Study the Suitability of Soil for Engineering Structures in Selected Sites from South of Babylon Al Kifil City (Hilla University).

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الخلاصة

تعتبر دراسة خصائص التربة من العوامل الاساسية في إقامة المنشأ الهندسي من خلال اختيار نوع الأساسات وطريقة إنشاءها وما هي المخاطر المستقبلية التي يمكن ان تؤثر عليها.

أجريت هذه الدراسة على تربة ابنية جامعية تابعة لجامعة الحلة الاهلية الواقعة في جنوب مدينة الكفل التابعة لمحافظة بابل مدينة الحلة. وتهدف إلى أجراء تقييم لبعض الخواص الفيزيائية والكيميائية والهندسية ودراسة أعماق المياه الجوفية في هذه المنطقة للاعتماد عليها في التصاميم الإنشائية ومدى ملائمة التربة لإقامة منشات هندسية عليها.

تضمنت الدراسة حفر أربعة آبار موزعة على المنطقة المذكورة وبعمق 15 متر، وتم استحصال المعلومات من العمل الحقلي وعلى نتائج الفحص المختبري للنماذج المخلخلة وغير المخلخلة المأخوذة من تربة منطقة الدراسة.

من خلال تحليل نتائج الفحوصات المختبرية والحقلية التي أجريت على منطقة الدراسة ، أظهرت نتائج البحث بأن التربة رملية ورملية غرينية وتوصف على انها كثيفة الى عالية الكثافة. تم إجراء تحليل كيميائي للتربة وللماء الجوفي في منطقة الدراسة حيث أشارت النتائج الى ان الماء الجوفي ذو قاعدية عالية اما الأملاح فكانت النسبة تتراوح بين متوسط إلى عالي ، وكذلك فان الماء يحتوي على نسبة الكبريتات للتربة يتراوح بين (0.41–1.74)% ، وبلغت قيمة النسبة المئوية لمحتوى المواد العضوية في التربة بحدود (0.34–0.67)%، وكانت قيمة الاملاح الذائبة الكلية (2.23.–10.27)%، في حين بلغت قيمة محتوى الجبس في التربة بين(0.88–3.74) %كما وقد تراوحت معدل عدد الضربات (SPT) لفحص الاختراق القياسي (14–81)ضربة،عمق المياه الجوفية(2.6–2.65) مترتحت مستوى سطح الارض ولجميع الحفر، ومحتوى الرطوبة يتراوح (23.1–25.5)% من وزن النماذج.وقد كانت نسبة الطين تتراوح (44–54)%، ونسبة الغرين بين (24–28)% كما كانت نسبة الرمل(19–32)%. بلغت قيمة حد اللدونة(18–19)% وحد السيولة(41–52)% اما قيمة معدل نسبة مؤشر اللدونة/نسبة الطين بلغت(0.56) ولهذا صنفت التربة على انها غير فعالة. بينما كانت قابلية التحمل للتربة بالطريقة الديناميكية (7.8–26.4)طن/م2، اما بالطريقة الستاتيكية كانت قيمة قابلية التحمل للتربة (5.86–9.92)طن/م2 وللاعماق (1–4)م. كما وبلغت قيمة الهبوط (2.971)سم وهو ضمن الحدود المسموح بها. وأظهرت ونتائج الفحص المختبري بأن التربة في موقع الدراسة تحتاج الى معالجات هندسية لغرض إقامة المنشآت الهندسية عليها.

الكلمات المفتاحية: الكفل، المنشآت الهندسية، ميكانيك التربة.

Abstruct

study the characteristics of the soil consider from the Fundamental factors in the structural design from which the type and the methods for creating the foundation of the structure, and the future possible dangerous events will be affect on it.

This study is done on a university structure soil belongs for Hilla University building project in Al-Raranjiya– Al-Kifil District , Babylon Governorate.

This study aims to evaluate some of the physical, chemical and engineering characteristics and study the groundwater depths in the study area and depending these characteristics in structural design.

