Engineering Evaluation of Bearing Strata at Selected Regions in Missan Governorate/South of Iraq

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ABSTRACT

19 boreholes extending to 20 m depth for each were drilled in seven selected regions at Missan Governorate/ south of Iraq in order to study some geotechnical properties of their soils. The results of standard penetration test and particle size analysis are used to classify the Quaternary deposits extending vertically to the consistency and compactness. These layers are; stiff brown silty clay and clayey silt **(CL,CH &ML)**, medium stiff brown and gray silty clay and clayey silt with little sand **(CL,CH & ML)**, stiff gray silty clay and clayey silt with sand **(CL &ML**), very stiff gray silty clay and clayey silt **(CL,CH &ML)**, medium dense gray silty sand (SM), hard brown clay-silt-sand mixture, silty clay and clayey silt **(CL & ML)** and dense and very dense gray silty sand (SM). The bearing capacity of the first layer is suitable to hold shallow foundations of different light buildings in the study area. For heavy structures, piles of different types must be extended to depths that vary between 14-17 m which represent the depth of 6^{th} and 7^{th} layers of high bearing capacity. Plasticity chart shows that most samples are classified as inorganic clays of medium and high plasticity. Most soils are considered to have very high degree of compressibility and high degree of expansion which must be taken in consideration at construction of shallow foundations. The depth of groundwater in study area is shallow, varies between 1-2.5 m, which affects the strength of soil and change the capacity of bearing strata.

KEYWORDES: Missan soils; Geotechnical properties; Soil classification; Standard penetration test; Quaternary deposits.

Introduction

Standard penetration test (SPT) is considered as one of the most common in-situ test to estimate the penetration resistance of soils. It consists of split spoon sampler 50.8 mm out diameter, 35 mm inner diameter, minimum 600 mm long and 63.5 kg hammer freely dropped from a height of 750 mm. Test is performed on a clean hole 50-150 mm in diameter. Split spoon sampler is placed vertically in the hole, allowed to freely settle under its own weight or with blows for first 150 mm which is called seating drive. The number of blows required for the next 300 mm penetration into the ground is the standard penetration number (N-values) (Waltham, 2009).

Terzaghi and Peck (1967) realized that the penetration resistance of split spoon sampler could provide useful in-situ test data that might correlated with the consistency of the cohesive soils and compactness of the noncohesive soils encountered as shown in Table 1.

Table 1: Estimated values of compactness of noncohesive soils and consistency of cohesive soils based on SPT N-values, (Rogers, 2006).

Compactness of noncohesive soil	**SPT N-values**	**Φ**	**Consistency of cohesive soil**	**SPT N-values**	**c kPa**
Very loose	<4	<30	Very soft	0-2	<20
Loose	4-10	30-32	Soft	2-4	20-40
Medium dense	10-30	32-36	Medium stiff	4-8	40-75
Dense	30-50	36-40	Stiff	8-15	75-150
Very dense	>50	>40	Very stiff	15-30	150-300
			Hard	>30	>300

SPT uses for calculating static and dynamic properties of coarse grained soils such as the internal friction angle (Φ), relative density (D_R), the allowable bearing capacity, shear wave velocity (V_S) of soils and liquefaction potential. Also, It has been applied to fine grained soils to estimate engineering properties such as undrained compressive strength (q_u), undrained shear strength (S_u), undrained cohesion, coefficient of volume compressibility (m_v) and compression index (C_c) (Das,2002) and (Graig,2004).

The primary soil constituent is defined as the material fraction which has the greatest impact on the engineering behavior of soils and usually represent the soil type. The particle size analysis is a simple informative classification test routinely performed in soil mechanics. Valuable information regarding the amount of each particle size can be determined in the laboratory. The purpose of soil classification is to provide the geotechnical engineer with a way to predict behavior of the soil for engineering projects. The unified soil classification system (USCS) is the most widely used as soil classification system (Day, 2006). The basic element of this system is the determination of the amount and distribution of the particle sizes of the soil. The system is based on both grain size and plasticity characteristics of soil. Soils are broadly divided into coarse-grained soils, fine-grained soils and organic soils (Ramamurthy & Sitharam, 2010). Grain size have significant influence on the engineering behavior of soils. Generally, the larger the particles, the higher the strength, and deposits consisting of a mixture of different-sized particles usually are stronger than those that are uniformly graded (Bell, 2007).

The aim of this study is to classify the bearing strata in selected regions at Missan governorate, south of Iraq by using the results of standard penetration test (N-values) and particle size analysis to give an idea about the engineering behavior of soils at these strata at construction, and some of their geotechnical properties.

This research can be considered as a part of a series of researches concerned with geotechnical properties of soils at southern part of Iraq (Mahmood & Albadran, 2002; Albadran & Mahmood, 2006 and Mahmood & Mutasher, 2011).

Location and geology

The study area is located in Missan governorate, south of Iraq between latitudes 31° 25′ and 32° 10′ north and longitudes 46° 40′ and 47° 25′ east Figure 1.

The study area is flat and featureless surface bounded by the foothill zone (Hemrin hills) in the northeast along the Iraqi-Iranian borders (Al-Abadi, 2011). It is located at Tigris subzone of the Mesopotamian zone of the stable shelf. Sediments of Holocene age cover its surface. They comprise fluvial and lacustrine deposits. Soils of the study area are transported soils as a result of erosion of Zagros and Torose mountains which redeposit in flood plain of Tigris river making a succession of clayey and silty deposits that represent the upper cohesive layer of recent sediments which cover the coarser non cohesive Pleistocene sediments of Dibdibba Formation (Mutlag, 2009). Aeolian deposition has also contributed to the sediments of the area. Human activities form a significant factor in the developing of the area for several thousand years (Jassim & Goff, 2006).

