------- Iraqi Jour. of Earth Sci., Special Issue* ,Part 1, pp. 6-16 , 2002 -------

Geotechnical Classifications and Distribution of the Quaternary Deposits in Basrah City, South of Iraq

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ABSTRACT

As due to the strategic importance of Basrah city, south of Iraq, the architectural development of the city requires a great deal of studies of the geotechnical properties, engineering behaviours and classification of the soil bearing strata represented by the Quaternary deposits. For such purposes a number of (121) sites distributed randomly all around the city through (491) boreholes of depths (10-48) m below mean sea level are studied.

The data are obtained from the test results of (SPT) , grain size distribution and the Atterberg's limits .

The Quaternary deposits are classified into two main groups; firstly is the cohesive deposits represented by the recent clay and silty clay as well as Alhammar Formation deposits. Secondly is the cohesionless deposits represented by sands of Dibdiba Formation.

According to the consistency of cohesive deposits and the compactness of cohesionless deposits, ten strata can be identified starting from the ground surface, as follows:

Hard brown silty clay, very stiff brownish-grey silty clay or clayey silt, stiff grey clayey silt, medium stiff grey clayey silt laminated with silt, soft grey clayey silt laminated with silt, medium stiff grey clayey silt, stiff grey clayey silt, very stiff grey clayey silt & sandy clayey silt, hard brown clayey silt and very dense grey sand with silty sand.

التصانيف الجيوتكنيكية وتوزيع رواسب العصر الرباعي في مدينة البصرة ، جنوب العراق

الملخص

تمتاز مدينة البصرة باهميتها الاستراتجية حيث يحتاج التوسع العمراني الذي تشهده المدينة حالياً وفي المستقبل الى دراسة متعمقة للخواص الجيوتكنيكية والتصرف الهندسي لرواسب العصر الرباعي اللاتي تمثل طبقات التحميل في المدينة.

لتحقيق هذا الغرض درست نتائج تحريات التربة المنجزة من قبل المركز القومي للمختبرات الانشائية لـ (121) موقعاً موزعاً على ارجاء المدينة ضمت (491) جسة اختبارية امتدت اعماقها ما بين

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*Papers of The First Geological Conference / Mosul University

(10 – 48) متراً من مستوى سطح البحر. انجزت الفحوص الحقلية والمختبرية على نماذج الرواسب التي استخرجت منها وتم تحليل البيانات الخاصة بقيم مقاومة الاختراق القياسي والتوزيع الحجمي للحبيبات وقيم حدود اتربرك.

تنقسم رواسب العصر الرباعي الى نوعين رئيسين هما الرواسب المتماسكة المتمثلة بالرواسب الطينية والغرينية الحديثة ورواسب تكوين الحمار، والرواسب غير المتماسكة المتمثلة بالرواسب الرملية لتكوين الدبدبة.

تم تقسيم رواسب العصر الرباعي في مدينة البصرة (هندسياً) الى عشر طبقات نسبة الى قوام الرواسب المتماسكة وتراص الرواسب غير المتماسكة من السطح الى الأسفل وكما يأتي:-

طبقة الطين الغريني البني الصلبة، وطبقة الطين الغريني او الغرين الطيني البني او البني – الرمادي القوية جداً، وطبقة الغرين الطيني الرمادي القوية، وطبقة الغرين الطيني الرمادي المتطبق مع الغرين متوسطة القوة، وطبقة الغرين الطيني الرمادي المتطبق مع الغرين الضعيفة، وطبقة الغرين الطيني الرمادي متوسطة القوة، وطبقة الغرين الطيني الرمادي القوية، وطبقة الغرين الطيني والغرين الطيني الرملي الرمادي القوية جداً، وطبقة الغرين الطيني البني الصلبة وطبقة الرمل والرمل الغريني الرمادي الكثيفة جداً.

