranged between 0.049-12.75 % with an average of 3.99 %, while that for carbonate ranged between 5-45 % with an average of 26.16%. Sulphates concentration ranged between 0.23-5.93 % with an average of 1.85%. Several treatment measures are proposed to stabilize the soil of the studied area.

Keywords: Soil, Geotechnical Properties, Soil Treatment, Geotechnical Assessments.

تقييم بعض الخواص الجيوتكنيكية لترب ضفاف نهر الفرات (الكوفة – المشخاب)، وسط العراق

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قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصه

تم أختيار 12 محطة على طول نهر الفرات ضمن مقطع كوفة– مشخاب وذلك لدراسة الخصائص الجيوتكنيكية والتي تتضمن دراسية الخصائص الكيميائية والفيزيائية والهندسية والمعدنية لمنحدرات ضفاف نهر الفرات ضمن مقطع كوفة–مشخاب. وقد أشارت النتائج الى ان توزيع الحجم الحبيبي للغرين هي أعلى من نسبة

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الطين والرمل على طول ضفة النهر. وقد صنفت المحطات طبقاً للمواصفات القياسية (USCS) والتي تتكون من الغرين بنسبة لدونة قليلة والتي تمثل 91% من التربة و بمناطق أخرى بنسبة لدونة عالية تمثل 9% من التربة. وقد تراوح قيم الكثافة المشبعة ما بين (1.75–2.073)غم/سم^3 وبمعدل 1.553 غم/سم^3 ، بينما تتراوح قيم الكثافة الجافة ما بين (1.307–1.740) غم/سم^3 وبمعدل 1.553 غم/سم^3 . وقد أعتبرت نتائج الكثافة الجافة والمشبعة ضمن الحدود المثالية. ومن جانب اخر فقد أظهرت نتائج أختبار القص المباشران قيم نسبة التماسك (C) تتراوح ما بين (15–55) كيلوا نيوتن/م^2 وبمعدل (34.8) كيلوا نيوتن/م^2، بينما أشارت زاوية الأحتكاك الداخلية الى ان التربة من نوع طيني ذو لدونة واطئة وقد تراوحت مابين (8.5^0–17^0) وبمعدل 9.91^0 . بينما الترب الأخرى فقد كانت من نوع طيني ذو لدونة عالية تتراوح مابين (9^0–17^0) وبمعدل قيم (25^0) لذلك فأن الترب من النوع الطيني ذو اللدونة العالية يمتاز بزاوية احتكاك داخلية اعلى من القيم المثالية. فيما أوضحت نتائج اختبارات الضغط الغير محصور والذي تراوح مابين (22.802–58.587) كيلوا نيوتن/م^2 وبمعدل بلغ (38.173) كيلوا نيوتن/م^2. أشارت اختبار النتائج المعدنية على طرف النهر بأستخدام جهاز الأشعاع السيني والذي أوضح المحتوى المعدني للتربة والتي تتكون بصورة أساسية من معدن الكوارتز و الكالسايت والكلورايت والمونتموريلانيت. وكما أشارت نسبة الحامضية التي تتراوح (6.4–7.55) وبمعدل (7.10) والتي تحوي على درجة قاعدية قليلة في التربة، وقد بينت نسبة الجبس في التربة والتي تتروح مابين (0.049–12.75)% وبمعدل 3.99%. وكما بلغت نسبة تركيز الكاربوناتمابين (5–45)% وبمعدل 26.16%، وقد بلغت نسبة تراكيز الكبريتات مابين (0.23–5.93)% وبمعدل بلغ 1.85%.

Introduction

The shoulders of rivers consist of the accumulation of fine sediments of sand, silt, and mud on the bank and at the highest point of the natural flood plain level, which act on blocking the river channel and appear in the form of a steep wall [1]. River water is prevented from tyranny to the nearby plains and used in the construction of parks and some engineering installations such as bridges, dams, liquefaction pumping stations, and others. When the shoulders are stable and safe, this encourages the process of exploiting them. On the other hand, when they are unstable and threatening to collapse, this leads to limiting the process of that exploitation. In the area of the sedimentary plain, the shoulders of the Euphrates and its branches are distinguished by their relative height from the level of the neighboring plains. The magnitude of this height varies from one region to another depending on the amount of sediments that the river deposits in its course[2].