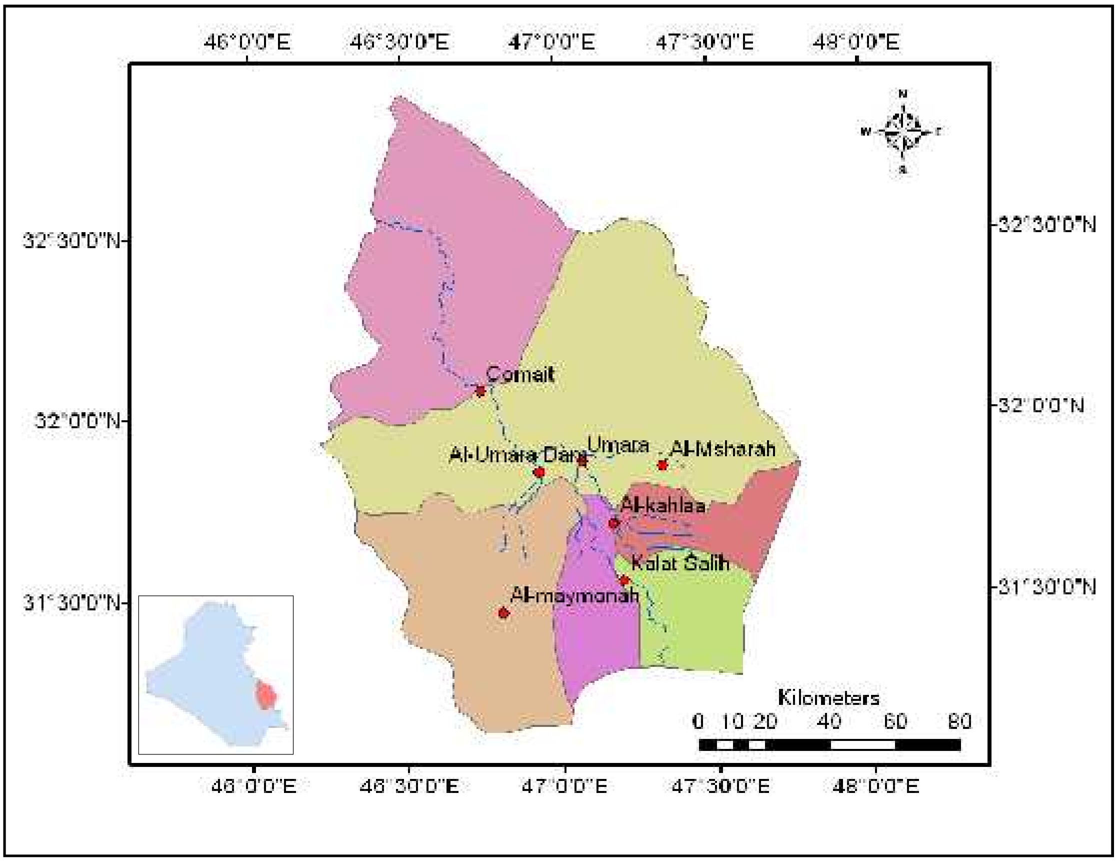

Figure 1: Map of Missan governorate and locations of the study areas

Methods

The data of this study are collected from soil investigation reports conducted by Basra Construction Laboratory of the National Center for Construction Laboratories and Researches (NCCLR) for seven sites distributed in Missan governorate at Comait, Umara, Al-Umara dam, Al-Msharah, Al-Maymonah, Al-Kahlaa and Qalat-Salih cities (Figure 1). These sites are given numbers from 1-7 respectively. The site investigations involved drilling of 19 boreholes to depths of 20 m for each, sampling disturbed and undisturbed samples, and standard penetration test (SPT) and the measurement of water table according to BS 5930:1999. At soil laboratory, particle size analysis and Atterberg's limits tests were done according to ASTM D422-63(2002).

The N-values of SPT are used for classifying the Quaternary deposits extending vertically to the depth of study area as layers according to their consistencies and compactness using the classification of Terzaghi & Peck (1967). The results of particle size analysis and Atterberg's limits tests are used for unified classification of soils in these layers as shown in Figures 2,3,4,5,6,7,8&9 and table 2. Atterberg's limits are used also to classify soils of study area according to their plasticity, degree of compressibility and degree of expansion.

Results and Discussion

Figures from 2 to 8 and table 2 show the results of standard penetration test and particle size analysis of soils at different depths at sites of study. It is easy to note that these soils are composed of alternating layers of cohesive and noncohesive soils with different consistency and compactness extend to different depths and lateral extensions with different thicknesses. According to that, these soils which represent the Quaternary deposits in the study area can be divided into seven layers of different geotechnical properties and bearing capacities as shown in table 2. These layers are illustrated through seven vertical sections shown also in figures from 2 to 8.

These layers are (From top to bottom):

-First layer: Stiff brown silty clay and clayey silt **(CL,CH &ML)**. It extends from the surface to depths 14,6,11,4,3,3&5 m at the seven sites respectively .

-Second layer: Medium stiff brown and gray silty clay and clayey silt with little sand in some regions **(CL,CH &ML)**. This layer extends from depths 6,4,3,6&5m, with thickness of 5,9,4,5 &8m at sites 2,4,5,6 &7 respectively.

-Third layer: Stiff gray silty clay and clayey silt with sand **(CL &ML)**. This layer extends from depths 11,13,9 &11m with thickness of 2,1,1&2m at sites 2,4,5&6 respectively.