This study includes drilling four exploring wells distributed on the study area at a depth of (15m) for each well. The information was obtained from the field work and results of laboratory testing for the disturbed and undisturbed samples taken from the study area.

From which the analysis of the laboratory and field results on the study area, the soil of this site was clayey silt of low to high plasticity and described as dense to very dense. Chemical analysis was done for groundwater and soil, which revealed that the groundwater with high alkalinity, but the silt was between medium to high, and a high amount of sulfate. The chemical analysis of soil shows the amount of sulfate between (0.41-1.74)% and the organic matter between (0.34-0.67)%, the TDS was between (2.23-10.27)%, but the gypsum content was between (0.88-3.74)%. The number of blows in the standard penetration test was ranged between (14-81) blows. The depth of groundwater was (2.6-2.65m) under the ground surface for all boreholes. The water content was between (23.1-25.5)% from

the sample weight. The percentage of clay ranged between (44-54)%, but the silt and sand was between (24-28)% and (19-32)% respectively. The plasticity limit percentage ranged between (18-19)% and the liquid limit was (41-52)%, but the percentage of (plasticity index /%clay) was (0.56) that it means the soil was inactive. The bearing capacity by the dynamic method was (7.80–26.40) T /m² for all boreholes, but the bearing capacity by static method for depths from (1-4)m was ranged from (5.86-9.92) T /m² . The expected settlement for this site is (2.971 cm). this value is within the permissible limits.

We found that this soil needs some engineering treatments when establishing the engineering structures.

Key words: Al kifil, engineering structures, soil mechanics.

1-Introduction

Study and examine the soil and its suitability to set up any engineering structure is very important where full knowledge of geotechnical and chemical composition and water table helps you choose how the structures you wanted and what remedies applicable to this structures to be successful .

geotechnical study includes know physical properties as porosity, atterberg limits, void ratio, grain size distribution and water content.

Geotechnical study expanding to include exploring the site and study of ground water and its relationship with soil to know soil behavior in case of certain structures on it.

Geotechnical assessment includes the study of geometric properties as well as the stress influenced on the soil as consolidation, resistance and compressibility.

But Soil chemical case as having its salts affect the physical and engineering properties. (Bowles, 1979).

Natural soil composition includes three cases which is solid part of mineral particles (grains) and free oxide and salts as well as organic matter and liquid part of soil water and its contents of solutes and the gas part and free gases, which vary for the parameter of environmental soil condition (Al Rawy *et.al.*, 1986).

For accessing to geological study of the subsurface based on drilling as away to optimal geotechnical testing (Al Sayab and Abdulhameed, 1979; khalaf, 2010).

And to know the cohesion of the soil depends mainly on grain size distribution and upon which to classify the soil so that the shape and size of the particles depends on the nature of weathering and duration of transport and type of transporting factor and this is turn has a significant impact on the stability at the soil.

Aterberg limits are dependent on the amount of water one drown to the surface of the particles and that this attraction depends on the amount of clay in the soil sample.

Based on this the soil efficacy depend on plasticity index that can be obtained from aterberg limits and the amount of fine (grain and clay)which has a role in soil geotechnic assessment.

Engineering use of limits of atterberg is in control of the soil used in filling and in empirical methods in engineering design.

Through the soil description and classification with physical and chemical properties and ground water have reached the field and laboratory examinations gets to the suitability of the soil for their engineering structures.

The purpose of the study is to determine a general investigation of the surface and subsurface conditions at the proposed site and physical and chemical properties for the foundation soil in order to provide the structural engineer with sufficient information for the design of the most suitable and safe foundation.