Location of the Study aria:

The study area is located within Al-Najaf Governorate, central part of Iraq, and it is part of the Mesopotamian plain. It represents a part of the Euphrates River and extends from Kufa Dam (north of Kufa city) to Al Mishkhab Dam (south of Mishkhab area). The study area is 6.37 km^2, located between the latitudes 32.1675-31.7931 N and longitudes 44.3532-44.5023 E, as shown in (Figure-1).

Aims of the Study

The present study was designed to investigate the physical, mechanical and chemical properties of the soil slopes of the banks and the mineral constituents of the soil. We also aimed at providing suggestions related to remedial measures to protect the river banks and their stability and ensure the optimum investments of the water resources of the river, both qualitatively and quantitatively.

Methodology of Research Data collection stage of this research involved the collecting maps and references about the study area.

Fieldwork covered 12 stations selected to study the geotechnical properties, where soil samples from the bank of the river were collected and the laboratory analyses were carried out.

Laboratory work involved physical and chemical tests of soil samples using (XRD) analysis.

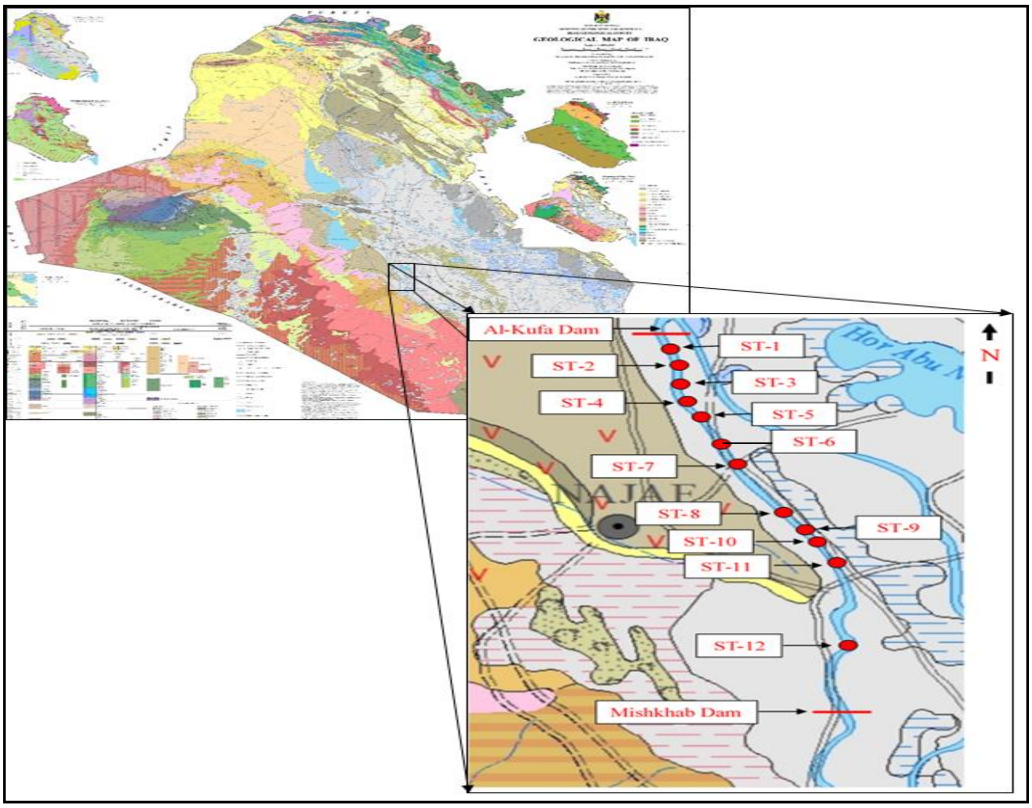

Figure 1- Map showing the location of the study area.