INTRODUCTION

Basrah city, South of Iraq, is an important strategic location which lead to a high population density and great urbanization expansion. Accordingly, it is requested a great deal of studies for the engineering properties and mechanical behaviours of the subsurface foundation soils as the bearing strata of the engineering projects. Due to the lack of documentation there is a great deal of interests and necessities to identify the vertical and horizontal distributions of the subsurface strata of a sufficient bearing capacity together with their mechanical and geotechnical properties. The Quaternary deposits are mainly represented the foundation layers which are considered in this study.

Limited works have been carried out to identify the layering sequence of the subsurface deposits in Basrah destrict in general (Toa Harbor, 1975; GESD & Polservice, 1979; Elamir & Hakki, 1986; Saeedy & Mollah, 1990; Karim, 1991; Khan et. al., 1992; Mohamad et. al., 1996; Albadran & Albadran, 1997 and Mahmood, 1997).

This work, however, is an attempt to analyze a large number of data of subsurface soil investigation available for the city center only to give detailed geotechnical classifications of the subsurface deposits and some of their engineering properties.

LOCATION AND GEOLOGY

Basrah city is located between latitudes (30° 23' and 30° 34') north and longitudes (47° 43' and 47° 52') east at the northwestern part of The Arabian Gulf with altitude of 2.4 m above mean sea level. The climate is hot, semiarid, and characterized by diurnal and annual temperature variation, which ranges between (42) °C in summer and (6) °C in winter. The mean annual rainfall is around (130) mm , which is considered as very low. Due to the hot weather ,especially in summer, the evaporation rates are high and very much exceed the precipitation rates (Alshalash ,1988).

Geomorphologically, the city is almost flat with small rivers network.

Geologically, the city is located at the Zubair subzone of the Mesopotamian, which represents the southern part of the unstable Arabian platform (Buday & Jassim, 1987).

The city settles on the deltaic depression of the Tigris, Euphraties and Shatt al Arab rivers (Alsaiab et.al., 1982). Most of the Mesopotamic deposits are deltaic and fluvial sediments. The fluctuation of the climatic conditions and the sea level were greatly affecting the physical properties of the deposits in this region (Buday, 1980). During the Quaternary period the upper part of Dibdiba , Hammar formations and the recent fluvial flood clay &silt and eolian particles had been deposited. These deposits are normally consolidated (Saeedy & Mollah,1990). The upper part is important for shallow foundations, while the Dibdiba deposits represent the layer of high bearing capacity for the heavy structures (Khan et.al., 1992),which consists of very dense sand laminated with hard clay (Toa Harbor, 1975).

METHODS

The data of this study are collected from subsurface soil investigation reports of (121) sites distributed all around the city, Fig (1). These involve (491) boreholes drilled to depths of (10-48 m) below mean sea level for the period 1978 to July 1999. These investigations were conducted by The Basrah Construction Laboratory of The National Center for Construction Labs. (NCCL).

The standard penetration test (SPT) (BS 5930: 1981), grain size distribution (BS 1377:1975), Atterberg's limits (BS 1377:1975) and other soil geotechnical tests results are used for the analysis in this study. The (N) values of SPT are used for classifying the Quaternary deposits which extend vertically down to (30) m as layers of different consistencies and compactness using the classification of (Terzaghi & Peck , 1967). The results are used to plot two cross-sections illustrating the engineering properties of subsurface layers in the city, Fig (2). Also the grain size distribution results are used for Shepard classification (1954) in (Pettigohn,1975), Fig.(3). However, the Atterberg's limits are used for unified classification of soil (ASTM D2487-83 in Howard, 1984),Fig. (4).

RESULTS AND DISCUSSION

The Quaternary deposits in Basrah city are divided into ten layers of different geotechnical properties, table (1). These layers are illustrated through two crossed profiles, Fig(2). The (AB) and (EF) profiles are extended from Shatt al Arab river to Shatt al Basrah canal and north to the south of the city respectively.

It can be seen clearly that there are two principal layers, the first is cohesive sediments represented by the recent clayey silt and silty clay sediments, underlain by the clayey silt sediments of Hammar formation. Whereas the second principal layer is cohesionless sediments represented by sand deposits of Dibdiba formation. The top stratum is hard silty clay. It is very solid layer like brick when dry, this may be attributed to the natural consolidation of the surface particles resulted from evaporation pumping.