-Fourth layer: Very stiff gray silty clay and clayey silt **(CL,CH &ML)**. This layer extends from depths 13,11&10m with thickness of 3,4&3m at sites 2,3&5 respectively.

-Fifth layer: Medium dense gray silty sand (SM). This layer extends from depths 14,16,13,13&13m with thickness of 2,1,1,4&2m at sites 1,2,5,6&7 respectively.

-Sixth layer: Hard brown clay-silt-sand mixture, silty clay &clayey silt **(CL &ML)**. This layer extends from depths 16,14,14,17&15m with thickness of 1,6,6,3&5m at sites 1,4,5,6&7 respectively.

-Seventh layer: Dense and very dense gray silty sand (SM). This layer extends from depths 17,17&15m with thickness of 3,3&5m at sites 1,2&3 respectively, and at site 6 has thickness of 3m between layers 1&2.

The first layer at location 1 has a lens of medium dense silty sand with thickness of 1m that extends from depth 10 to 11m. Also, the second layer at locations 4,5&7 have lenses of loose silty sand extend from depths 8,7&9 m with thickness of 1,2&1m respectively.

The bearing capacity of the first layer which vary between 150-300 kN/ m^2 is suitable to hold shallow foundations of different light buildings in the study area. For heavy structures, piles of different types must be extended to depths varying between 14-17 m which represent the depth of 6th and 7th layers of high bearing capacity at study area.

Table 2: Classification and geotechnical properties of Quaternary deposits in area of study.

Layer No.	Thickness of layer m	SPT N-values blows/30cm	Clay%	Silt %	Sand%	L.L%	PI%	Consistency kN/m^2	Bearing capacity kN/m^2
1st layer	3-14	8-15	19-77	21-69	0-37	32-68	11-36	75-150	150-300
2nd layer	3-9	4-8	21-63	26-73	2-30	29-56	9-34	40-75	75-150
3rd layer	1-2	8-15	27-58	34-56	2-29	37-47	10-24	75-150	150-300
4th layer	2-4	15-30	32-87	11-52	1-16	26-60	20-36	150-300	300-600
5th layer	1-4	10-30	5-11	10-31	60-83	—	—	--	100-300
6th layer	1-6	>30	26-77	20-64	3-37	37-51	16-23	>300	400-800
7th layer	3-6	30->50	4-12	9-34	54-86	—	—	--	>600

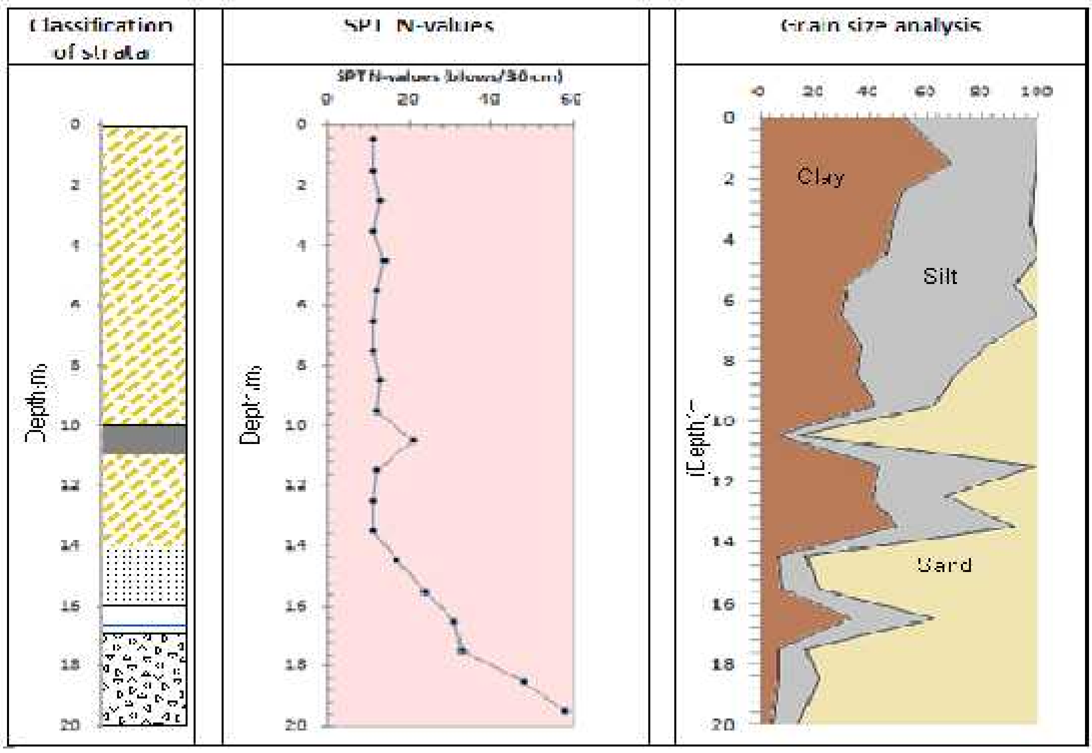

Figure 2: Bearing strata, N-values and grain size analysis of soils at Comait city (Site 1)

