Geotechnical Evaluation of soil at selected sites to build up Shatt Al-Arab Spillway in Basra City/ Southern Iraq

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Abstract

The physical, chemical and engineering properties of soil had been carried out to evaluate the characteristics of Sehan and Al-bhar soil sites and their suitability for setting up Shatt Al-Arab spillway. Four boreholes drilled by Al-Ma'awal Company for soil investigation with depths ranging between (1- 40) m. The laboratory tests results for soil samples had been obtained from drilled boreholes showed that the soil in two sites divided in to several layers : 1st layer is a soft sandy silty clay soil (CH) with fill material from (0.0-1m) which should removal through building. 2nd layer is a very stiff sandy silty clay soil (CH) high density (1.78-1.81) gm/cm^3 with bearing capacity (qa) ranged between (11- 41 T/m^2) in two study sites at depths (1 to 5, 6.5 m) this layer is suitable for light loads of Shallow foundation. 3rd layer is a soft to medium stiff silty sandy clay soil (CH, CL) medium to high density (1.77-1.87) gm/cm^3 with qa ranged between (2-9T/m^2) at (6, 7 to 18m) depths which unsubtle for foundation because of high water content (28-30%) and high range of clay that led to settlement with time. Fourth layer is a very stiff [silty sandy clay soil (CL, CH)] to hard [silty sand soil (SW, SP)] with qa ranged between (12-40 T/m^2) at (20 to 40 m) depths because increase the bulk density (1.84-2.12) gm/cm^3 with depth as a result to compaction or a static load with appears dense silty sand strata this layer is suitable for heavy loads of deep foundation such as spillway structure. The results of chemical tests shows fluctuation in behavior through depths where the values of (SO_3, T.S.S, $CaCO_3$) shows increasing with depth and exceeded on permitted limits that need improvement, while the values of (Gyp, CL, O.M, pH) shows changing between increasing and reducing under normal levels with depths.

Key Words: consistency, Borehole, Sehan, Albhar, Bearing capacity

1. Introduction

Spillway is a structure controls the amount of potable water passing from the Shatt al-Arab to a shallow water reservoir. Two different locations adjacent to Shatt al-Arab had been studied in Basrah province southeast of Iraq. First site were chosen in Sehan area (N: 30.31277217 E: 48.21716100) about 50 km from the Basra city. Second site in Albhar area (N: 30.116170 E: 48.3799060) 30 km far away from Sehan site, as shown in figure (1).