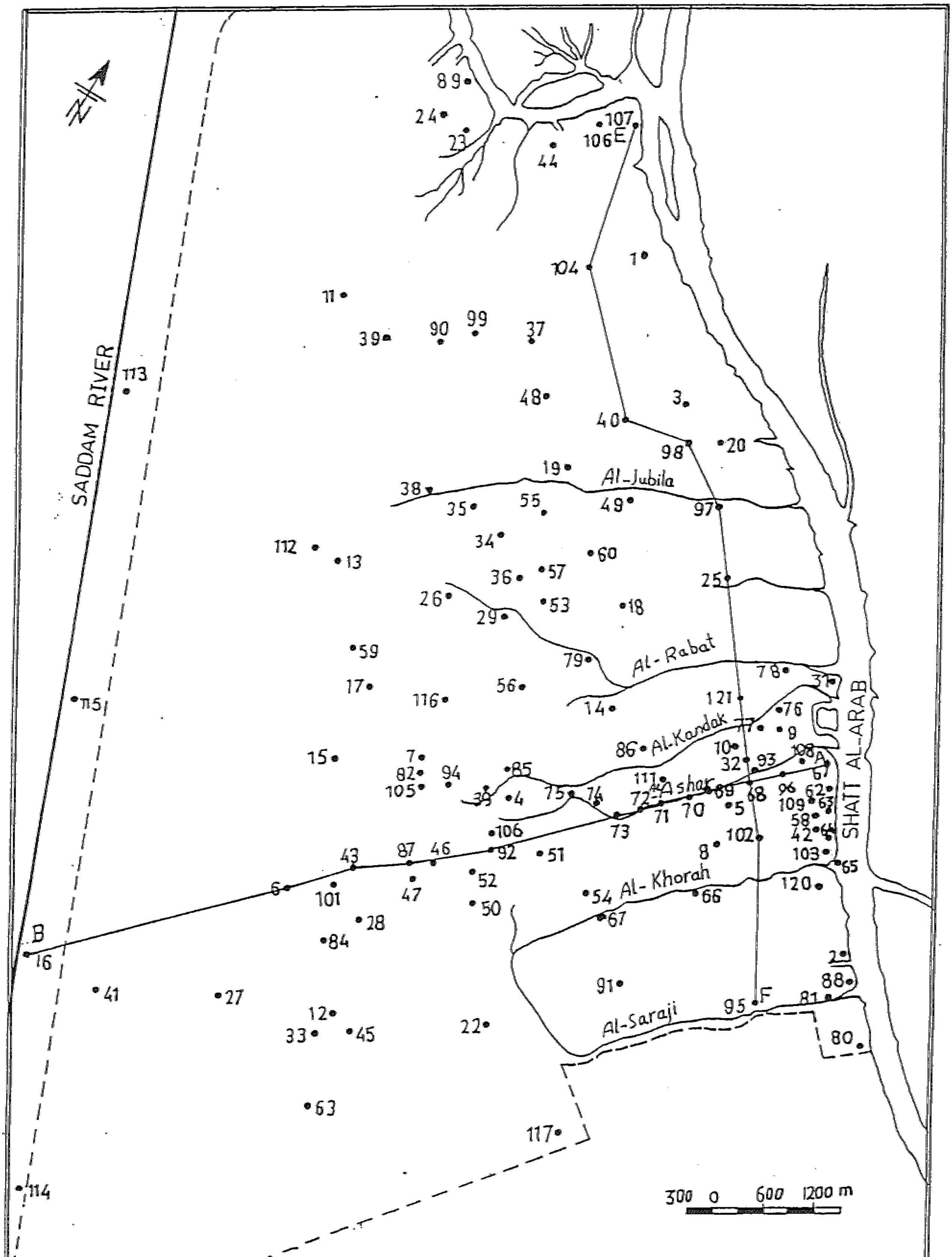

Fig. (1) : Sites of investigation in the region of study

