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Geotechnical Features of Basrah City, Iraq

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Abstract

Basrah is considered as the economic capital of Iraq. In recent years, it showed a rapid growth in population and, accordingly, an increasing investment in construction industries. This paper presents information about the geotechnical characteristics of Basrah soil. For this purpose, geotechnical data have been collected covering wide areas of the city. The study area was divided into two zones, one of them was further divided into three subzones. For each of the zones considered, geotechnical information including typical soil profiles, Standard Penetration Test (SPT-N) values, Atterberg limits, sieve analysis results, consolidation test results and other physical aspects were given. Furthermore, chemical analysis of Basrah soil was also presented. According to field and laboratory results, soils in this region can be classified into two distinct zones. The eastern zone, which mainly forms of soft and medium cohesion soils extended from the soil surface down to a depth of (16 – 26) m, and, the western zone, which can be identified by the sandy surficial and stratigraphic soil.

Keywords: Basrah soil, Geotechnical properties, SPT-N, Soil texture.

1. Introduction

Basrah is located in southern Iraq and represents its international border with both Kuwait and Iran. It is the only port of Iraq overlooking nearly 60 km on the Gulf coast. In addition to its strategic location, the oil industry makes this city one of the most attractive region in the world for foreign investment. Until a few years ago, the majority of the city's population is located nearby rivers. Recent economic developments of the city have heightened the need for exploring the subsoil conditions to gain more detailed geotechnical data for future construction projects. Available information concerning the geotechnical aspects of Basrah soils is rather limited and mainly refers to limited areas of the city. Furthermore, most of the available published studies have focused on and conducted in uninhabited areas, such as oil fields and water treatment plants. Little is known about soil profiles in the city center, or other districts like Qurna, Fao and Abu Al-Khaseeb, as shown in Fig. 1.

Even within a closed area, soil layers and properties may vary from one place to another. Soil information obtained from field investigations cannot be considered as a valuable tool for geotechnical engineers unless it is deeply studied and properly classified. Such information collected from certain locations provides a good predictive value for projects constructed on or nearby the studied locations and provides a guide for preliminary design purposes.

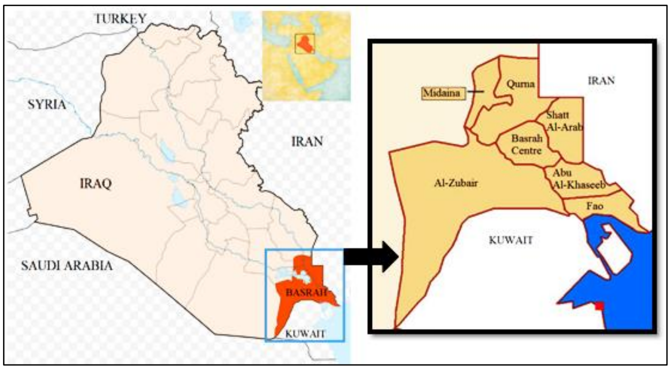


Fig. 1 Location of the study area.

Few researchers have reported information on geotechnical proprieties of Basrah soils. In this context, Hanzawa [1] studied the behavior and properties of Fao clay, the city which located further south of Basrah. According to this study, Fao clay can be classified into normally consolidated young and aged clay depending on its location. Soil profiles with their in situ and lab measurements were investigated at three locations in the study area. It was found that sampling and preparing of samples caused stress distortion and changing in the original water distribution over the soil samples. Therefore, the author suggested using in situ methods rather than laboratory tests to determine soil strength parameters. Mahmood and Albadran [2] carried out a soil investigation program to study the engineering behavior of soils in the city center. It was found that soil strata in this area can be divided into 10 layers. Some layers are quite different, others had no significant differences. Generally, the main soil strata can be categorized in silty clay, clayey silt, and sand. Muttashar et al. [3] evaluated factors affecting consolidation settlement of Basrah soil. Samples were collected from four locations at eastern side of the city. Kadhim et al. [4] used GIS and GPS techniques to develop a number of geotechnical maps of Basrah city center including the distribution of its main geotechnical properties. Hani [5] investigated the formation of subsoil of West Qurna oil field which is located in northern Basrah. For road construction projects, the author suggested to replace the top 1 m soft soil layer with suitable mixed aggregate. Al-Taie et al. [6] tested the bearing capacity of Basrah soil by analyzing the data obtained from nine boreholes drilled at various locations. The results showed that the maximum and minimum bearing capacities of the study area were 84 kN/m^2 and 24 kN/m^2, respectively. Al-Taie [7] carried out laboratory and field investigation on some Basrah soils. The studied area was located in Al-Zubair district, southwest Basrah. A total of 39 boreholes were drilled at three sites in the district, to depths of 30 m. Utilizing data collected, a set of figures showing average values of soil properties against depth was plotted.