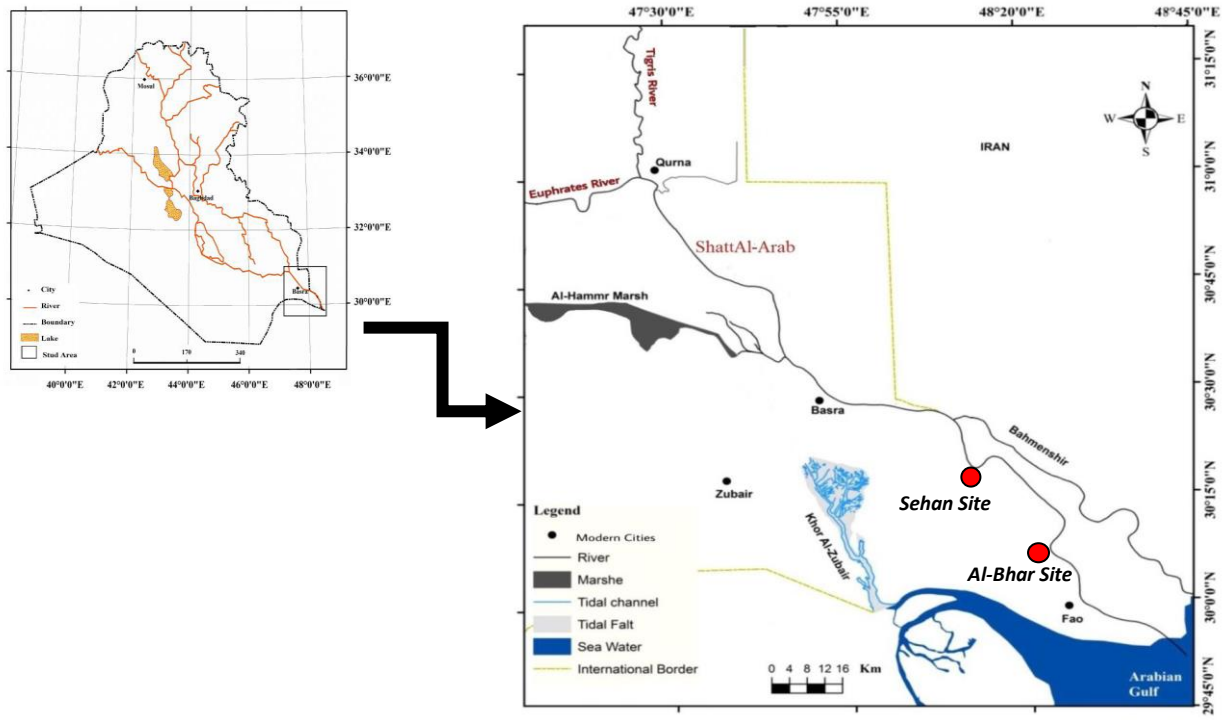


Fig (1) Map of study sites

Quaternary deposits from Pleistocene period – modern formed Mesopotamian plain zones in Iraq [1]. Deposition in this period of Al-Dibdibba Formation that composed of sand and gravel with igneous origin [2]. Then marine sediments Al-Hammar Formation which lower segment consists of the sand and silt and clay mixture with shells represent top segment [3]. The Site soil comprised mainly from the cohesive deposits of Tigris, Karun and Shat Al-Arab rivers. The nature of these alluvial clayey sediments. The importance of Quaternary deposits being abase underpins a shallow and deep foundations to various buildings and engineering constructions in Basra city and a source of many Groundwater Aquifers [4].

3. Methodology

This research included studying the physical, engineering, and chemical properties of the study area soil by dividing the work into two main phases:

Reconnaissance investigation: Study sites are selected in three different locations adjacent to Shatt al-Arab, in province of Basra after detailed map study to Shatt al-Arab course. The location of the selected sites is believed to be suitable for a proposed spillway construction.

Site investigation: four boreholes were drilled by rotary drilling method according to the American Society for Testing [5] specifications. A mechanical (Flight Auger) type with a diameter of (10 cm) digs into the earth. The total depths of drilling reached to (40 m) from the surface of the natural earth (NGS). Physical, engineering and chemical properties were tested at each site. Field and Laboratory work were carried out by Al-Ma'awal Company for soil investigation as below:

1- Physical Properties of Soil

- Grain Size Analysis
- Atterberg limits
- Clay activity (C.A)

2- Engineering Properties of soils

- Standard penetration test (SPT)
- Settlement test.

3- Chemical Properties of soil

- Sulfite content (SO3)
- Gypsum content (Gyp.)
- Chloride content (CL)
- Total soluble salts (T.S.S)
- Organic matter content (O.M)
- Carbonate content (CaCO3)
- pH value .

4- Ground Water Table Observation: The underground water level was measured at end of boring at the time of sub-soil investigation (April, 2017) from the natural ground surface Table (1). The specified depth was fixed after 24 hours of boring termination. However, this depth fluctuates during the seasons of the year.

Table (1) the ground water level

Study sites	The date of measurement	ground water table W.T (m)	Bored method	Bored Depth (m)	Bored Diameter (m)	BH.NO
Sehan	April -2017	3.10	Flight Augers	40	0.10	1
	=	3.20	=	40	=	2
Al-Bhar	April -2017	3.30	Flight Augers	40	0.10	1
	=	3.40	=	40	=	2

4. Results and discussion

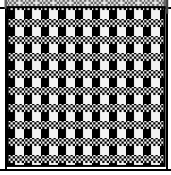
Based on American standards (ASTM) [5] the laboratory tests of study area were conducting for obtaining the physical, engineering and chemical properties of the study area soils as follows:

4-1 Physical Properties of Soil

A. Grain Size Analysis: The results of grain size distributions showed that the soil in two sites was fill material with sandy silty clay soil in depth (0.0-1) m. While sandy silty clay soil high density (1.78-1.81) gm/cm^3 in depth (1-6.5) m in Sehan, and from (1-4) m in Albhar site. Then silty sandy clay soil medium to high density (1.77-1.87)gm/cm^3 at depth (7-32.5) m in Sehan site, (5-21.5) m in Albhar site. Then the soil in two sites was silty sand very high density (1.84-2.12) gm/cm^3 at depth (33-40m) in Sehan site and (22-40 m) in Albhar site. The details of soil stratification for boreholes are shown in fig (2, 3) the consequent changes of sub-soil strata is related to way of deposition**.**