Geology of the Study Area

Euphrates River valley, which is a part of the Mesopotamian Basin in central Iraq, has been exposed to the modern reactivation processes of the subsurface geological structures or cutting structures through the river and its course in western, central, and southern parts of Iraq. The natural factors are one of the most significant factors that are affecting the behavior of the Euphrates, which led to significant changes in its course. As a result of this activities, high areas of no more than a few centimeters per 100 years, which reached a number of meters after thousands of years. Also, remarkable changes occurred to the river watercourse and topography of the plains of low slopes [3]. These impacts occurred especially since the main river model was cut during its course in Al-Anbar Governorate within the desert plateau first, which then took its course towards the lowlands of Tharthar, Habbaniyah, and Razazah, through the calcareous and gypsums rocks. This area is slightly higher than the surface of the old Gulf; hence the influx of flooded sediments was raised on the surface of the Euphrates River itself [4]. Repeated flooding led to the creation of secondary river streams to the nearby lowlands between the Tigris and the Euphrates, which became agricultural areas, especially after the runoff of the river at the south of the city of Fallujah. Contrast in the areas where the river flows led to increase the height of the river bottom due to lack of slope and increased deposition due to lack of drainage. By continuing this process, the river course took another direction according to the new gradients; studies indicated that the Euphrates has been subjected to a number of changes and phases due to the impacts of sediment and mud during the ancient times.

The most important geological formations in the study area, ordered from youngest to the oldest, are as follows:

A. Quaternary Deposits (Holocene)

These sediments extend from the north of Ramadi, adjacent to the Euphrates River and its branches to Karmat Ali, in addition to a range to the west of Al-Hammar Marsh. These sediments consist of sand, gravel, and sand clayey deposits, as well as larger materials with more gravel and stones contouring the western side of the Mesopotamian Plain. Besides, it contains the deposits of bottom valleys of the western plateau and the valleys of the edge of the Jezira Area, east of the Euphrates River, consisted of sedimentary clay and limestone. The general direction of the Euphrates between Fallujah and Al-Hindiya Dam forms a convex which is directed towards Tigris River, while it forms a concave towards Tigris River between Al-Hindiya Dam and Al-Hammar Marsh. The Quaternary Deposits are characterized with little resistant to river erosion in the middle and lower parts of the Euphrates. The lower layers of the river's levees, opposing the current in the meander areas, are prone to collapses due to the river's outflow. The continuing deposition processes in the area lying between south of Nasiriyah have their effects on the formation of marshes, including Al-Hammar Marsh [5]. The thickness of these sediments ranges from 0.1 to 1.5m [6]. This is reflected in the quantities of water flow of the Euphrates, reflected by the exposure of discharge rates and water table to events of decrease and increase according to the climatic conditions and the multiple uses of river, water in this region. The deposits of the flood plain represent most of the deposits of the study area, which arose as a result of the repeated flooding of the rivers on the surrounding lands, followed by the deposition of the different sediments on these lands periodically and continuously during different historical stages. At the part of the study area represented by Al-Kufa River, the western and eastern extensions of these deposits are represented by the western plateau and the floodplain of the Tigris River flows, respectively. These sediments took different geomorphological forms, which arose according to their location from the river, such as the river levees, river canals, and river eruptions. The thickness of these deposits ranges from (12-15m) and consists of silty clay, which forms the bulk of the deposits of the flood plain, in addition to silt and sand [7]. The deposits of the slopes result from the flooding of the gravel and the detritus during its rapid flow on very steep surfaces [8].

B. Dibdibba Formation

The age of the formation is Late Pliocene - Early Pleistocene. It consists of a mixture of gravel and sand, but sandstone is predominant in its colors (white, pink and grey), as well as clay balls and silty claystone. The formation also contains a reservoir of groundwater where the depth varies and the levels rise in the rainy periods of the year. The effects of groundwater reach to the waters of Euphrates River, where the overall downslope of the area is west-easterly [9].

C. Injana Formation (Upper Miocene)

This formation is composed of various rock components, mostly red mudstone, grey siltstone, claystone, sands, and sandstone, varying in thickness due to erosion and sedimentation. The formation is also characterized by the action of physical weathering processes of saturation and drought in clay stone and granular deflation [10]. This contributes to the fragmentation of sediments and increases the change in the physical characteristics of the river water with the increase of deposited clays.