The purpose of the current study is to provide an overall picture to the geotechnical properties and main characteristics of Basrah soil by analyzing data obtained from different zones covering the main locations of the city.

2. Geology of Basrah

Basrah is a part of the Mesopotamian plain, which forms a flat terrain with few hills of relatively slight high. The location of the city has played a major role in understanding the geology of the Mesopotamian plain. The geological studies showed that the city was formed as a result of sedimentation processes caused by the deposition of marshes, rivers and Gulf sediments during geological ages. Its location as a lower deltaic area of Tigris, Euphrates, Karun and Shatt Al-Arab rivers had a great reflection on the formation of alluvial (marine Hammar formation) and fluvial sediments. These deposits can be considered as normally consolidated [2]. In addition to these deposits, geologists have recognized surficial coarse-grained sediments as a result of Dibdiba deposits.

3. Used Data

In the present study, geotechnical data from boreholes, drilled by the Engineering Consulting Bureau of the University of Basrah, were used. The purpose of this investigation was mainly to explore the subsoil conditions of some proposed sites, to support the foundation design and construction program as requested by the clients. The soil exploration described in this study consists of field investigation, laboratory testing and subsoil stratification. As a result, an overall assessment of subsoil conditions based on essential requirements of foundation design was provided.

The boring equipment used in carrying out the fieldwork was the rotary drill method with the use of thin-wall tube samplers (Shelby tube) for taking undisturbed samples. Disturbed and undisturbed samples were collected carefully to ensure an accurate assessment of subsoil conditions.

The boreholes were distributed over a wide area of the district. Therefore, to make the investigation more specified, the study area was divided into two zones, see Fig. 2.

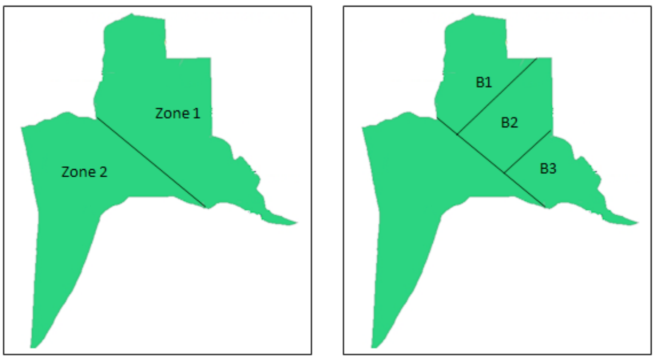


Fig. 2 Zones of the study area.

The first zone (Zone 1) covers the northern and eastern parts of the study area and contains districts like Qurna, Midaina, Shatt Al-Arab, Fao, Abu Al-Khaseeb and City center. The second zone (Zone 2) includes Al-Zubair district, which represents southern and western areas. As the subsoil condition of the first zone could vary according to location, this zone was further divided into three subdivisions namely B1, B2 and B3, see Fig. 2.

4. Geotechnical Characteristics of Zone 1

As mentioned in the previous section, this zone has been divided into three subzones. Qurna and Midaina were represented by subzone B1, while the city center and Shatt Al-Arab district were included in subzone B2. The southern part represented by Abu Al-Khaseeb and Al-Fao was identified by subzone B3. The soil samples used to study the subsoil condition of zone B1 were obtained from 12 boreholes drilled up to 35 m deep in two sites in Qurna and Midaina, north of Basrah. The groundwater table in this zone was varied from 0 to 1.6 m, as observed at the time of investigation. For zone B2, geotechnical data were collected from 17 sites distributed over Shatt Al-Arab district and the city center. Field tests indicated that the depth of groundwater ranged between (0 - 0.8 m) below the natural ground level. Information gained from 5 sites was used for zone B3 located mainly in Al-Fao district, with the water table in the range of (0 - 1.3 m).

4.1. Subsoil Material Description

For subzone B1, the soil strata, in general, were found to be consisting of four layers as follows:

1. A layer of medium to soft, brown to gray, clayey silt with trace or a little of sand was encountered at the majority of boreholes from the ground surface to a depth ranged between 11.0 - 19.5 m.
2. A thin layer of stiff to very stiff, brown to gray, clayey silt with trace or a little of sand sandwiched between the top clayey silt layer and the next strata. This layer extends to a depth of 14.0 - 21.0 m.
3. At a depth ranged between 23.5 - 30.5 m, a layer containing medium to dense, gray to green, poorly graded fine sand was found.
4. The last layer which extends to the termination depth of boreholes at 35.0 m consists of very stiff to hard, brown to gray, clayey silt with sand or clayey silt with a little of sand with low plasticity.