B. Atterberg limits: With the plasticity index and liquid limit known the case of soil relative to moisture content. The Casagrande Plasticity chart shows that the both study location have cohesive soil to wide range of plasticity CL (clays of medium plasticity) and CH (clays of high plasticity) and as shown in borehole log (2,3). Based on plasticity index, soils have been classified as indicated in table (2)**.**

Sehan Site

Layer No.	Lithologic symbol	Description	Depth (m)
1		fill material , Soft brownish ,grayish sandy silty clay soil (CH)	0.0-1
2		stiff to V.stiff grayish sandy silty clay soil (CH) (1.78-1.80) gm/cm^3	1-6.5
3		Soft to M.Stiff grayish silty sandy clay soil (CH,CL) (1.77-1.81) gm/cm^3	7-18
5		Stiff to Hard brownish silty sandy clay soil (CL) (1.83-1.86 gm/cm^3)	19-23.5
6		Stiff to V.Stiff grayish silty sandy clay soil (CL ,CH) (1.82-1.87 gm/cm^3)	24-32.5
7		Hard to very dense grayish silty sand soil (SW,SP) (1.95-.2.12) gm/cm^3	33-40

Al-bhar Site

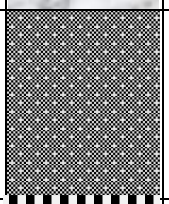
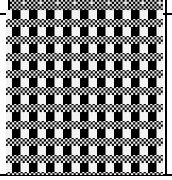
Layer No.	Lithologic symbol	Description	Depth (m)
1		fill material , Soft brownish ,sandy silty clay soil (CH)	0.0-1
2		V.Stiff grayish sandy silty clay soil (CH) (1.79-1.81)gm/cm^3	1-4
3		M.Stiff grayish silty sandy clay soil (CH,CL) (1.80-1.83gm/cm^3)	5-18
4		V. Stiff grayish silty sandy clay soil (CL) (1.81-1.84)gm/cm^3	19-21.5
5		Hard to very dense grayish silty sand soil (SW,SP) (1.84-2.11)gm/cm^3	22-40

Fig (2, 3) borehole log in Sehan and Al-Bhar sites

Table (2) Classification of cohesive soils according to their plasticity [6]

Plasticity index %	Plasticity
0	Non plastic
< 7	Plastic
7-17	Medium Plastic
>17	High Plastic

C. Clay activity (C.A): Clay activity defined as the ratio of plasticity index to clay content. In Sehan location average ratio of clay activity equal to (0.62) and equal to (0.61) in Albhar location. The result of clay activity refers that the soil of study sites has poor clay activity according to ASTM specifications, so this soil has low swelling tendency. The results generally indicate that the value of moisture content is closer to the plastic limit than to the liquid limit table (4, 5).Table (3) view classification of soil according to clay activity.

Table (3) Classification of soil according to Clay activity. [7]

Classification	Activity
Non Active	<0.7
Normally Active	0.7-1.25
Active	1.25-2.0

Table (4) Grain size distribution and index properties and clay activity in Sehan site

Type of sample	B.H. No	Depth (m)	System of classification					Properties index			C.A
			Clay %	Silt %	Sand %	Grave. %	Soil class. symb.	PL %	LL %	Pi %	
DS	1	6.5-7	51	27	22	0	CH	21.0	53.0	32.0	0.62
DS	1	16.5-17	45	24	31	0	CL	15.0	44.0	29.0	0.64
DS	2	14-14.5	46	25	29	0	CL	19.0	47.0	28.0	0.60
DS	2	24-24.5	45	22	33	0	CL	17.0	45.0	28.0	0.62

Table (5) Grain size distribution and index properties and clay activity in Al-bhar site

Type of sample	B.H. No	Depth (m)	System of classification					Properties index			C.A
			Clay %	Silt %	Sand %	Grave. %	Soil class.symb.	PL %	LL %	Pi %	
US	1	3.5-4	58	28	14	0	CH	18.0	55.0	37.0	0.63
DS	2	6-6.5	58	28	14	0	CH	17.0	48.0	31.0	0.62
DS	2	11.5-12	48	25	27	0	CL	15.0	44.0	29.0	0.60
DS	1	21-21.5	48	23	29	0	CL	17.0	45.0	28.0	0.60

4-2 Engineering Properties of soils

A. Standard penetration test (SPT): It is commonly utilized in geotechnical field test and it indicates to soil bearing capacity, consistency and soil conditions. The results of standard penetration test in study locations in fig (4) and tables (7, 8).