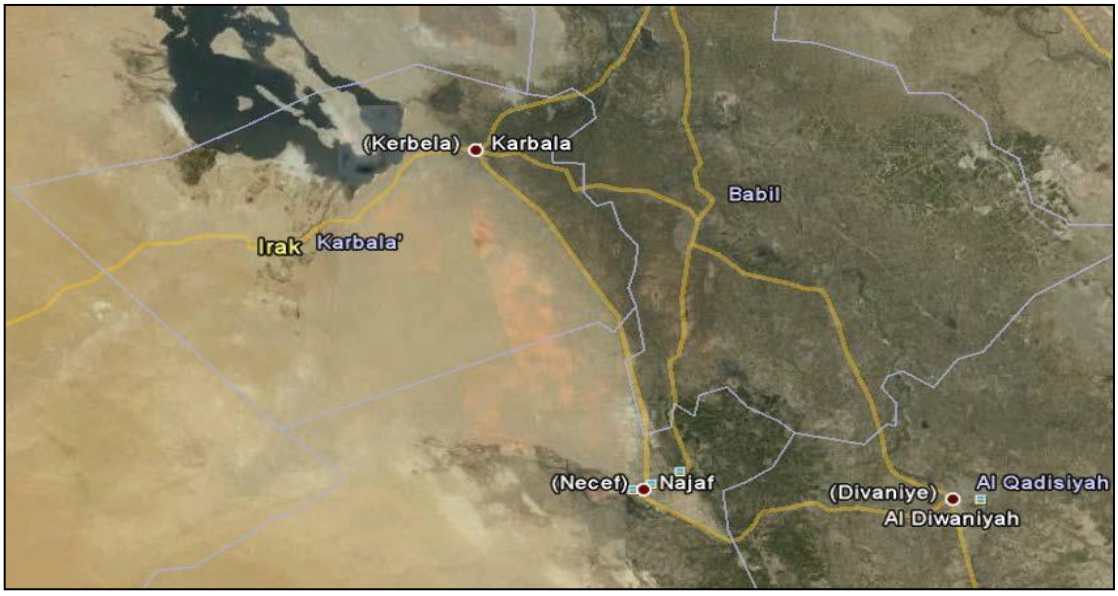
2-Location and geology of the study area

Babil governorate located in the middle of Iraq, at the south of capital Baghdad 100Km distance, the center of Babil governorate is Al Hilla city. The study area

located at the south of Al Hilla city in Al Kifl city, which an agricultural city, considered a link between Middle Euphrates governorates (Karbala, Najaf, Kadisiya and Waset). The location of the study area can be seen in figure(1).

Babylon Governorate (Hilla District) is part of flood plain region, which represent the recent surface formation of Iraq geology, since it contains the recent alluvial sedimentation deposit from the two rivers, Tigers and Euphrates.

However, the site is free from old rock erosion surface. The formation of this flood plain is belonging to Pleistocene period. On the other hand there is depression with fill deposits which accumulated due to successively floods. It consist primary soft layers of fine sand and silt, clay, and silty clay, these layers are present in several region of Babylon Governorate including the investigated site.



-a- . Location of the province of Babylon

-b- Satellite image of the investigation area

Figure(1) Location of the study area

3- Soil layer description or soil profile

The soil consists of the following layers:

a-The sub -soil strata starting from natural ground surface consisting a layer consists of brownish , grayish , greenish silty clay soil (CL , CH) with sand, medium consistency. This layer extends from the depth of (0.0-4.5) m .

b- a layer consists of greenish silty sand (SW,SP), loose to medium dense .This layer extends from the depth of (3.5-6.5) m.

c- a layer consists of greenish , reddish silty clay soil (CL, CH) with sand, medium to stiff to very stiff consistency. This layer extends from the depth of (4.5-10.5) m.

d- a layer consists of greenish silty sand (SW,SP), dense to very dense .This layer extends from the boring end depth of (10.5-15) m.

This consequent changes or sub-soil strata is related to way of deposition , Soil stratification layers with soil properties below the lower part of ground surface in table(1).

Table-1-Soil stratification layers with soil properties below the lower part of ground surface

Layer no.	Soil Layer Description	Av. Thickness (m)
1	Silty sandy clay / sandy silty clay	0.0-4.5
2	silty sand	3.5-6.5
3	Sandy silty clay / silty sandy clay	4.5-10.5
4	Silty sand	10.5-15 m up to E.O.B

Examining the tests results, it can be seen that the range of sulphate (SO_4) in water between (1069-1074) mg/l, while the range of chloride content is between (388-395) mg/l [For water samples]. On the other hand it also noted that the range of pH value for water samples were (7.8-7.9) It can be seen that the TDS of water samples is high and varies from (1251-1258) mg/l.