At the city center and Shatt Al-Arab district (subzone B2), the main stratigraphic units can be summarized as follows:

1. Medium, brown, silty clay with trace of sand. This layer extends from the ground surface to a depth of about (3.0 - 4.0 m).
2. Soft to very soft, brown to gray, clayey silt with trace and sometimes a little of sand. This layer extends to a depth of about (19.0 - 21.0 m).
3. The bottom soil layer can be described as dense, brown to gray, poorly graded and sometimes well graded sand.

The subsoil strata of subzone B3 consist mainly of three layers, these are:

1. The top soil layer, which extends to a depth ranged between (4.0 - 6.0 m), consists of medium to soft, brown clayey silt with trace of sand.

2. The second layer consists of soft to very soft, gray, clayey silt with trace and sometimes a little of sand. This layer extends to a depth of about (26.5 - 29.0 m).
3. The bearing stratum, containing dense to very dense, gray, poorly graded sand.

Typical geotechnical profiles for these zones are illustrated in Fig. 3.

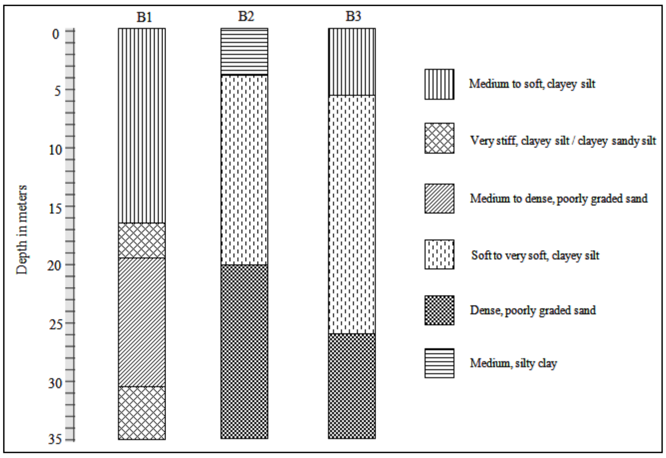


Fig. 3 Typical geotechnical profiles for subzones B1, B2 and B3.

4.2. *Consolidation Test Results*

Consolidation tests were conducted for some undisturbed soil samples. The maximum and minimum values of preconsolidation pressure (P_c), compression index (C_c), recompression index (C_r), and the initial voids ratio (e_o) for selected boreholes and depths are shown in Table 1. Comparing test results with the overburden pressure computed at the selected depths indicates that the cohesive soil layer, in general, is normally consolidated. The values of initial void ratio agreed well with those obtained by Al-Taie [7].

Table 1 Consolidation test results for Zone 1.

Properties	B1		B2		B3	
	Min.	Max.	Min.	Max.	Min.	Max.
P_c (kN/m^2)	44.5	88.62	37.65	46.83	33.1	40.45
C_c	0.103	0.166	0.072	0.112	0.082	0.123
C_r	0.029	0.043	0.017	0.027	0.031	0.041
e_o	0.711	0.942	0.820	1.041	0.895	1.126

4.3. *Atterberg Limits*

Fig. 4 compares the average values of liquid limit (L.L), plastic limit (P.L) and plasticity index (P.I) for the three subzones with depth. Plasticity characteristics of the northern and eastern regions, shown in Fig. 5, demonstrate the range of variation in consistency limits for the three subzones. It can be seen that the liquid limit and plasticity index for zone B1 are in the range of (33 - 47) and (11 - 23) respectively. This Figure shows the similarity in consistency of B2 and B3 soils with L.L and P.I ranged between (35 - 46) and (8 - 15), respectively. The results indicate that the cohesive soil, up to 20 m depth, having low plasticity (LL < 50).