Geotechnical Tests of the Study Area

A. Physical Properties of Soil

In the bank soils of the Euphrates throughout Kufa and Mishkab, the silt percentage is higher than those of the clay and sand. The maximum value of silt percentage (60%) is found in stations No.3 and No.5, whereas the minimum value (13%) is found in station No.12. The average silt percentage is 45.50%. The maximum value of clay percentage (56%) is found in station No.9, whereas the minimum value is 5% in station No.10. The average clay percentage is 39.16%. The maximum value of sand percentage is 73% in station No.10, whereas the minimum value is 3% in stations No.9. The average sand percentage is 15.33%, as shown in Table-1.

In the study area of soil bank slopes, the maximum value of liquid Limit (LL) percentage is 53% in station No.12, whereas the minimum value (0%) is in station (No.10) and the average value is 38.66%, (Table-1). One soil sample has an LL value greater than 50% (stations No.12), while soils in the other 11 stations have values less than 50%. Soils with a high plasticity index (PI) values tend to be clay, while those with lower values tend to be silt, and those with a value of 0 (non-plastic) tend to have low or no content of silt or clay (10). The bank soils in the Euphrates river along Kufa and Mishkab are classified, depending on the Unified Soil Classification System (USCS), as having low plasticity (if LL>50) or high plasticity (if LL<50). The stations along the Euphrates river between Kufa and Mishkab showed either low plasticity (CL) (stations 1,2,3,4,5,6,7,8,9,10, and 11)or high plasticity (CH) (station 12), as shown in Figure-2.

The moisture content of soil samples is demonstrated in Table-1. The values are ranging from a maximum of 40.21% in station No.8 and a minimum of 17.8% in station No.10, with an average of 27.27%. When the moisture content of clayey soil increases, it causes swelling of the soil at the bank and causes its failure. The values of saturated density of soil samples are listed in Table-1. The values range from a maximum of 2.073 g/cm^3 in station No.10 to a minimum of 1.75 g/cm^3 in station No.12, while the average is 1.953 g/cm^3. The values of dry density range from a maximum of 1.740 g/cm^3 in station No.10 to a minimum of 1.307 g/cm^3 in station No.12, with an average of 1.553 g/cm^3.

Table 1- The results of physical tests of the bank soil of Euphrates river along Kufa-Mishkab sector.

ST. NO.	Particles size distribution & Hydrometer analysis			Index Properties			System USCS	S. G.	Unit Weight g/cm^3	
	Clay %	Silt %	Sand %	LL %	PI%	M.C %			Wet	Dry
1	28	59	13	34	Non plastic	24.7	ML	2.69	1.939	1.554
2	29	58	13	32	Non plastic	24	ML	2.7	1.900	1.535
3	30	60	10	36	15	24.5	CL	2.71	1.98	1.582
4	31	59	10	38	16	24.5	CL	2.70	2.011	1.602
5	32	60	08	40	16	24.85	CL	2.73	2.029	1.625
6	52	43	05	44	22	38	CL	2.74	1.98	1.54
7	54	42	04	46	23	40	CL	2.73	1.964	1.521
8	50	45	05	45	21	40.21	CL	2.72	1.99	1.62
9	56	41	03	48	21	39	CL	2.71	1.94	1.581
10	05	22	73	Non	Non	17.8	SM	2.66	2.073	1.740
11	49	44	07	48	22	31.9	CL	2.73	1.888	1.431
12	54	13	33	53	23	33.78	CH	2.73	1.75	1.307
Av	**39.16**	**45.50**	**15.33**	**38.66**	**14.91**	**27.27**		**2.71**	**1.953**	**1.553**