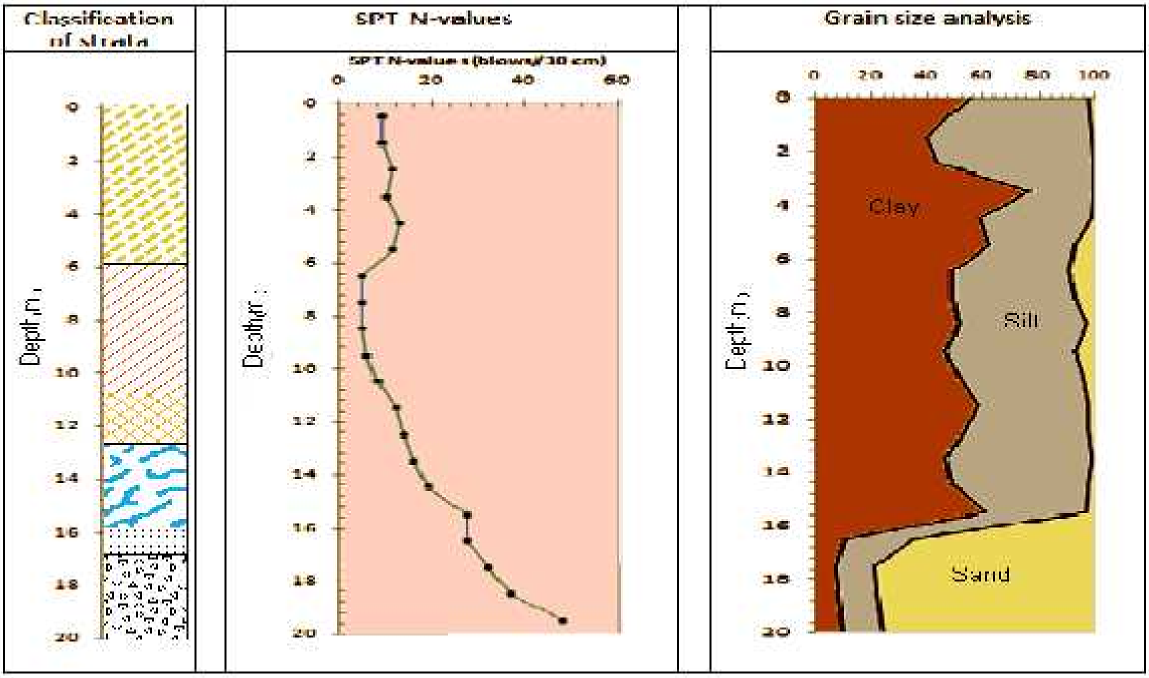

Figure 3: Bearing strata, N-values and grain size analysis of soils at Umara city (Site 2)

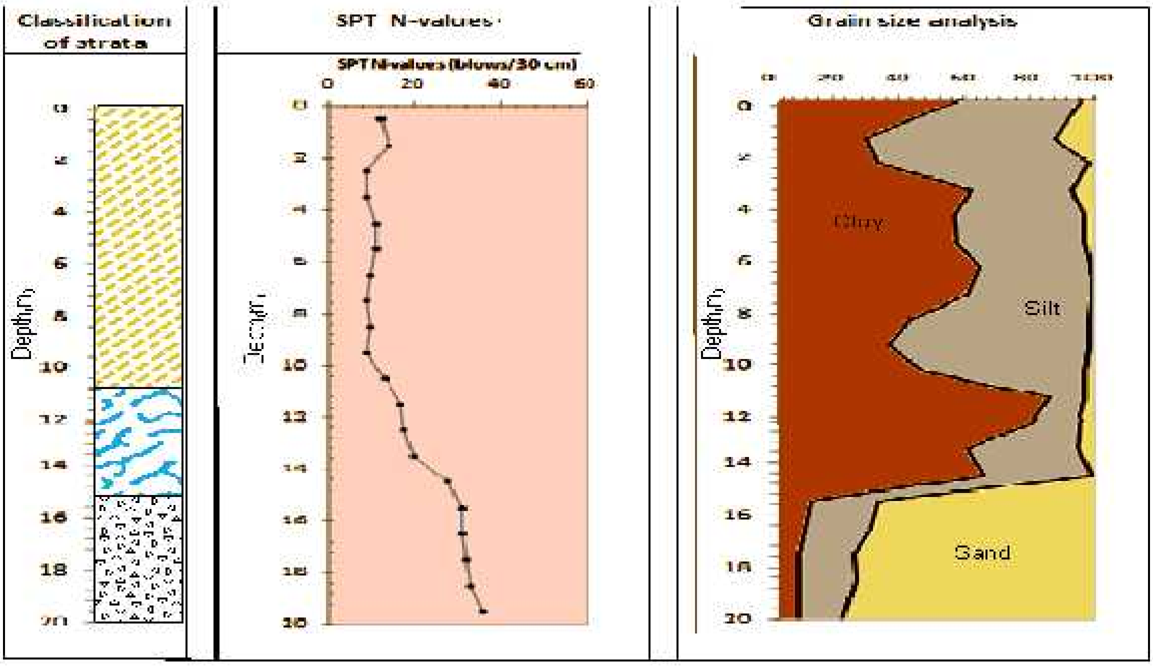

Figure 4: Bearing strata, N-values and grain size analysis of soils at Al-Umara dam (Site 3)