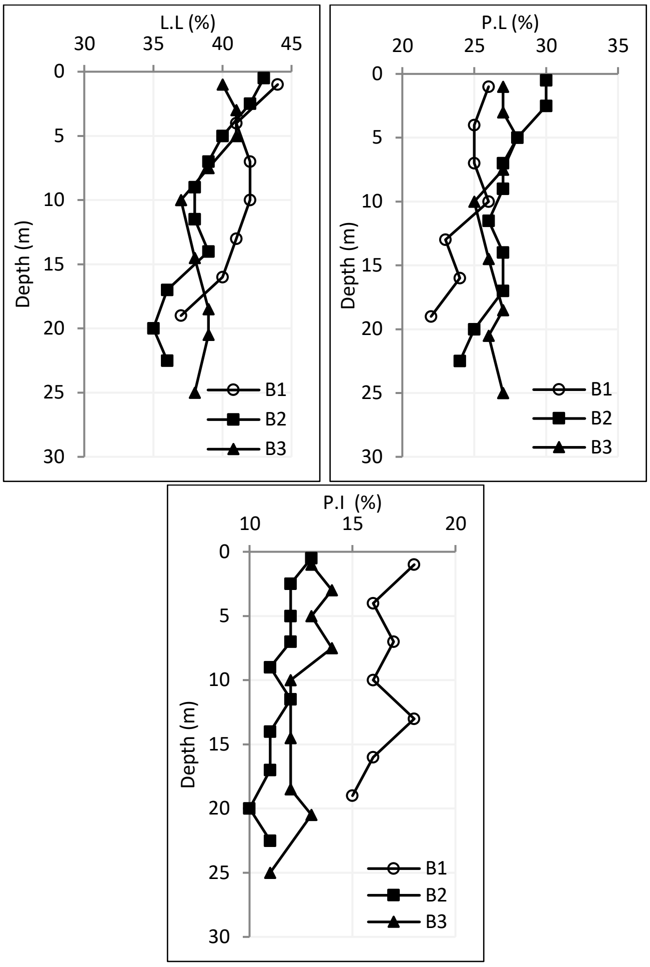


Fig. 4 Average values of L.L, P.L and P.I for soils of Zone 1.

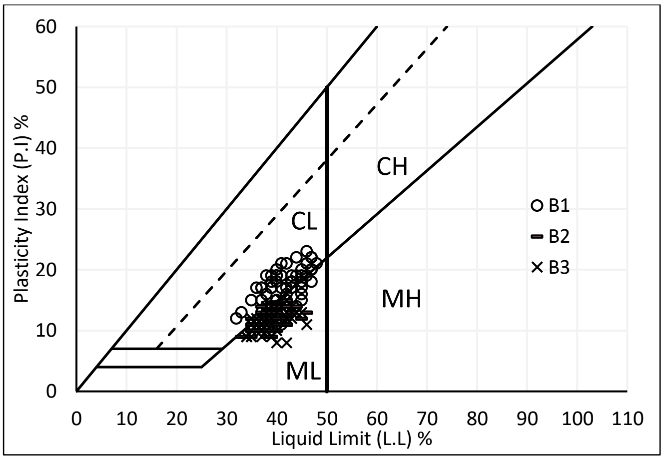


Fig. 5 Plasticity chart for soils in Zone 1.

4.4. *Unit Weight, Moisture Content and Specific Gravity*

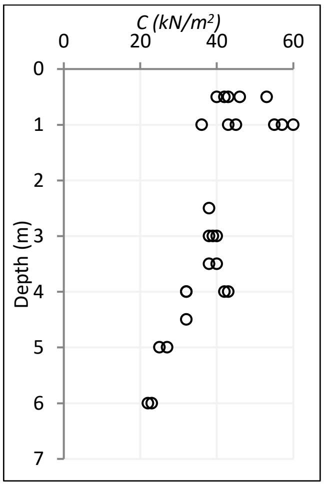
The maximum and minimum values of moisture content, specific gravity, bulk and dry unit weight recorded at the three subzones are illustrated in Table 2. Measurements show that moisture contents are distributed uniformly with depth over the study area. Also, laboratory investigation shows increasing in the values of specific gravity with depth. As a result of decreasing void ratio at deeper layers, both dry and bulk unit weight values, generally, increased with depth with an average of 1.49 and 1.86 g/cm^3 for Zone B1, 1.51 and 1.87 g/cm^3 for Zone B2 and 1.47 and 1.83 g/cm^3 for Zone B3, respectively.

Table 2 Physical properties of Zone 1 soil.

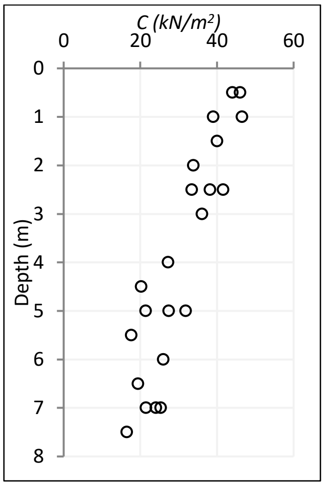
Property	B1		B2		B3	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
M_C %	17.2	34.1	19.7	35.2	25.9	35.6
G_s	2.34	2.86	2.35	2.81	2.30	2.79
γ_d (gm/cm^3)	1.36	1.64	1.44	1.63	1.39	1.63
γ_b (gm/cm^3)	1.71	2.05	1.78	2.02	1.73	2.04