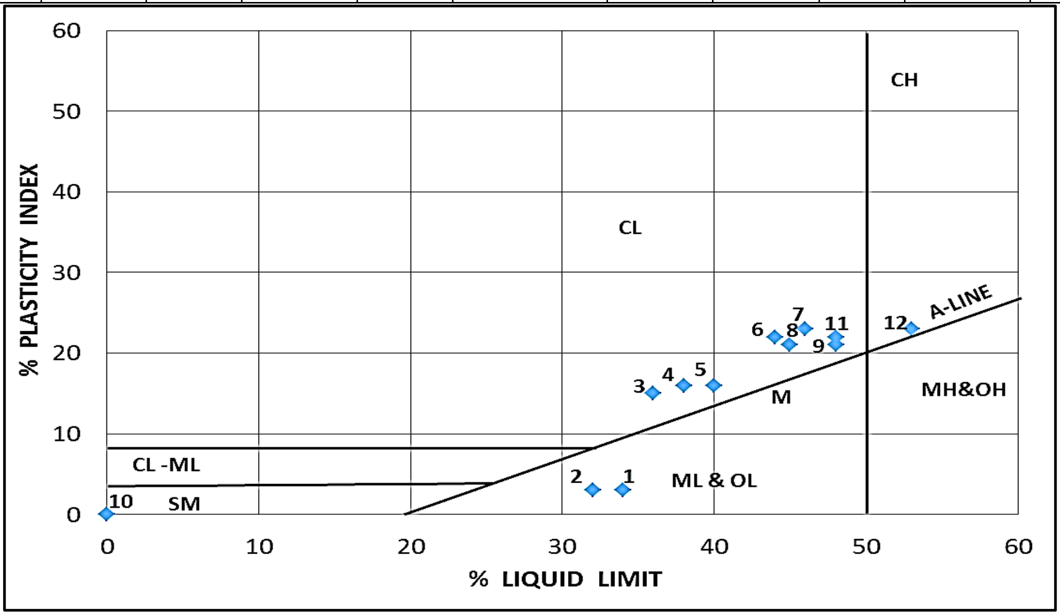

Figure 2- The (USCS) plasticity chart and the soil classification along banks of Euphrates River in the study area.

B. Engineering Properties of Soil

1. Shear Strength

The shear strength for the undisturbed samples relatively decreased because of the remolding process. This phenomenon is called sensitivity, which is the ratio between the shear of the undisturbed soil to that of the disturbed soil.

The direct shear results of soil in the bank slopes are shown in Table-2. The Ø° values range from a maximum of 17° in station No.10 to a minimum value of 6° in station No.11, with an average of

9.91°. Cohesion (C) values range from a maximum value is 55 kN/m^2 in station No.7 to a minimum of 15 kN/m^2 in station No.10, with an average of 34.8 kN/m^2.

Some stations have high values of C because of the high amount of clay and silt. The values of shear strength for the stations are shown in Table-2.

2. Unconfined Compression of The Soil (U.C.)

The value of the unconfined compressive strength (q_u), sometimes called the ultimate bearing capacity, can be extracted by examining the unconfined compressibility [11]. This test is a special case of triaxial test, where σ2 is equal to σ3 and is equal to zero [12]. Since the soil examined in this way is not surrounded by lateral pressure, this test is valid only for the cohesive soils [13].

Te uniaxial compressive strength for in Euphrates ranges from a maximum value of 58.587 kN/m^2 in station No.11 to a minimum value of 22.802 in station No.10, while the average is 38.173 kN/m^2. The compressibility test classified the soil as having very soft to medium consistency, as shown in Table-3.

Table2- Compression and shear strength values and soil type for some stations along Euphrates River banks in the study area.

St. No.	Type of Sample	Type of soil	Uniaxial compressive Strength (kN/m^2)	Shear strength parameters	
				C (kN/m^2)	Ø°
1	Disturbed (Remoulded)	ML	28.5	11	25
5	Disturbed (Remoulded)	CL	29.42	8.5	40
7	Disturbed (Remoulded)	CL	51.135	8	55
10	Disturbed (Remoulded)	SM	22.802	17	15
11	Disturbed (Remoulded)	CL	58.587	6	49
12	Disturbed (Remoulded)	CH	38.599	9	25

Table-3 Descriptive terminology of clayey soils consistency vs. numerical value of compressionstrength in the units of kN/m^2 [14].

Unconfined compressive strength kN/m^2	Consistency
Less than 25	Very soft
25-50	Soft
50-100	Medium
100-200	Stiff
200-400	Very stiff
Over 400	Hard

C. Chemical Properties of Soil

1. Calcium carbonate ($CaCO_3$ %): The percentage of calcium carbonate content in the soil was also studied, since it is known to have impacts on soil strength and resistance if it is present in large proportions. This occurs due to its solubility in water and acid which may result in soil gaps, the size and distribution of which depend on $CaCO_3$ percentage in the soil. A percentage of 30% and higher of CaCO3 is hazardous and may lead to serious engineering problems, such as sinkholes or soil weakness [15]. The values of $CaCO_3$, shown in Table-4, range from a maximum of 45% in station No.10 to a minimum of 5% in stations No.12, while the average is 26.16%.