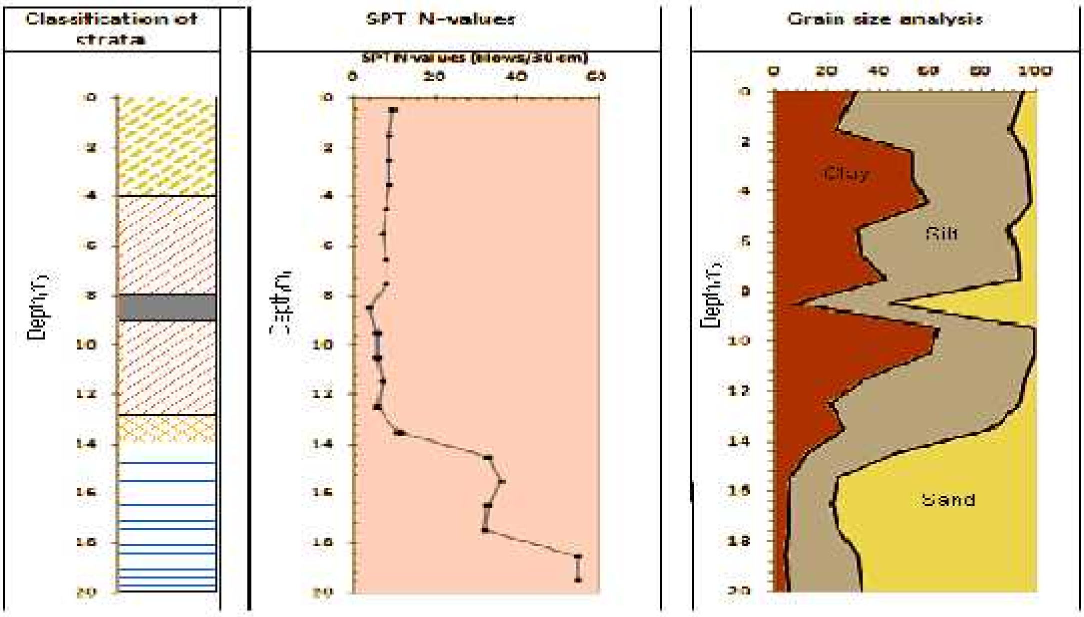

Figure 5: Bearing strata, N-values and grain size analysis of soils at Al-Msharah (Site 4)

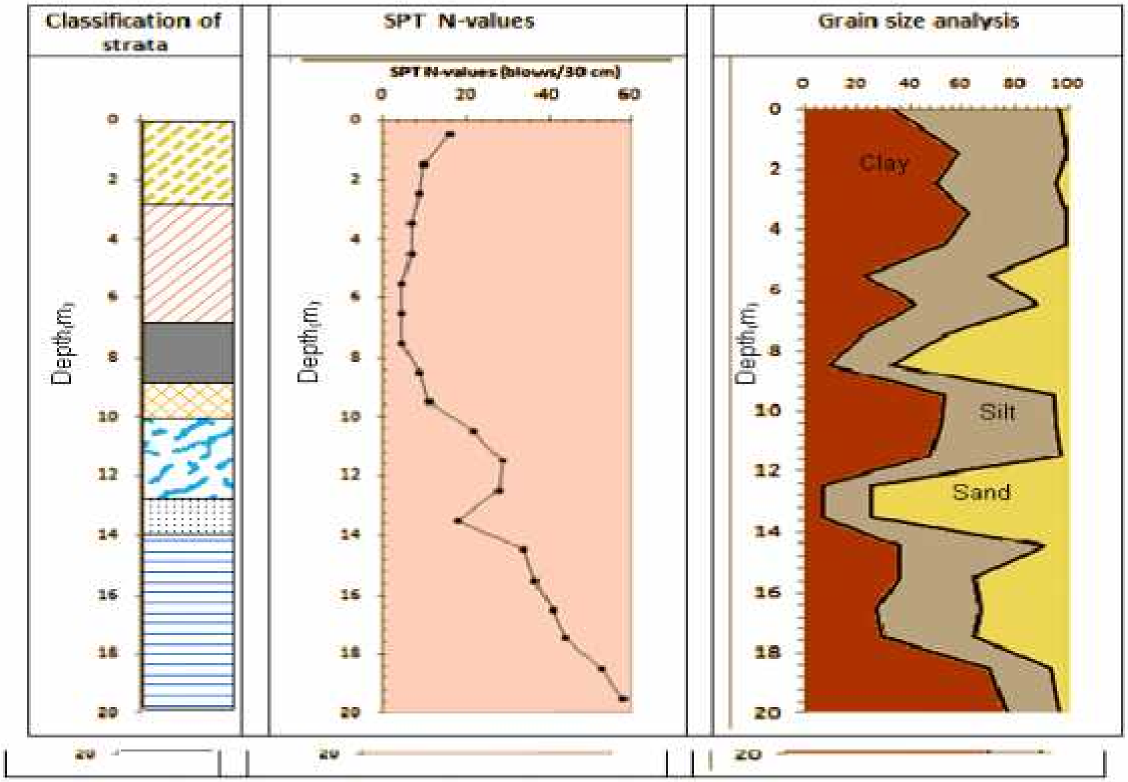

Figure 6: Bearing strata, N-values and grain size analysis of soils at Al-Maymonah (Site 5)