4- Methods of study:

All tests are performed according to ASTM and B.S standards.

4-1-Field work

4-1-1- Drilling and sampling

Four boreholes have been bored during March -2016 by using mechanical machine type "Flight Auger" drill method by Al Mawal Company for soil Investigations. The method of drilling was carried out according to the standard of the American Society for Testing and Materials (ASTM D-1452 –D5783) which are used for taking the samples. The depth of boring were selected by the Client to extend to underneath the zone of influence of significant foundation pressure to materials that were relatively incompressible. The depth of boring was 15m from the existing Natural Ground Surface (N.G.S) . Three types of sample were taken;

- Disturbed samples (DS) were obtained according to (ASTM D-1586) at intervals of (0.5-1.5) meters, and are required to determine the classification of the soil layers. All disturbed samples were sent to the laboratory for further examination and testing.
- Split Spoon Samples (S.S) were taken from Standard Penetration Test (S.P.T) carried out in site. These were also used as disturbed samples.
- Undisturbed Samples (US) were obtained according to (ASTM D-1587) at intervals of (1-2m) or any change of strata to cover all layers. After extraction, the undisturbed sample was trimmed off, capped with polyethylene sacks or paraffin wax from top and bottom, and sealed properly at both ends, transported to laboratory for further examination and testing as shown in table (2).

Water table measured after 24 hours of boring according to (ASTM D-4750).

Table -2- Types of samples and tests

Type of sample	Method of executed	Test carried on sample
1) Disturbed sample (DS)	Helical auger of machine	Consistency, grain size distribution, chemical analysis, specific gravity.
2) Undisturbed sample US	Shelby Tube	Strength tests, consolidation tests, density.
3) Undisturbed sample SS	Split Spoon	Consistency tests, grain size ,chemical tests, density, strength.

4-1-2- In site testing

4-1-2-1- Standard penetration test (SPT) was carried out at various depths in all boreholes. The tests were performed in accordance with ASTM D 1586-99.

The test consists of driving a standard split spoon (35mm) inside diameter and (50.8mm) outside diameter through three successive lengths by a (63.3kg) hammer falling freely through a height of (76cm) on the head of the drilled rod connected to the upper of the spoon.

The number of blows required to drive through each of the three 15cm lengths was recorded. Generally the summation of the number of blows require for the second and third 15cm lengths (=30cm) is taken as the standard penetration.

The actual depths of SPT (N-values) of each borehole are shown in the borehole logs and on the record test result sheet in appendix A for all boreholes .

If the soil was soft the penetration is fast and the number of blows was little, but if the soil was hard the penetration is slow and many more blows.(Al Asho, 1997).

4-1-2-2- Groundwater table observation

The underground water level (actually it is at the same the river water level) was measured at end of boring at the time of sub-soil investigation (March, 2016) from the natural ground surface (+0.00m) shown in Table (3). The specified depth was fixed after 24 hours of boring termination. However, the depth March fluctuate during the seasons of the year.

Table -3- the underground water level

BH. NO.	The date of measurement	G.W. depth from G.S.
1	March-2016	2.60
2	=	2.60
3	=	2.65
4	=	2.60

4-2-Laboratory work

After completing the first phase above, and after transferring samples to the lab begin phase two (lab work), where laboratory tests are performed on soil samples add to field tests. The study included identifying the required lab testing program, as well as, physical and chemical tests and engineering for soil study area, and required tests are specified on each sample depending on the type of examination sample (DS, US and SS) in accordance with ASTM and BS for each test. Test program included the following laboratory tests:

4-2-1- Physical properties of soil

* Natural moisture content.
* Grain size analysis.