2. Gypsum ($CaSO_4.2H_2O$) (Gyp. %): Gypsum is composed of hydrous calcium carbonate (CaSO4.2H2O), a white substance that is very soluble in groundwater if it is present in the soil. Gypsum is one of the most affected substances in the process of leaching that is the process of washing soluble salts and minerals and then separating them from soil [16]. The presence of gypsum reduces optimum dry density, increases moisture content, and reduces soil strength. Values of gypsum content in soil samples are listed in Tables-4. The values range from a maximum of 12.75% in station No.10 to a minimum of 0.049% in station No.5, with an average of 3.99%.

Table-4 The values of chemical contents of soil bank slopes of Euphrates river.

St.	$Caco_3$%	Gyp. %	SO_3%	T.S.S	pH
1	25	0.88	0.411	2.74	7.27
5	31	0.49	0.23	0.88	7.32
7	29	0.75	0.35	1.71	6.57
10	45	12.75	5.93	13.2	6.4
11	22	7.35	3.42	7.61	7.55
12	5	1.74	0.81	2.1	7.49
Av.	**26.16**	**3.99**	**1.85**	**4.70**	**7.10**

3. Sulphate (SO_3 %): The sources of sulfates in soil are Na_2So_4, Mg_2So_4, and Ca_2So_4. The sources of this compound in natural water are numerous, such as human activities, construction works, and fertilizers or pesticides used in agricultural activities [17]. Values of sulfates in soil samples, shown in Table-4, range from a maximum value of 5.93% in station No.10 to a minimum of 0.23% in stations No.5, with an average of 1.85%.

4. Total Soluble Salts (TSS%): This parameter reflects the weight ratio of water-soluble salts to soil. The solubility of salts varies by nature. Chloride salts are generally easier to dissolve than carbonates and sulphates. Dissolution is affected by temperature, pH value, and dissolved CO2. TSS is considered as high if the value is higher than 0.5%. TSS values of the studied soil samples, shown in Table -4, range from a maximum of 13.2% in station No.10 to a minimum of 0.88% in station No.5, with an average of 4.70%.

5. pH: The pH values of the soil samples, shown in Table -4, range from a maximum value of 7.55 in station No.11 to a minimum of 6.4 in station No.10, with an average of 7.10. Therefore, The soil in the study area is generally of low alkalinity.

D. Mineralogical Study of Soil

The results of X-Ray diffraction of two selected samples, form stations 2 and 12, were obtained using XRD analysis device in the Department of Geology, College of Science, University of Baghdad. The samples showed a mineral content that is composed mainly of quartz, calcite, chlorite, palygorskite, and montmorillonites, as shown in Figures-(3 and 4).