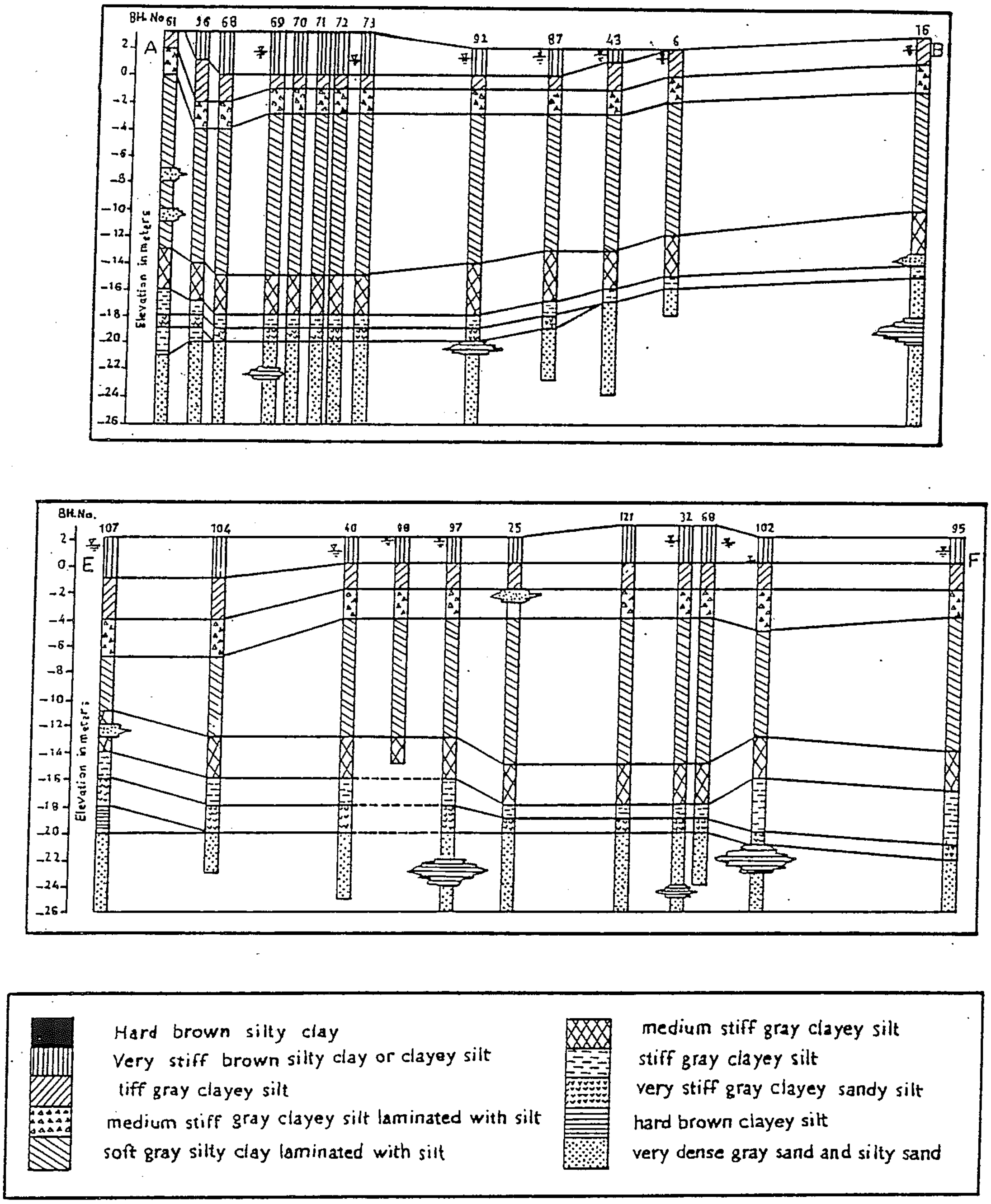

Fig. (2) : Two profiles through Quaternary deposits in Basrah city .