* Atterberg Limits.
* Specific gravity.
* Unit weight (natural and dry)
*Soil Activity

4-2-2 Engineering properties of soil

*standard penetration test
* Consolidation tests, and swelling test
* triaxial compression test (UU)
* Unconfined compression test.
* Direct shear.
*settlment

4-2-3 Chemical Analysis on soil and water

* Total Soluble salts test for soil. (T.S.S)
*Ph test for both soil and water.
* Chloride content cl-.
* Gypsum content.
* Carbonate Content $CaCo_3$.
* Organic matter.
* Sulphat content as So_3 for soil and So_3 for water.

All the tests were conducted according to the current standards of BS1377:1990 part 9 , MD 8264-9 Earth Manual, ASTM standards, mentioned above against each test.

The results of these tests are shown in the record of tests sheet in appendix (1).

5- Results and conclusion

By depending on US and BS international standards in conducting lab tests of sample study area for the purpose of obtaining physical and chemical and engineering properties of the soil of study area as follows:

5-1- Physical properties of soil:

5-1-1- Grain size analysis: Grain size analysis considered the basis for soil classification and inference on their properties (Bowles,1984) The grain size distribution curves of soil samples taken from the boreholes at site were determined using sieve analysis. The experimental equipment and procedure are defined in paragraph entitled "grain size analysis with sieve". The sieving method consists of sorting soil grains by size by passing the soil sample through a stack of sieves. The experimental results of different boreholes are tabulated in Appendix (2).

According to Unified Soil Classification System (USCS), the site soil can in general, be classified as poor to well graded sand (SP to SW) to poorly graded sand with silt (SP-SM) to silty sand (SM). On the other hand, the cohesive soil pockets that encountered at different depths in some locations can be classified as clayey silt of low to high plasticity (ML to MH). The percentage of clay ranged between (44-54)%, but the silt and sand was between (24-28)% and (19-32)% respectively.

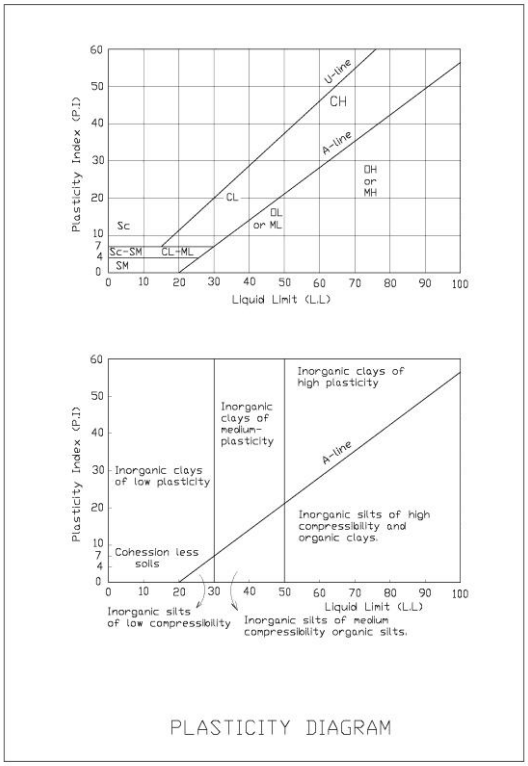
5-1-2- Atterberg limit: Atterberg limit clear impression whether the soil will be exposed to swell or shrink. (chen, 2000).

The liquid limit(L.L) percentage ranged(41-52) but plasticity index (p.L.) ranged (18-19). The average ratio of plasticity index to %clay content equal (0.56)which release that this soil have poor clay activity according to ASTM specifications, so this soil has low swelling tendency.

Results of Liquid Limit (LL), Plastic Limit (PL) and natural moisture content (MC) are plotted against depth as shown in table (4). This test was conducted on samples exhibits cohesive behavior and for cohesive constituents that mixed within cohesionless soil. Liquid Limit and plasticity Index values put on Casagrande Chart

to make material classification as a result of Atterberg Limit Test and **CH "medium-high plasticity clay"** is determined from table (5&6).