4.5. *Soil Strength Parameters*

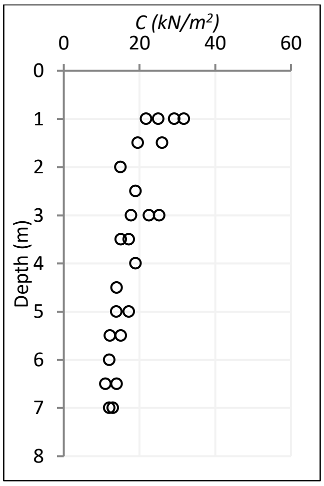
A series of Undrained Triaxial tests were adopted to evaluate the values of cohesion, C, for disturbed samples taken from the top 6 m of boreholes drilled in Zone B1. Cohesion variation with depth started from soil surface down to 6 m depth is illustrated in Fig. 6 (a). The Figure reveals values of cohesion in the range of (40 - 60 kN/m^2) recorded at the top 1 m of the soil. After that, these values tend to decrease at deeper depths. At this range of depth, soil consistency can be identified as medium to soft. Zones B2 and B3 share approximately the same variation of cohesion with depth, see Fig. 6 (b) and (c). Again, a gradual decrease of cohesion values was recorded with the increase in depth. Soil strength measurements at shallow depths refer to a medium consistency for Zone B2 and medium to soft strength for Zone B3.



(a) B1



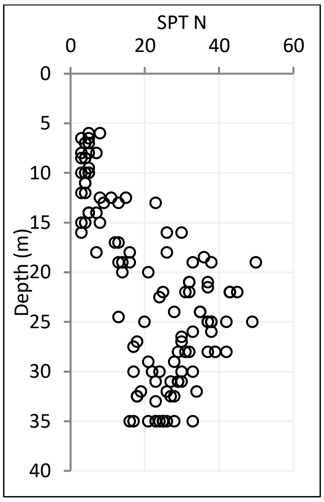
(b) B2



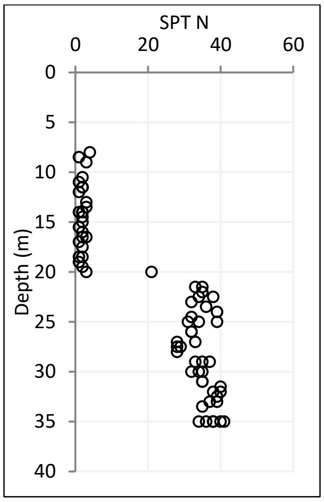
(c) B3

Fig. 6 Cohesion values for Zone 1.

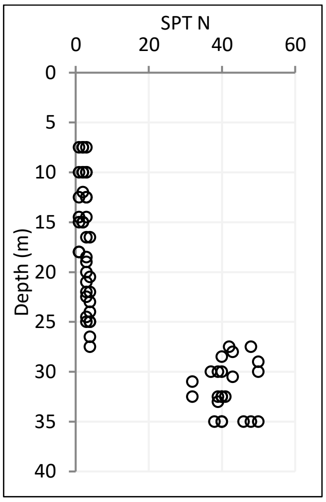
The variation of corrected values of standard penetration test results (SPT-N) measured from a depth of 6.0 m down to 35.0 m for zone B1 is presented in Fig. 7 (a). It can be seen that the values of (SPT-N) at depths ranging between 6-12 m did not exceed 10 blows/300 mm. The soil at this depth can be classified as "soft to medium" in consistency. At deeper depths, sand content increased, reflecting the higher values of (SPT-N) with maximum values recorded at depth 20 - 25 m. The top silty clay/clayey silt layer for Zones B2 and B3 is supported by a soft to very soft clayey silt of low plasticity layer, as indicated by the measured SPT-N values Fig. 7 (b) and (c). This problematic layer extends to a depth of about 20-27 m, making pile foundations with lengths up to this depth is not a favorable choice. The end of this layer showed the appearance of the bearing layer which extends down to the end of boring > 35 m. This stratum typically comprises dense, poorly graded sand.