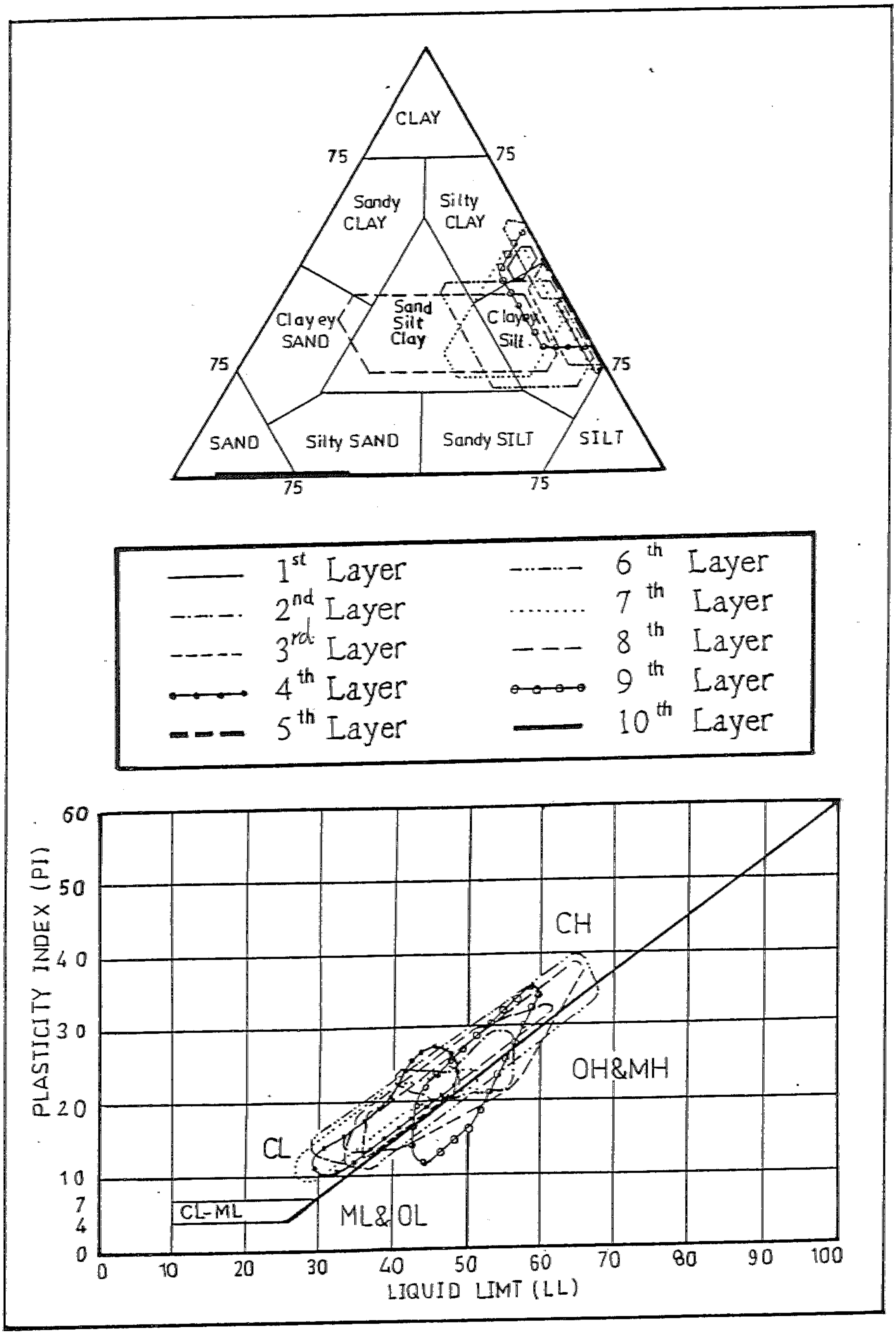

Fig. (3) Classification of soils in the different layers according to (Shepard, 1954).
Fig. (4) Classification of soils in the different layers according to (Unified Soil Classification System).

The following two layers are very stiff & stiff which extend to depth (2-5) m. These layers are considered as problem layers in terms of groundwater movement and fluctuation due to their low permeability ($1*10^{-6}$) cm/min (Hunt.1984), the rainfalls and waters from other resources percolate very slowly downward through them, (Albadran and Mahmood in press).These three layers represent the surfacial deposits which bear the shallow foundations of buildings in the city . Fig.(1) shows the presence of these layers at the surface of Basrah city.