Table-4- Casagrande plasticity Chart

Grain size (No.200 >%50)	Low Plasticity Silts and Clays (W_L < %50)	ML	Low plasticity inorganic silts and clayey silts	
		CL	Low plasticity inorganic Clays and Silty Clays	
		OL	Low plasticity organic Silts and Clayey Silts	
	High plasticity Silts and Clays (W_L > % 50)	MH	High plasticity inorganic Silts and Clayey Silts	
		CH	High plasticity inorganic clays and Silty Clays	
		OH	High plasticity organic Clays and Silts	
	Organic soils	Pt	Peat soils and other organic Soils	

PLASTICITY DIAGRAM

Table-5- Index test results and soil classification

Bore-Hole No.	Depth	Water Content	USCS Soil Classification	Sieve analysis		Atterberg limits			Specific gravity
	(m)	%		#10(+)	# 200(-)	% LL	% PL	% PI	
BH-1	1.5-2	8.9	CH	21	79	49	19	30	2.73
BH-2	5.5-6	25.5	CL	25	75	45	18	27	2.72
BH-4	8.5-9	24.8	CL	32	68	43	20	23	2.71

Table-6- Plasticity Index and Liquid Limit PL=LL-PI

Type of sample	B.H. No	Depth (m)	System of classification Sieve &Hydrometer				Properties index			Mc	LI	A
			Clay %	Silt %	Sand %	Grave.%	PL %	LL %	PI %			
US	1	1.5-2	51	28	21	0	19.0	49.0	30.0	8.9	-0.337	0.588
US	2	2-2.5	49	29	22	0	18.0	48.0	30.0	16.7	-0.043	0.612
DS	3	7.5-8	54	27	19	0	19.0	52.0	33.0	25.1	0.185	0.611
DS	4	8.5-9	44	24	32	0	19.0	41.0	22.0	24.8	0.264	0.500

5-1-3- Water content: The water has two effects on the soil, first, it generate the pressure between the grains and the second, it generate a pore pressure which affects the soil behavior. (Fattohi *et.al.*, 1990).

Soil plasticity is also a sign of moisture content. The role of soft parts have been instrumental in changing the physical properties of moisture content change. (Yasin, 1996; Al Jobory, 2002).

The water content is calculated and it ranged from (23.1-25.5), and this high water content causes problems in the process of consolidating and soil swelling and shrinkage And reduce to cohesion.

Where the soil study area as mentioned above is (silty sand clay) near surface. ground water rise is the main cause of high water content and helping the flat the earth makes an easy drainage (Al Zubaidy, 2006).

Water content was determined and ranged between (23.1-25.5)% as described in appendix (1). This percentage of water content considered high and cause troubles in consolidation, swelling and shrinkage, and decease the cohesion of soil. The main reason of high water content is the high level of groundwater.

5-1-4- Activity of soil: With the plasticity index and liquid limit known the Casagrande plasticity chart shows the cohesive soil to have wide range of plasticity CL (clays of medium plasticity) and CH (clays of high plasticity) and OL or ML (silts of medium or high compressibility and clay as shown in Table (4) and Appendix (3). The average ratio of plasticity index to clay content equal (0.56) which release that this soil have poor clay activity according to ASTM specifications, so this soil has low swelling tendency. The results of Plasticity Index have been plotted against its Liquid Limit in Appendix (3) to give the Plasticity Chart, as shown in table (4).

Table -7- Plasticity Index and Liquid Limit PL=LL-PI

Type of sample	B. H. No	Depth (m)	System of classification Sieve &Hydrometer				Properties index			A
			Clay%	Silt %	Sand %	Grave%	PL%	LL%	PI%	
US	1	1.5-2	51	28	21	0	19.0	49.0	30.0	0.588
US	2	2-2.5	49	29	22	0	18.0	48.0	30.0	0.612
DS	3	7.5-8	54	27	19	0	19.0	52.0	33.0	0.611
DS	4	8.5-9	44	24	32	0	19.0	41.0	22.0	0.500

The study area soils are classified as to be ineffective depending on the degree of their effectiveness and less than 0.75. as shown in table (8).