(a) B1



(b) B2

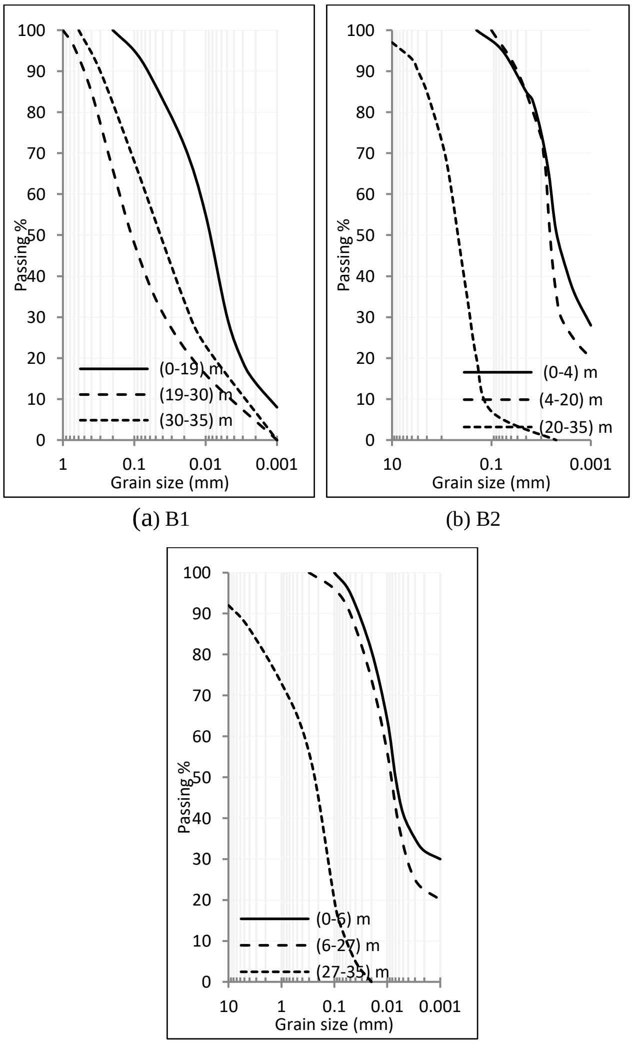


(c) B3

Fig. 7 SPT-N values for Zone 1.

4.6. *Grain Size Distribution*

Fig. 8 (a) shows the average change in soil texture of zone B1 with depth. For the first 19 m of the soil, the average fractions of sand, silt and clay are 7 %, 64 % and 29 %, respectively. The sand fraction, then, increases to about 60 % for depths ranged between 19 - 30 m. Accordingly, silt and clay contents decrease to 30 % and 10 %, respectively. At deeper depths (30 - 35 m), the average content of sand particles is about 38 %, while silt and clay fractions increase to about 45 % and 17 %, respectively. No gravel was found at any depth of zone B1. The average grain size distribution for zones B2 and B3 are almost the same, see Fig. 8 (b) and (c). Down to (4 - 6 m) under the soil surface, fine grains content is divided equally into clay and silt with a very small amount (1 - 3 %) of sand. At the intermediate weak layer, which extends down to 20 - 27 m, the average fractions of silt, clay and sand were 33 %, 63 % and 4 %, respectively. The bearing layer (26 - 35 m) was found to contains 86 % of sand with a little of gravel and silt of about 4 % and 10 %, respectively.



(a) B1 (b) B2

(c) B3

Fig. 8 Average grain size distribution with depth of Zone 1.

4.7. Chemical Test Results

Chemical tests for soil include the determination of total soluble salts, sulphate contents, chloride contents, gypsum content and pH value. All tests are carried out according to BS: 1377 [8]. The chemical tests for the soil are shown in Table 3.

Table 3 Chemical tests results of Zone 1.

	B1			B2			B3		
	Min	Max	Ave	Min	Max	Ave	Mi.	Ma.	Av.
SO_3 %	0.49	0.64	0.54	0.42	0.69	0.56	0.33	0.49	0.41
T.S.S %	9.65	10.3	10.0	7.01	9.61	8.13	6.54	12.0	8.90
Gyp %	7.52	9.66	8.69	6.02	8.32	7.35	5.56	8.91	7.09
Cl %	0.10	0.18	0.13	0.09	0.14	0.11	0.06	0.11	0.08
pH	6.9	7.3	7.0	6.4	7.0	6.7	6.3	7.4	7.0
ORG %	-	-	-	0.21	0.55	0.45	0.32	0.57	0.44

5. Geotechnical Characteristics of Zone 2

The second zone of the study area contains Al-Zubair district. Sand dunes and desert form the majority of this area. Inhabited areas are distributed along and near the contact border with Zone 2. This zone is globally known for its oil and gas fields distributed over the area, e.g. Al-Zubair field, Rumaila field and Safwan field. Moreover, it contains some of most important locations for petroleum industries in Iraq such as the Basrah Refinery plant. Oil fields were the major source of presented data of Zone 2 with more than 23 sites with a water table in the range of (0-15.0 m). Table 4 presents some of the main physical and chemical characteristics of soils in Zone 2.

Table 4 Physical and chemical properties of soils in Zone 2.