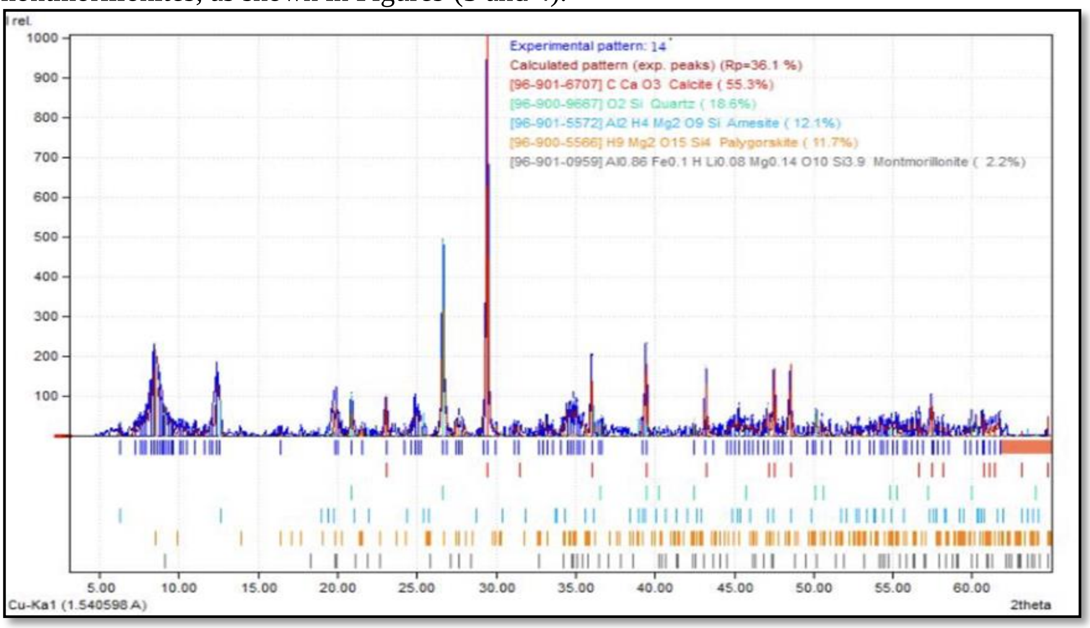

Figure 3-XRD chart of Euphrates river bank soil samples of Kufa-Mishkab sector (ST. 2).

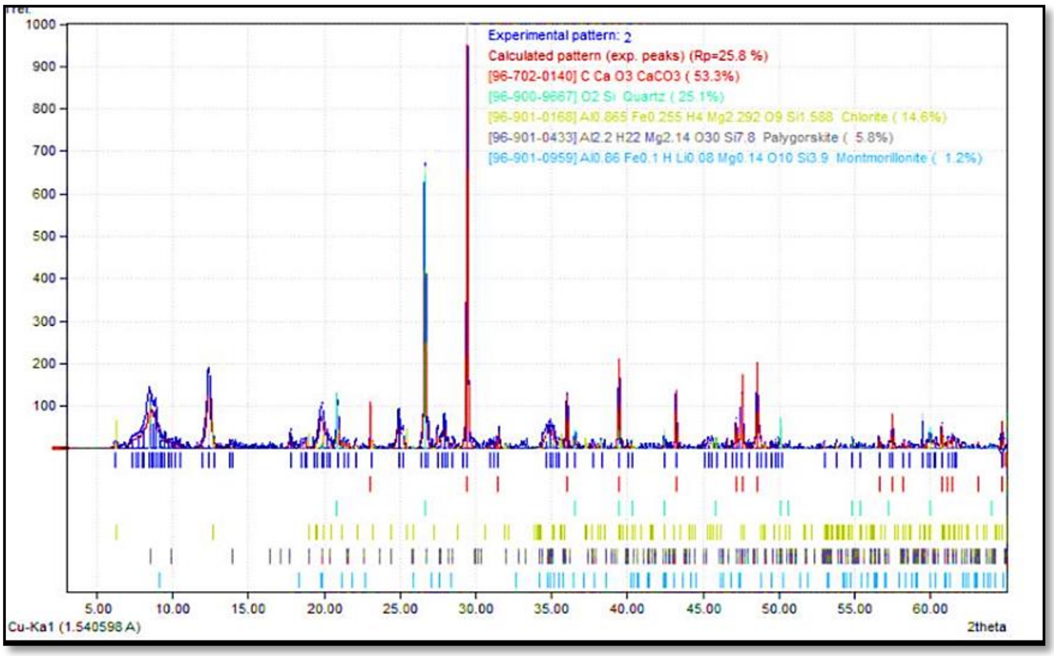

Figure 4 XRD chart of Euphrates river bank soil of Kufa-Mishkab sector (ST. 12).

3. Soil Slopes Stabilization

The following table presents the most important methods proposed for stabilizing soil slopes of the river banks of the study area and the reasons for their use.

Table 5- The methods of slope stabilization for installation techniques.