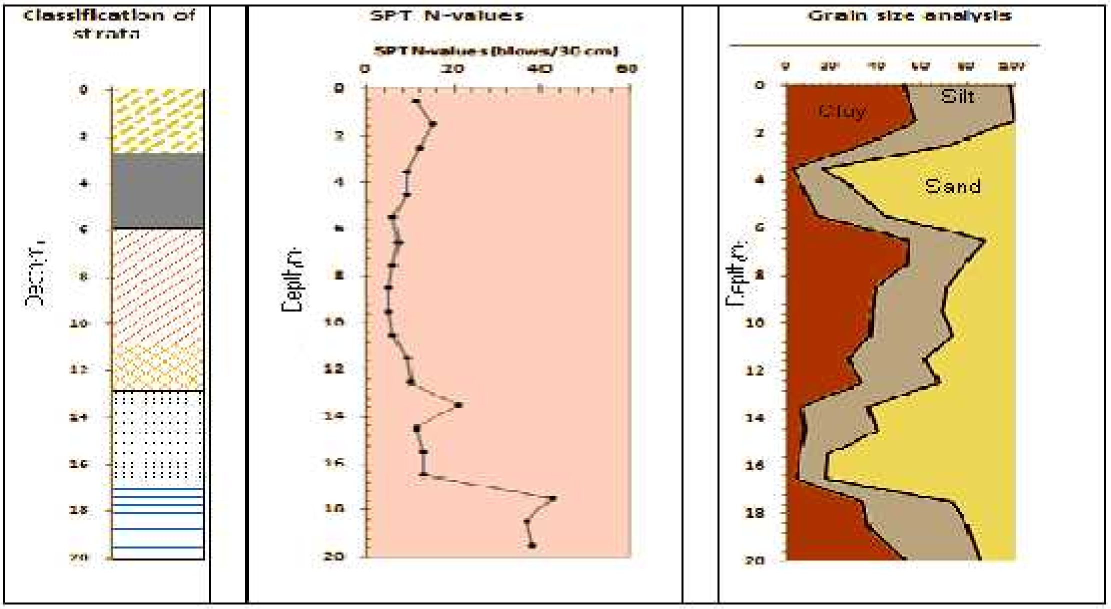

Figure 7: Bearing strata, N-values and grain size analysis of soils at Al- Kahlaa (Site 6)

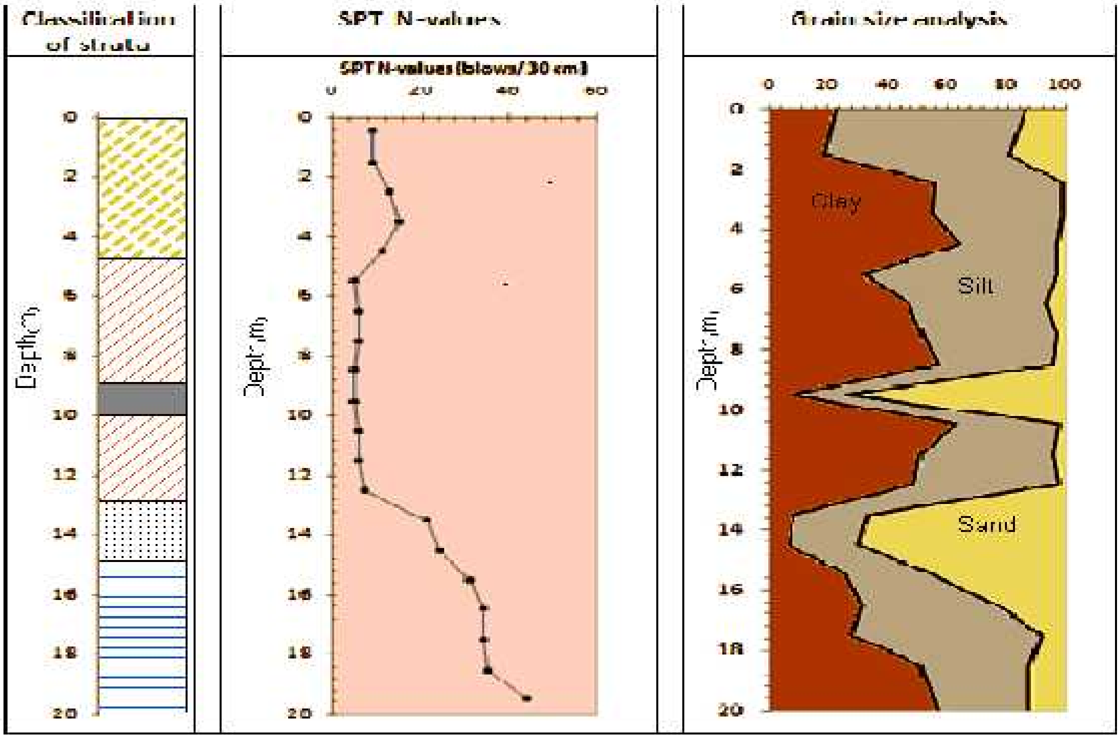

Figure 8: Bearing strata, N-values and grain size analysis of soils at Kalat Salih(Site 7)

Clays are often encountered in combination with other soil constituent such as silt and sand. If a soil exhibits plasticity, it contains clay. The amount of clay can be related to the degree of plasticity, the higher the clay content the greater the plasticity (Hunt, 1984). The interaction between the coarse and fine grain matrices affect the overall mechanical behavior of the mixture of these soils. Fines may affect the compressional characteristics of coarse grained soils (Cabalar, 2008).

Geologic age also has an influence on the engineering behavior of clay deposits. In particular, the porosity, moisture content and plasticity normally decrease in value with increasing depth and there by age, whereas the strength and elastic modulus increase (Bell, 2007).

Atterberg's limits are index of soil properties that are mainly used for identification, description and classification of fine soils. Depending on the water content, the behavior of soil can be divided into four basic states–solid, semisolid, plastic and liquid. Atterberg's limits are the boundaries between these states which are called shrinkage limit, plastic limit and liquid limit respectively (Das, 2002). Liquid and plastic limits provide information about the nature of cohesive soils. Engineers use them for correlation of several physical soil parameters such as permeability, coefficient of consolidation, compression index and swelling potential as well as for soil identification (Saad,2012).