Properties	Zone 2		
	Min.	Max.	Ave.
M_C %	6.2	15.7	9.3
Gs	2.62	3.07	2.81
γ_d (gm/cm^3)	1.62	1.82	1.75
γ_b (gm/cm^3)	2.04	1.86	1.90
O.M.C %	9.0	9.5	9.3
Max. γ_d (gm/cm^3)	1.93	2.03	2.00
CBR	8	13	10
SO3 %	0.44	0.57	0.50
T.S.S. %	9.47	10.88	10.23
Gyp %	10.50	12.01	11.23
Cl %	0.09	0.12	0.10
pH	6.7	6.9	6.8

5.1. Subsoil Material Description

The soil strata are found to be consisting of the following three layers:

1. The first soil layer, which extends to a depth ranged between (19.5 - 24.0 m), contains medium to dense, brown, poorly graded sand with or without gravel and sometimes with fine materials.
2. The layer directly beneath the top layer extends to a depth ranged between (22.0 - 24.0 m) and consists of very dense, brown, poorly graded gravel with sand. This layer is sandwiched between two poorly graded sand layers.
3. The last layer, which extends to a depth of 30 m, consists of dense to very dense, brown, poorly graded sand with gravel.

Typical soil profile of this zone is shown in Fig. 9. The Figure shows the variation of SPT-N values with depth.

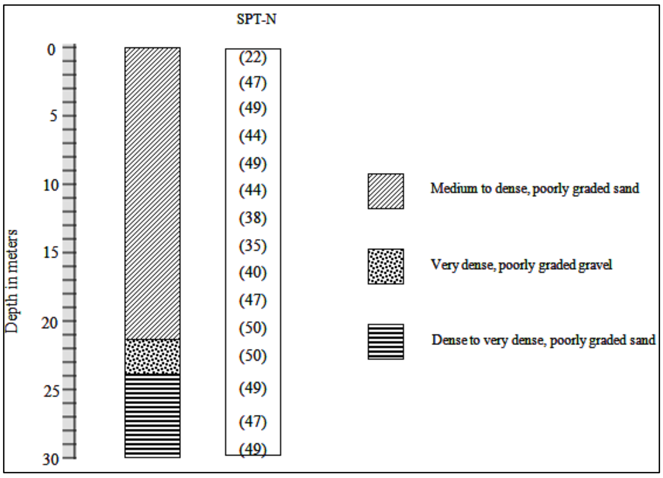


Fig. 9 Typical soil profile and SPT-N values of Zone 2.

Although soil profile characteristics for boreholes drilled in this zone had some differences regarding soil stratigraphy, SPT-N values were found to be consistent with those reported in Fig. 9. The distribution of SPT-N values with depth at various locations of Zone 2 is illustrated in Fig. 10. The difference in the values of SPT-N can be noticed in the shallow depth of less than 5 m. Otherwise, no significant difference in SPT-N values with depth was detected, in which soil layers can be said to have the same consistency limits.

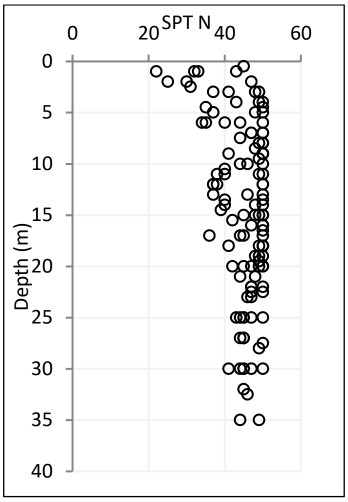


Fig. 10 SPT-N values recorded at Zone 2.

Shear box test results for selected depths showed that the cohesion values are ranged from 0 to 7 kN/m^2, while angles of internal friction for the study area are in the range of (35° - 44°), as shown in Fig. 11.

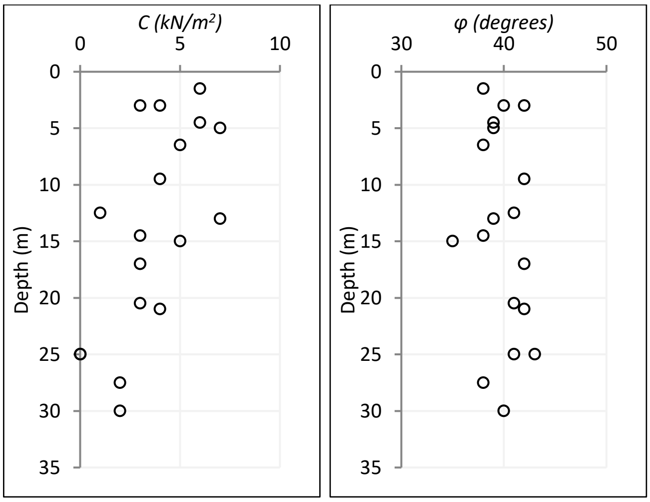


Fig. 11 Variation of *C* and *φ* with depth, Zone 2.