Stabilization Technique	Location	Explanations for Use
Stabilization by Calcium Oxide (CaO)	At Stations 6, 7, 8, 9, 11 and 12	Used for high plasticity clay soils, when adding calcium hydroxide to the soil increases calcium ions (Ca^{++}) in the double ionic layer surrounding the clay particles, which leads to charge the ions around them, thus reducing water absorption, i.e., decreasing its substrate.
Stabilization by Cement	At Stations 1, 2, 3 and 4	Used for stabilizing clay and sandy soils by adding a limited percentage of cement with water and leaving it for a certain period.
Stabilization by Tar	At station 10.	Used to stabilize the sandy soil, because tar connects soil minutes together due to the availability of bonding strength.
Stabilization by Arming the Soil	All stations	Reinforcement of the soil is one of the latest methods of stabilization and is very expensive so it is excluded.
Stabilization by Rock Masses	All stations	A very practical method used to cover the slopes of banks that contain large corrosion and is of the specifications resist the movement of water and waves.
Stabilization by Vegetation	All stations	Plant cover is a support factor for the soil as it protects it from collapse and erosion, which gives it long-term stability. It is one of the cheapest methods of stabilization.

Conclusions

1. Distribution of grain size of the bank soil of the Euphrates River section (Kufa-Mishkhab) shows that the percentage of silt is higher than those of clay and sand.

2. According to the USCS classification system, the soil consists mainly of low-plasticity silty sandstone, followed by low-plasticity sandy clayey silt and high-plasticity clay soil.

3. Specific weight values vary between 2.66 and 2.74, with an average of 2.71. The difference in the specific weight values is relatively small because the soil is formed in the same sedimentary area.

These values are based on the specific weight values of material constituents that form the soil and the mineral components of the granules.

4. Moisture content values vary between 0-53% with an average of 38.66%. The higher the moisture content in the clay soil, the more the swelling that affects the soil of the slopes of the bank, causing soil failure.

5. The values of the saturated density vary between 1.88 g/cm^3 and 2.07 g/cm^3 with an average of 1.95 g/cm ^{3}, while the dry density values range between 1.30 g / cm ^{3} and 1.74 g / cm ^{3}, at an average of 1.55 g/cm^3. dry and saturated density values are located within the ideal density values.

6. The direct shear values for soil consistency range from 15 kN/m ^{2} to 55 kN/m ^{2}. The high values in some stations are due to the high percentage of clay and silt. The soil water content is highly effective on the strength of cohesion; the more water content the less the number of particles in the unit size, thus decreasing the strength of cohesion. The value of resistance to cohesion is affected by the type of soil; the more clay content in the soil the higher is cohesion.

7. The Ø° varies between 6-17°, which decreases with the increase of the plasticity index (PI). It is clearly affected by the percentage of clay materials, where it decreases with the increase of clay materials. It is also influenced by the value of soil compaction. The low value of this angle, which is below the ideal limit of the required values, is due to the presence of clay minerals such as illite and chlorite, which help to slip and reduce resistance during shear.

8. Non-confined pressure resistance values range from 22.8-58.58 KN/m^2.

9. The results of the XRD analysis showed that the main component of the riverbank slope soils is calcite (53.3%) followed by quartz (25.1%), chlorite (14.6%), Palygorskite (5.8%), and finally montmorillonite (1.2%).

10. pH ranges between 6.4 -7.5 at an average of 7.1; hence they have a low to moderate baseline.

11. Sulfate concentrations vary between 0.23%-5.93%, with an average of 1.85%. The values indicate that the sulfate concentration is high. Therefore, when cement is used to stabilize the soil, it must be of sulfate resistant type.

Recommendations

After studying all field observations and geotechnical characteristics of Euphrates River soil section (Kufa-Mishkhab), the study recommends that:

1. Work should focus on increasing the gradualness of the steep slopes of the bank by reducing the angle of slope, or by reducing the height, which will increase the stability of those slopes. The processing of toppling should be performed by filling the slopes of the banks exposed to the underground abrasion, and then working on the paving of boulders and cobbles. The processing of the banks exposed to erosion and collapse should be performed by reducing the slope, and then working on the paving by rock masses in order to protect the banks from erosion and collapse in the future.

2. The use of mechanical compaction technology for the purpose of reducing the pores in the soil of the bank slopes and increasing their strength and resistance.

3. Conducting the necessary geological and geotechnical surveys before selecting a particular site on the banks of rivers for constructing buildings and parks, especially rivers of the Mesopotamian Plain because they are subjected to change and collapse.

4. Achieving similar studies on other sections of the Euphrates River to determine soil failure, for the purposes of future treatment.

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