B. Bearing capacity (qa): The results of bearing capacity obtained from SPT ranged between (11- 41 T/m^2) in (1-5,6 m) depth and between (1-9 T/m^2) in (6,7-20m), while ranged (12-40 T/m^2) in (20-40m) depth .The layers of soil study sites depending on bearing capacity (Table 6) divided in to three layers: the first layer is a stiff to very stiff in two study sites and ranged between (1 to 5and 6 m) depths because of compaction and contain of sand, silt, with clay. The second layer is a soft to medium stiff which ranged between (6, 7 to 18m) because of water content and high range of clay. The third layer is a very stiff to hard and ranged between (20 to 40 m) depths because increase the bulk density with depth as a result to compaction or load of the layers with appears dense silty sand strata.

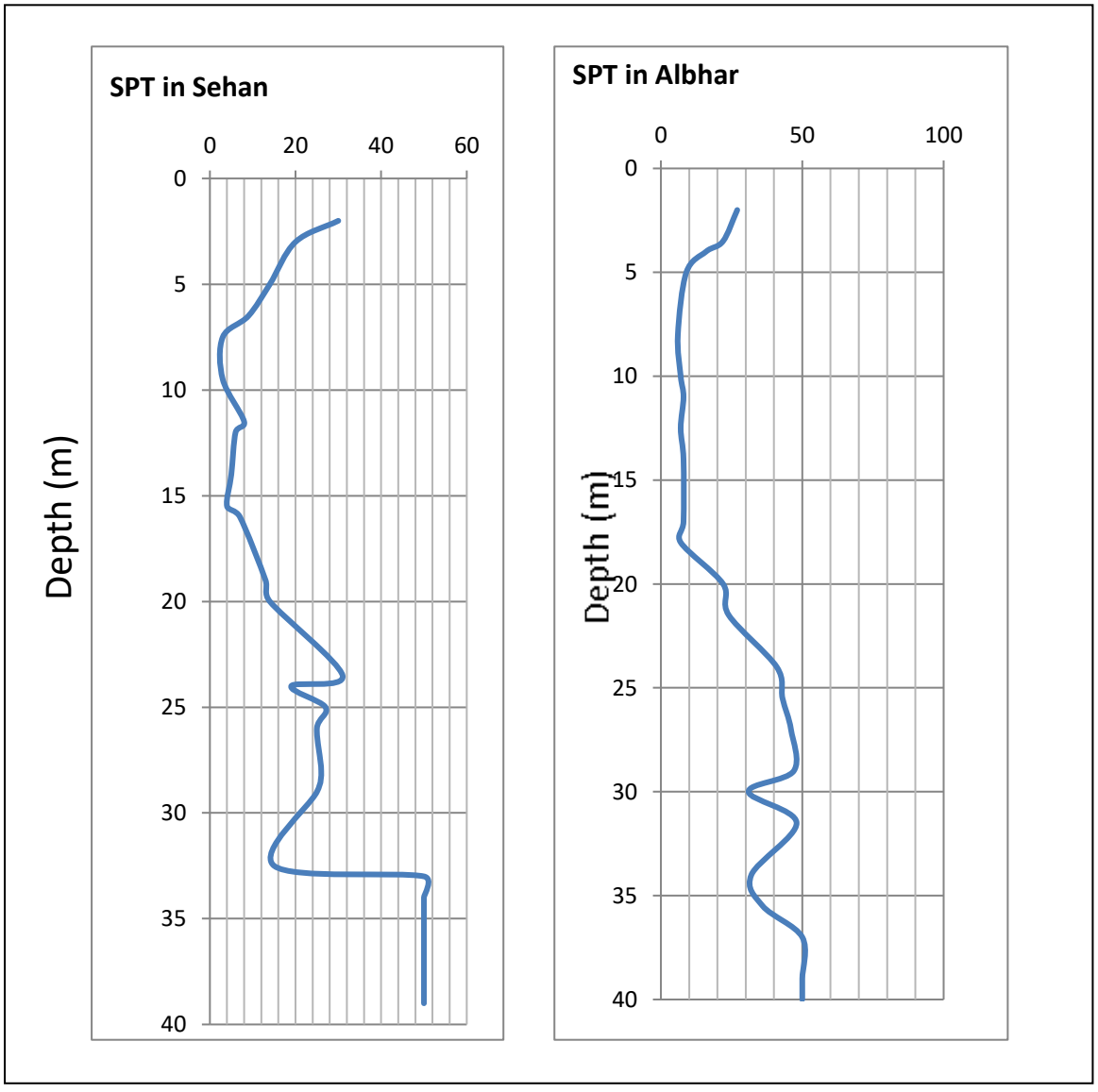


Fig.(4): SPT log in study

Table (6) approximate correlation between standard penetration test (SPT), consistency and and of clay and silt. [8] Ultimate bearing capacity