5.2. Grain Size Distribution

Grain size distribution at different depths of Zone 2 is illustrated in Fig. 12. At any depth of soil, fine grains content did not exceed 10 %. The top 22 m contains 80 % and 11 % of sand and gravel, respectively. The next 2 m showed an increase in gravel fraction reached to about 66 %, while sand content decreased to 28 %. From a depth of 24 to 30 m, sand formed the majority of soil particles (56 %) with 34 % of gravel fraction.

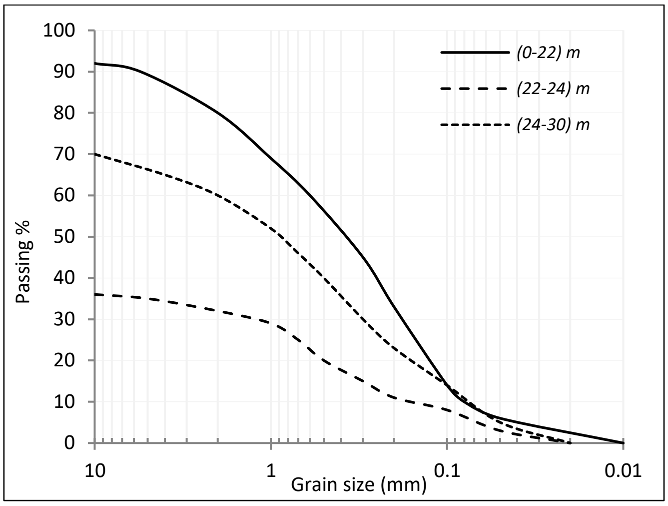


Fig. 12 Average grain size distribution with depth of Zone 2.

7. Conclusions

Geotechnical investigation aimed to explore the subsoil condition of Basrah is reported. A number of fundamental soil properties, which might be important for geotechnical engineers for preliminary assessment of foundation design can be identified. Among these properties are the following:

1. The eastern zone (Zone 1) mainly forms of soft and medium cohesion soils extended from the soil surface up to a depth of 26 m for the middle and southern part of this zone, and down to 16 m for the northern part (Qurna and Midaina). On the other hand, the western zone (Zone 2) can be characterized by sandy surficial and stratigraphic soil.
2. The bearing layer of Zone 1 consists mainly of dense poorly graded sand starts from the end depth of the upper cohesion soil layer to the end of boring.
3. The middle and southern parts of Zone 1 can be considered as one zone as they share similar geotechnical properties, e.g. soil stratigraphy, particle size distribution and standard penetration test results (SPT).
4. According to Atterberg limits and plasticity chart, all types of Basrah fine-grained soils can be identified as low plasticity clay/silt mixtures.

References

[1] H. Hanzawa, "Geotechnical properties of normally consolidated Fao clay", Soils and Foundations, Vol. 17, No. 4, pp. 1-15, 1977.

[2] R. A. Mahmood, and A. A. Albadran, "Geotechnical classification and distribution of the Quaternary deposits in Basrah City, South of Iraq", Iraqi Journal of Earth Sciences, Special Issue, Part 1, pp. 6-16, 2002.

[3] W. R. Muttashar, F. K. Al-Amari, and M. A. A. Al-Hussein, "Geotechnical analysis for types of surficial fine-grained soils at eastern side of Basra region, southern Iraq", Journal of University of Thi-Qar, Vol. 7, No. 2, pp. 1-11, 2012.

[4] M. M. Kadhim, N. K. S. Al-Saoudi, and A. R. T Ziboon, "Digital geotechnical maps of Basrah city using geographical information systems technique", Engineering & Technology Journal, Vol. 31, pp. 599-617, 2013.

[5] H. D. Hany, "Aggregate and fill source study of West Qurna and adjacent area, southern Iraq", Journal of Thi-Qar Science, Vol. 4, No. 3, pp. 137-142, 2014.

[6] E. Al-Taie, N. Al-Ansari, T. E. Saaed, and S. Knutsson, "Bearing capacity affecting the design of shallow foundation in various regions of Iraq using SAP200 & SAFE softwares", Journal of Earth Sciences and Geotechnical Engineering, Vol. 4, pp. 35-52, 2014.
[7] A. J. Al-Taie, "Profiles and geotechnical properties for some Basra soils", AL Khwarizmi Engineering Journal, Vol. 11, No. 2, pp. 74-85. 2015.
[8] BS 1377: 1990 British Standard Methods of Tests for Soils for Civil Engineering Purposes, Part 3-Chemical and Electrochemical Tests, British Standard Institution, London, 1990.

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