Plasticity chart is useful indicator of likely behavior for soils. Those that plot well above the A-line behave as inorganic clays, and those that plot well below behave as organic clays or inorganic silts indexes. The materials classified as CH, MH and OH are typically unsuitable for construction and must be avoided (Keystone,2003). (Das,2002). The information provided in the plasticity chart is the basis for the classification of fine grained soils in the Unified Soil Classification System (Kayabali, 2011). Figure 9 show the plasticity chart and the classification of cohesive soils at different bearing strata in the study area according to their liquid limits and plasticity

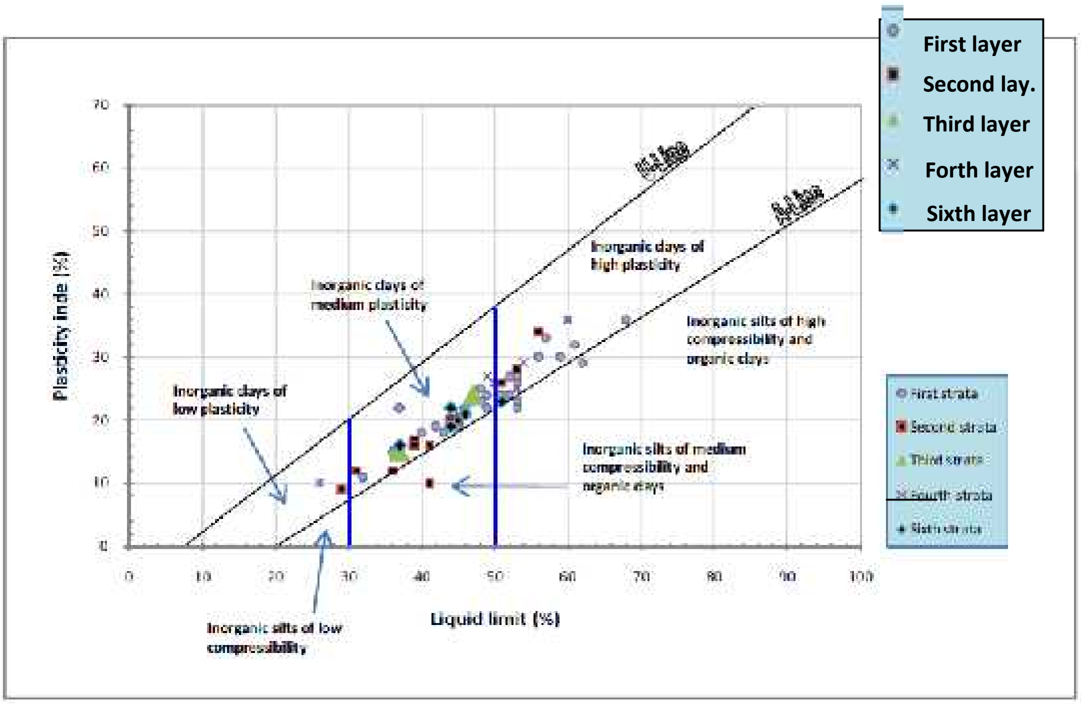

Figure 9: Classification of soils at study area according to plasticity chart after (Das,2002)]

Plasticity chart show that 2 samples are classified as inorganic clays of low plasticity, 38 as inorganic clays of medium plasticity, 16 as inorganic clays of high plasticity, 1 as inorganic silts of medium compressibility and organic clays, and 3 samples as inorganic silts of high compressibility and organic clays.

Based on plasticity index, soils have been classified as indicated in table 3. Among 60 samples had been tested, soils of 14 samples are considered to have medium plasticity with plasticity index between 7-17%, whereas the others are considered to be highly plastic with plasticity index between 18-36%.

Table 3: Classification of cohesive soils according to their plasticity.[after(Al-Kasabi,2006)]

Plasticity index %	**Plasticity**
0	Non plastic
< 7	Low plastic
7-17	Medium plastic
>17	Highly plastic

The compressibility of clay can be expressed in terms of compression index (C_c) which tends to be applied to normally consolidated clays. Skempton (1944 in Wesley, 2003) related the compression index to the liquid limit (LL) by the expression:

$$C_c = 0.009(LL-10) \quad \ldots\ldots\ldots\ldots\ldots 1$$

The compression index (C_c) increases with increasing clay content and so with increasing liquid limit. Table 4 shows an approximation of the degree of compressibility of fine soils (Bell, 2007).

Table 4: Range of compressibility of fine soils.[after (Bell, 2007)].

Soil type	Rang of compression index	Degree of compressibility
Soft clay	> 0.3	Very high
Clay	0.15-0.3	High
Silt	0.075-0.15	Medium
Sandy clay	< 0.075	Low

The compression index of 60 samples from 1st, 2nd, 3rd, 4th & 6th layers had been calculated as shown in table 5. The results vary between 0.144 to 0.522 with average 0.325. So, the soils of study area are considered to have a very high degree of compressibility.

Table 5: The values of compression index of soils at study area.

LL	C_c	LL	C_c	LL	C_c	LL	C_c	LL	C_c	LL	C_c
40	0.27	48	0.342	48	0.342	41	0.279	44	0.306	26	0.144
42	0.288	59	0.441	53	0.387	51	0.369	47	0.333	53	0.387
68	0.522	52	0.378	53	0.387	29	0.171	37	0.243	45	0.315
62	0.468	49	0.351	43	0.297	36	0.234	60	0.45	44	0.306
44	0.306	46	0.324	52	0.378	41	0.279	45	0.315	51	0.369
36	0.234	37	0.243	56	0.414	51	0.369	60	0.45	44	0.306
61	0.459	49	0.351	49	0.351	31	0.189	45	0.315	46	0.324
47	0.333	45	0.315	53	0.387	39	0.261	54	0.396	37	0.243
37	0.243	53	0.387	57	0.423	39	0.261	50	0.36	47	0.333
51	0.369	32	0.198	53	0.387	45	0.315	49	0.351	42	0.288

One of the most notable characteristics of clays from the engineering point of view is their susceptibility to slow volume changes. They can expand and contract, which can cause structural damage. If the swelling pressure of a soil is very high the damaging potential of the soil will also be very high and vice versa (Sabat, 2012). Clay used as bearing soils may require mitigation such as heavier loads, subgrade removal and replacement below the foundation, or moisture control within the subgrade. According to Seed et al. (1962 in Hakari & Puranik, 2010), degree of expansion of clayey soils can be estimated from liquid limit results as shown in table 6. At study area, the values of liquid limit vary between 26 to 68% (as shown in table 2) with an average of 45.3%. Therefore, soils are considered to have high degree of expansion which must be taken in consideration at construction of shallow foundations.