Consistency	Standard Penetration Test N-value	qu	
		Ton/m^2	kN/m^2
Very Soft	<2	<2.5	<25
Soft	2 – 4	2.5 – 5	25 – 50
Medium stiff	4 – 8	5 – 10	50 – 100
Stiff	8 – 15	10 – 20	100 – 200
Very Stiff	16 – 30	20 – 40	200 – 400
Hard	>30	>40	>400

Table (7) the values average of N and bearing capacity to BH$_1$, BH$_2$, and consistency of Sehan soil location

Depth (m)	Average SPT(N) Total	Ave. Qa T/M^2	consistency	Depth (m)	Average SPT(N) Total	Ave. Qa T/M^2	consistency
1.0	30	32	V.Stiff	24.0	19	8.8	V.Stiff
3.0	20	25	V. Stiff	25.0	27	16	V. Stiff
5.0	14	19	Stiff	26.0	25	15	V. Stiff
6.5	9	11	Stiff	28.0	26	13	V. Stiff
7.5	3	1.6	Soft	29.0	25	30	V. Stiff
9.5	3	1.6	Soft	32.5	15	15	Stiff
11.5	8	4.0	M.Stiff	33.0	50	25	Hard
12.0	6	3.0	M. Stiff	34.0	50	28	Hard
14.0	5	2.6	M. Stiff	35.0	50	30	Hard
15.5	4	2.0	Soft	36.0	50	30	Hard
16.0	7	3.6	M. Stiff	37.0	50	30	Hard
19.0	13	6.7	Stiff	38.0	50	45	Hard
20.0	14	9.3	Stiff	39.0	50	42	Hard
23.5	31	12.0	Hard	40.0	50	42	Hard

Table (8) the values average of N and bearing capacity to BH_1, BH_2, and consistency of Albhar soil location

Depth (m)	Average SPT(N) Total	Ave. Qa T/M^2	consistency	Depth (m)	Average SPT(N) Total	Ave.Qa T/M^2	consistency
1.0	27	41	V.Stiff	21.5	24	10	V.Stiff
2.5	22	25	V.Stiff	24.0	41	14.5	Hard
4.0	16	19	V.Stiff	25.5	43	15.1	Hard
5.0	9	11	Stiff	27.0	46	15.8	Hard
8.0	6	3.0	M.Stiff	29.0	47	16.1	Hard
10.0	7	3.6	M.Stiff	30.0	31	17.4	Hard
11.0	8	4.5	M.Stiff	31.5	48	16.4	Hard
12.5	7	3.6	M.Stiff	34.0	32	12.2	M.Stiff
14.0	8	8.0	M.Stiff	35.5	36	20.2	M.Stiff
17.0	8	8.0	M.Stiff	37	50	30	Hard
18.0	7	5.7	M.Stiff	39	50	30	Hard
20.0	22	9.6	V.Stiff	40	50	40	Hard

C. Settlement: Through conducting the consolidation test on some soil samples of boreholes, it was found that the expected settlement in the locations of the study area is within acceptable limits and that the cohesive soil is over consolidated. The variations of overburden (Po) and preconsolidation (Pc) pressures with depth which are shown in Table (9)**.**

4-3 Chemical Properties of Soil*:* the study of salts content in soil is very important because its affection on engineering behavior of soil that led to stability of foundations and buildings [8]. The results in Table (10, 11) and figs (5, 6) shows:

Table (9) consolidation parameter with depth

Sites	No of BH	Depth m	Consolidation test				
			e0	Cc	Cr	Po T/ m^2	Pc T/ m^2
Sehan	BH.1	5.5-6	0.827	0.194	0.036	10.68	15.5
	BH.2	12.5-13	0.748	0.174	0.039	23.40	20.0
Al-Bhar	BH.1	7.5-8	0.755	0.107	0.042	14.32	18.5
	BH.2	5.5-6.0	0.726	0.136	0.030	9.84	14.5

1- Sulfate content values (SO3) ranging between (0.34-1.71%) in the sites that mean slightly increasing on standard value (1%) which may causes concrete erosion and failure of structures [9].while values of gypsum (Gyp.) were between (0.77-9.68%) which not exceeds on standard value (10%) So consider no dangers on engineering properties of soil [10].