The underlain five layers extend to various depths, i.e. (18 to 23) m with medium stiff, soft, medium stiff, stiff and very stiff consistency, fig.(2). The strength and penetration resistance of these layers are very low but increasing gradually when close to the very dense sand layer.

The maximum strength of the soil and resistance to penetration can be found at the top of the second principal cohesionless layer, which consist of very dense sand and silty sand laminated with hard clayey silt. This layer extends to a depth of more than (30)m.

These deposits are mainly affected by the natural consolidation resulted from mechanical compaction caused by increasing of the overburden pressure during deposition processes (Albadran & Albadran ,1997). The resulted phenomena are the increase of shear strength, high compaction, and low permeability (Lambe & Whitman, 1969). Nevertheless, the inverse grading of soil resistance to penetration from top downward to depth (7)m from the surface may be attributed to the natural dissection of the surface layers(Saeedy&Mollah,1990).

The results indicate a high percentage of clay in the first layer and part of the second layer. Then, a gradual increase of silt contents in the third, forth, and fifth layers, followed by a little increase of sand in the sixth, seventh and eighth layers. Then the sand is decreasing in the ninth layer, but it is increasing by a high percentage (90%) in the tenth layer , fig.(4).

The high percentage of clay (40-59) in the surficial layers resulted in low permeability, and thus the water moves by the capillary suction from the groundwater table. On the other hand, the increase of water retaintion in this soil gives high values of plasticity index and bulk density. More or less, low drainage is the main character of these layers. Thus, quite long time is needed for the dissipation of pore water pressure when these soils are used for embankments. Accordingly, long-term settlement must be considered to occur after layout..

Swelling and shrinking are other phenomena affecting the engineering behaviour of surficial layers which are attributed to the presence of different types of clay minerals (Bell, 1980). The common clay minerals of Basrah city soils are Illite-Palygorskite (61%), Kaolinite (25%), Chlorite (8%), and Montmorillonite (6%)(AL-Marsoomy & Abbas ,1997). Such phenomenon plays a distinctive role on foundation stability. The values of plasticity (20-30) is considered as moderatly effective during the seasonal groundwater fluctuation,(Bell,1980). Thus, during construction it is necessary to avoid the potential zone of soil effected by groundwater fluctuation that is known as effective zone of soil,(Albadran & Mohmood in press).

Liquefaction may be expected during the movement of groundwater through the layers from (3 to 8) of the sequence due to the presence of high percentage of silt content, which increases permeability. This may cause quick conditions, piping and cavities. These behaviours, in fact, reduce soil strength and increase instability and settlement of the structures, (Hunt, 1984). The strength of soils in these layers developed from the friction and apparent cohesion of cohesive material which are reduced during saturation. Accordingly these layers are considered to be of high compressibility and low shear strength. If one of these layers become surficial due to excavation as example, it would show variation in strength according to the change of soil water content. This is greatly effective in fillings and foundations. It is recommended, thus, not to use these materials for filling, this suggestion is supported by (Leonards ,1980).

The increase of sand materials in layers (6-8) increases permeability and bearing capacity. These layers are composed of well graded grains .So, they give less compressibility and high strength as becomes densely packed materials.

The tenth layer of very dense sand and silty sand which laminated with hard clayey silt of ninth layer is considered as the main bearing stratum for heavy structures in Basrah city. It has a different depths (18-34 m) and it's surface inclined with angle $(43)^{\circ}$ toward east & $(30)^{\circ}$ toward north, fig(5). It can be approached by using pile foundations for very heavy constructions. It has bearing capacity of more than (11000) KN/m^2, and characterized by it's low water content (< 10%) due to the overburden pressure, which leads to the migration of water through pores and gradual compactness of sand.