Table 6: Estimation of degree of expansion of clayey soils from liquid limit values. [After Seed et al. (1962 in Hakari & Puranik, 2010)]

Liquid limits	**Degree of expansion**
60-70	Very high
40-60	High
30-40	Medium
20-30	Low

Clay deposits are composed principally of fine Quartz and clay minerals. The three major clay minerals are Kaolinite, Illite and Montmorillonite. Both Kaolinite and Illite have non expansive lattices and their clays are inactive, whereas the Montmorillonite is expansive and montimorillonitic clays are active. Active clays have a relatively high water holding capacity and high cation exchange capacity. They also have low permeability and low resistance to shear (Nassaji & Kalantari, 2011).

Results of mineralogical analysis by the X- ray diffraction show that the clay minerals in selected regions at Missan soils are Montmorillonite 36%, Illite 23%, Montmorillonite-Chlorite 20%, Palygorskite 19%, Kaolinite 17% and Chlorite 7% (Sameen, 2011).

Consolidation of silts is influenced by grain size, particularly the size of the clay fraction, porosity and natural moisture. Settlement may continue for several months after construction is completed because the rate at which water can drain from the voids under the influence of applied stress is slow (Bell, 2007). The clay particle content is very important factor effecting the soil liquefaction which may occur due to the increasing of silt percentage (Liang et al., 2000).

Densely packed sand are almost incompressible if a wide range of particles sizes is present, the void space is reduced accordingly, hence the maximum density is higher. Settlement in sand is relatively rapid. The internal shearing resistance of coarse soil is generated by friction when the grain in the zone of shearing are caused to slide, rolled or rotate against each other (Bell, 2007).

The depth of groundwater in study area is shallow, vary between 1-2.5m. The presence of water table at foundation depth affects the strength of soil and change the capacity of bearing strata. Further, the unit weight of soil to be considered in the presence of water table is submerged density and not dry density. Evaporation & transpiration from vegetative cover is major cause of water loss from soils in semi – arid regions (Bell, 2007)

CONCLUSIONS

- Quaternary deposits within the depth of the study area are cohesive and noncohesive soils which can be classified into seven bearing strata of different consistency and compactness with different lithology, color, vertical and horizontal extensions and thicknesses.

- The bearing capacity of the first layer is suitable to hold shallow foundations of different light buildings in the study area. For heavy structures, piles of different types must be extended to depths ranging between 14-17 m which represent the depth of 6th and 7th layers of high bearing capacity at study area.

- Most samples are classified as inorganic clays of medium and high plasticity.

- According to values of compression index, soils of study area are considered to have a very high degree of compressibility and expansion which must be taken in consideration at construction of shallow foundations to prevent damages in construction.

-The depth of groundwater in study area is shallow, varying between 1-2.5 m. The presence of water table at foundation depth affects the strength of soil and change the capacity of bearing strata.

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التقييم الهندسي للطبقات التحميلية في مناطق مختارة من محافظة ميسان / جنوب العراق

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الخلاصة:

حفرت 19 جسة اختبارية بعمق 20 مترا لكل منها في سبعة مناطق مختارة بمحافظة ميسان/ جنوب العراق لغرض دراسة بعض الخواص الجيوتكنيكية للتربة. استخدمت نتائج فحص الاختراق القياسي والتحليل الحجمي للحبيبات في تصنيف رواسب العصر الرباعي في منطقة الدراسة إلى سبع طبقات ذات سعة تحميل مختلفة اعتمادا على التماسك والتراص فيها وهي طبقة الطين الغريني و الغرين الطيني البنية القوية، طبقة الطين الغريني و الغرين الطيني مع قليل من الرمل البنية والرمادية متوسطة القوية، طبقة الطين الغريني والغرين الطيني مع الرمل الرمادية القوية، طبقة الطين الغريني و الغرين الطيني الرمادية القوية جدا، طبقة الرمل الغريني الرمادية متوسطة الكثافة، طبقة خليط الطين- الغرين- الرمل والطين الغريني والغرين الطيني البنية الصلبة، وطبقة الرمل الغريني الكثيف والكثيف جدا الرمادية. تكون سعة التحميل للطبقة الأولى مناسبة لحمل الأسس الضحلة للبنايات الخفيفة، ولكن للمنشآت الثقيلة يجب أن تمتد الركائز المختلفة إلى عمق 14-17 مترا وهو عمق الطبقتين السادسة والسابعة ذات سعة التحميل العالية. نسبة إلى مخطط اللدونة فان معظم ترب المنطقة تعد تربا طينية غير عضوية متوسطة إلى عالية اللدونة، ذات جهد انتفاخ عالي ومعامل انضغاط عالي جدا الأمر الذي يجب أخذه بنظر الاعتبار عند إقامة الأسس الضحلة. يتراوح عمق المياه الجوفية مابين 1-2.5 مترا وتعد ضحلة ومؤثرة في مقاومة التربة.

كلمات مفتاحية: ترب ميسان، الخواص الجيوتكنيكية، تصنيف التربة، فحص الاختراق القياسي، رواسب العصر الرباعي.