2- The values of total soluble salts (T.S.S.) in Sehan site ranging from (2.11-12.39%) so that exceeded permitted limits(10%) that possible increase the strain between the layers of clay soil and then change the distance between the grains [11]. The average values of chloride (CL %) content is normal in two sites about (0.029-0.062%).

3- The average of organic matter (O.M) in the soil sites under normal levels about (0.03-0.031%) , The proportion of organic matter in soil described as high if it exceeds (1%), but a ratio of (0.5%) may be sufficient to have problems with the strength of the soil compressibility as mentioned[12].

4- The values of ($CaCO_3$) ranging from (10.0 - 44.0%) in both sites. If the values of ($CaCO_3$) exceeds on standard value(30%) that led to formation of Cavities and the increase in the size of the gaps, especially the lower layers of the soil, which become unsuitable as a basis for the foundations[13] . The values of (pH) function of the soils in the two study sites are within the moderate base which does not cause danger to the buried concrete.

Table (10) Results of chemical tests of soil samples in Sehan site

No. of BH	Depth (m)	SO3 (%)	Gyp. (%)	TSS (%)	O.M (%)	CaCO3 (%)	pH %	CL%
BH.1	1.5-2	0.35	1.82	2.16	0.031	10.0	8	0.062
=	3.5-4	0.47	2.61	4.09	0.032	12.0	8	0.062
=	6.5-7	0.53	3.24	5.27	0.031	15.0	8.1	0.058
=	10.5-11	0.67	3.59	5.46	0.03	16.0	8.1	0.058
=	13-13.5	0.82	4.70	6.52	0.032	17.0	8.1	0.045
=	16-16.5	1.15	7.42	10.56	0.032	20.0	8.1	0.045
=	20-20.5	1.21	7.87	10.18	0.032	22.0	7.8	0.033
BH.2	23-23.5	1.34	8.50	11.84	0.03	25.0	7.8	0.033
=	25-25.5	1.40	7.81	10.21	0.03	27.0	8.2	0.029
=	28.5-29	1.47	9.13	12.60	0.031	30.0	8.1	0.029
=	31.5-32	1.53	9.20	12.73	0.031	32.0	8.1	0.061
=	34.5-35	1.58	8.65	11.23	0.032	36.0	8.1	0.061
=	36.5-37	1.60	9.41	12.11	0.032	37.0	8.1	0.057
=	39.5-40	1.71	9.68	12.39	0.032	40.0	8.1	0.057

Table (11) Results of chemical tests of soil samples in Al-Bhar site

No. of BH	Depth (m)	SO3 (%)	Gyp. (%)	TSS (%)	O.M (%)	CaCO3 (%)	pH %	CL%
BH.1	2.5-3	0.34	0.77	2.11	0.03	12.0	8.0	0.061
=	4.5-5	0.51	0.89	2.40	0.031	14.0	8	0.056
=	7.5-8	0.58	0.95	2.53	0.03	15.0	8.1	0.044
=	9.5-10	0.65	1.78	3.34	0.032	18.0	8.1	0.031
=	12-12.5	0.72	2.50	4.23	0.031	19.0	7.9	0.061
=	14.5-15	0.79	2.31	4.20	0.031	22.0	8.1	0.054
=	17.5-18	0.86	5.48	7.39	0.03	24.0	8	0.042
BH.2	21-21.5	0.95	5.36	7.42	0.032	27.0	8	0.033
=	24-24.5	1.14	6.32	9.15	0.03	31.0	8.1	0.062
=	27.5-28	1.21	6.41	9.28	0.031	33.0	8.1	0.055
=	31.5-32	1.29	6.86	9.45	0.031	34.0	7.9	0.041
=	33.5-34	1.40	5.42	8.82	0.03	37.0	8.1	0.032
=	35.5-36	1.48	7.54	10.12	0.03	41.0	8	0.062
=	37.5-38	1.56	8.30	11.86	0.032	42.0	8	0.057
=	39.5-40	1.63	8.52	11.26	0.031	44.0	8.1	0.044