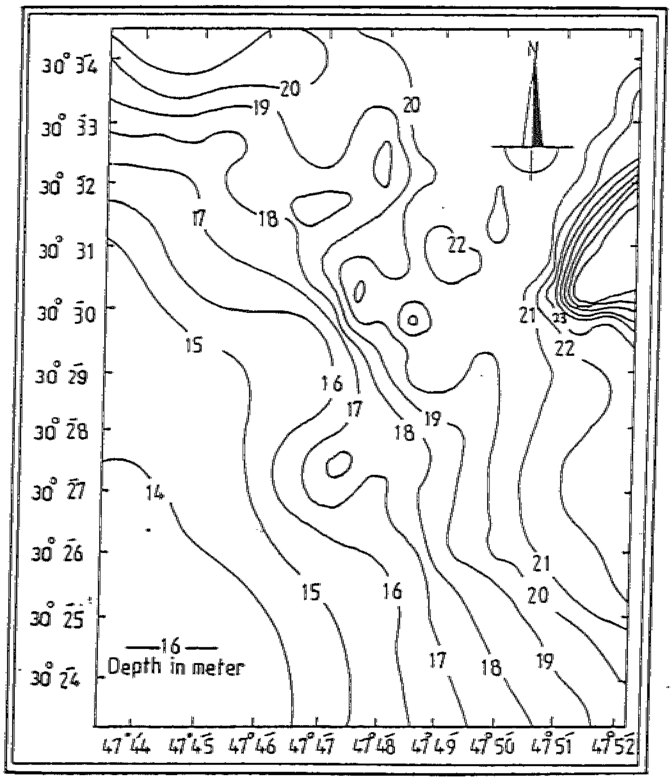

Fig (5) Contor map of high bearing strata depths at Basrah City.

Table (1) Classification and geotechnical properties of the Quaternary deposits in Basrah City

Layer No.	*Thickness of layer m*	*S.P.T N.Values blows/30 cm*	*Particle size distribution*			*Atterbergs limits*		*Symbol of unified classification system*	*Consistency $KN\backslash m^2$*	*Bearing capacity KN/m^2*	*Description of soil*
			Clay %	*Silt %*	*Sand %*	*L.L*	*P.L*				
First layer	1 – 2	>30	37 – 53	44 – 48	1 – 8	43 – 56	21 – 31	CL & CH	>300	400-800	Hard brown silty CLAY
Second layer	1 – 3	15 – 30	40 – 59	38 – 59	0 – 5	40 – 56	21 – 30	CL , CH & OH	150 - 300	300-600	Very stiff brown & brownish gray silty CLAY or clayey SILT.
Third layer	2 – 3	8 – 15	25 – 50	50 – 58	0 – 7	32 – 48	9 – 24	CL	75 - 150	150-300	Stiff gray clayey SILT.
Fourth layer	1 – 3	4 – 8	25 – 40	58 – 75	0 – 3	29 – 49	12 – 26	CL	40 - 75	75-150	Medium stiff gray clayey SILT laminated with SILT.
Fifth layer	4 – 18	2 – 4	25 – 49	51 – 75	-	33 – 65	14 – 39	CL, CH, ML & OH	20 - 40	<75	Soft gray clayey SILT laminated with SILT.
Sixth layer	7	4 – 8	19 - 45	37 - 73	2 - 25	30 - 67	13 - 39	CL , CH ML & OH	40 - 75	75-150	Medium stilt gray clayey SILT.
Seventh layer	1 - 2	8 - 15	22 - 52	41 - 62	3 - 30	30 - 48	11 - 24	CL	75 - 150	150 - 300	Stiff gray clayey SILT.
Eighth layer	1 - 2	15 - 30	23 - 42	15 - 65	8 - 48	36 - 63	14 - 32	CL & CH	150 - 300	300 - 600	Very stiff gray clayey SILT &sandy clayey SILT.
Ninth layer	1 - 2	>30	28 - 57	42 - 69	1 - 11	43 - 59	17 - 36	CL, CH & ML	>300	400 - 800	Hard brown clayey SILT.
Tenth layer	>10	>50	-	8 - 35	65 - 92	-	-	SM	-	>11000	Very dense gray SAND & silty SAND.

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