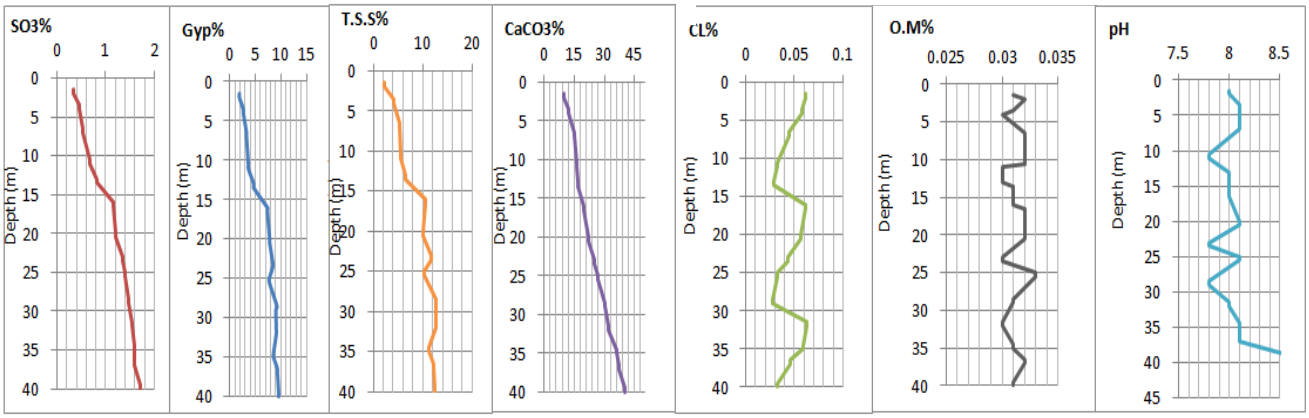


Fig (5) chemical properties behavior with depths in Sehan soil site

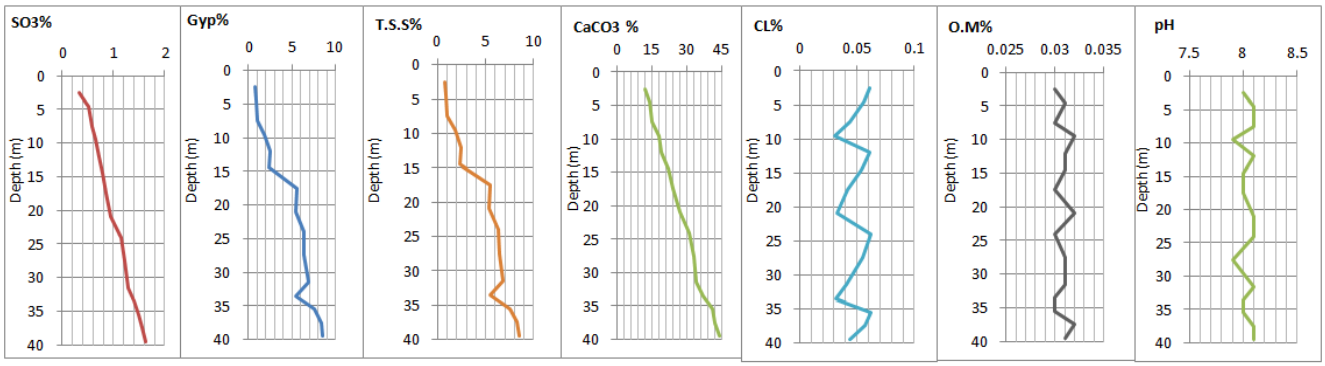


Fig (6) chemical properties behavior with depths in Albhar soil site

5. Conclusion

- Because of the closeness in geotechnical properties, so the two sites are suitable for spillway structure after some improvement.
- The soil of the study area has considerably fluctuating properties and includes a high variation in the proportions of the grain sizes consisting of the soil, as the results of the volumetric granular analysis of the soil have shown, making it difficult to give the characteristics a single shape similar to the increase or decrease with depth. This is due to the diversity of soil to the diversity of environments depositional represented the fluvial and filling deposits.

- The soil in Sehan site was sandy silty clay high density in depth (1-6.5) m, and from (1-4) m in Albhar site. While the soil is silty sandy clay medium to high density at depth (7-23.5) m in Sehan, and (5-21.5) m in Albhar site. As well as silty sand soil very high density at depth (33-40m) in Sehan and (22-40) m Al-bhar site.
- According to the Unified Classification System (USCS), the prevalent in soft soils, it was predominant in the study area of low and high plasticity clay (CH, CL) respectively. As for coarse soils was poorly graded sand (SP), and well graded sand (SW).
- The soil in the study sites is generally considered No-Active.
- The total of Standard Penetration test (SPT) for two locations shows the N values at 2^{nd} layer ranged between (9-30) in (1-6m) depth, at 3^{rd} layer ranged between (3-13) in (7-19m) depth, while ranged (14-50) in (20-40m) at 4^{th} layer.
- The results of bearing capacity ranged between (11- 41 T/m^2) at 2^{nd} layer in depth (1-7m), and between (2-9T/m^2) at 3^{rd} layer in depths (6-20m), while ranged from (12-40 T/m^2) at 4^{th} layer in depth (20-40m).
- The consistency layers of study sites is divided in to: the 1^{st} layer is a soft fill material from (0.0-1m) that should removal through building, 2^{nd} layer is a stiff to very stiff in two study sites and ranged between (1 to 5, 6 m) depths and is suitable for light loads of shallow foundation. 3^{rd} layer is a soft to medium stiff which ranged between (6, 7 to 18m) that unsubtle for foundation may led to settlement .4^{th} layer is a very stiff to hard and ranged between (20 to 40 m) because increase the bulk density with depth as a result to compaction or load of the layers with appears dense silty sand strata this layer suitable for loads of deep foundation such as spillway structure.

- The depth of the groundwater table ranged from (3.10-3.20) m in Sehan site and (3.30-3.40) m in Al-Bhar site below the normal ground surface (N.G.S).
- The Chemical behavior is fluctuating through depths where the (SO3, T.S.S, CaCO3) shows increasing with depth, while the (Gyp, CL, O.M, pH) shows slight change between increasing and reducing under normal levels with depths.

6. Recommendation

- It's important to prevent establishing any foundation on weak zones (soft strata) in mentioned depths because of its risks.
- The study suggests using sulfate resistance Portland cement (SRPC) for foundation and all concrete in contact with soil to prevent the damage effect of (SO_3).
- Due to the high soluble salts in the soil sites, all concrete works which in touch with soil should be protected by coating all the footing faces by a layer of hot bitumen type 20/30 with 8.0 mm thickness.

  The surface of soft fill material from (0.0-1) m should removal through building.

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7.References

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التقييم الجيوتكنيكي للتربة في مواقع مختارة لأنشاء ناظم شط العربي في مدينة البصرة/ جنوبي العراق

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المستخلص

يهدف البحث الى دراسة الخصائص الفيزيائية والكيميائية والهندسية لترب من مواقع سيحان وناحية البحار ومدى ملائمتها لانشاء ناظم شط العرب. تضمنت اربع حفر اختبارية باعماق تتراوح من (1الى 40) م. اظهرت النتائج ان الترب السطحية في الموقعين هي ترب املائية طينية غرينية نسبة من الرمل عالية اللدونة عند الاعماق (0-1)م. وتربة طينية غرينية رملية عالية اللدونة وذات كثافة عالية عند الاعماق (1- 4 و6.5) م. وتربة طينية غرينية رملية عالية - واطئة اللدونة ذات كثافة متوسطة تتخلها طبقات ضعيفة عند الاعماق (7-32.5) م في موقع سيحان وتراوح عمقها(4-21.5)م في موقع البحار . وتربة رملية غرينية جيدة ورديئة التدرج ذات كثافة عالية عند الاعماق (33 الى 40) م في موقع سيحان و(22الى40) م في موقع البحار. اما السعة التحملية فقد تراوحت لترب الموقعين مابين (11 الى 41 طن / م^2) في الاعماق (2 الى 6) م هذه الطبقة تعتبر قوية جدا ومناسبة للاحمال الخفيفة ذات الاسس الضحلة. وتراوحت بين (2الى 9 طن / م^2) عند الاعماق (7 الى 18) م هذه الطبقة متوسطة الى ضعيفة القوة بسبب المحتوى المائي ونسبة عالية من الاطيان. بينما تراوحت مابين (12 الى 40 طن/ م^2) عند الاعماق (20 الى 40) م , هذه الطبقة تصنف قوية جدا الى صلبة بسبب زيادة الكثافة مع العمق بفعل الانظغاط او الحملي الاستاتيكي مع ظهور طبقات الرمل , هذه الطبقة مناسبة لحمل المنشأت الثقيلة ذات الأسس العميقة كما في الناظم المراد انشاءه. اظهرت نتائج الفحوصات الكيميائية وجود تذبذ في السلوك خلال الاعماق حيث كانت نسب الكبريتات والاملاح الكلية القابلة للذوبان تزداد مع العمق وتجاوزت الحدود المسموح بها. بينما محتوى الجبس والكلوريدات والمادة العضوية فقد كانت نسبها ضمن الحدود طبيعية.