Table -8- showing soil classification according to their effectiveness (Al Asho, 1991)

Effective a	Soil classification
Less than 0.75	Non active
From 0.75-1.25	Normally active
From 1.25-2.0	Active

5-2- Engineering properties of soil:

5-2-1- Bearing capacity: The depth of foundation is depending on the nature, texture, type bearing capacity of the soil and water table of ground water.

Calculating B.C. by **Dynamic method** From the results of in-suite the allowable bearing capacity of the soil from N-SPT method for depth from (1.5 m to 15.0m) is ranging from (7.80–26.40) T /m² for all boreholes, and calculated depend on (Meyerhof,1965) as follows:

$$qull=N/0.08\ [(B+0.3)/B]^2(1+0.33\ Df/B)$$

Results are shown in Table (9) below..

Table -9- allowable bearing capacity of the soil from N-SPT method

Depth (m)	SPT(N) Total for 300mm BH.1	SPT(N) Total for 300mm BH.2	SPT(N) Total for 300mm BH.3	SPT(N) Total for 300mm BH.4	Average SPT(N) Total for 300mm	NC= correction Average SPT(N) Total for 300mm	Ave. B.C T/M^2
1.5	16	12	-	17	15	15	8.25
2.5	-	-	17	-	17	16	8.80
3.0	15	16	-	25	19	17	9.35
4.0	-	-	14	-	14	14	7.80
5.0	22	10	-	13	15	15	8.25
7.0	-	-	20	-	20	18	10.00
8.0	43	38	-	31	37	26	14.30
10.0	-	-	52	-	52	34	18.70
11.0	52	45	-	47	48	32	17.60
12.0	-	-	61	-	61	38	21.00
13.0	61	58	-	-	59	37	20.35
14.0	-	-	-	81	81	48	26.40
15.0	75	91	70	-	79	47	25.85

Calculating B.C. by **static method**: This method for calculating bearing capacity by depending on the Engineering tests. The allowable bearing capacity for foundation shown in Table (10).

The results indicate that the consistency of cohesive soil layer is medium to stiff to very stiff and the relative density of cohesive less soil layer is medium to dense to very dense.

Table-10- The allowable bearing capacity for foundation

Df= the depth of foundation (m)	allowable bearing capacity T/m^2
(1.00) m	(5.86) T/m^2
(2.00) m	(7.10) T/m^2
(3.00) m	(8.23) T/m^2
(4.00) m	(9.92) T/m^2

5-2-2- Settlement

The expected settlement for this site is (2.971 cm). this value is within the permissible limits of (5cm) (ASTM). It was found that the over consolidation ratio OCR varies from (1.177-1.794), In addition the value of compression index and swelling index are ranging from (0. 136-0.174) and(0.024-0.031), respectively. Volume Change Coefficient mv : 0. 00041-0.00052 m^2 / MN , Vertical Consolidation Coefficient c_v : 0. 00022-0.00031 m^2 / MN . The variations of overburden (Po) and preconsolidation (Pc) pressures with depth, as shown in table (11) below.

Table -11- Consolidation parameters with depth.

No of BH	Depth m	Parameters of Consolidation test									
		γ_t g/cm^3	Mc	e_0	C_c	C_r	P_o T/ m^2	P_c T/ m^2	mv m^2/MN	Cv m2/MN	OCR
BH.1	5.5-6	1.84	25.2	0.841	0.136	0.024	11.04	13.0	0.00041	0.00022	1.177
BH.3	3-3.5	1.83	25.3	0.709	0.174	0.031	6.41	11.5	0.00052	0.00030	1.794

5-3- Chemical Test:-

5-3-1- Chemical test of the soil:

From the chemical tests of the soil samples were analyzed for sulphates, chloride content, organic matters content, calcium carbonate, pH, TSS and gypsum

content. The results are summarized in table (12). It is clears that the highest value of sulfate as SO_3 % is in the range of (0.41-1.74%) for soil and the range of chloride content is (0.032-0.054) %. Organic matter of soil samples is varied from 0.34 to 0.67 %. On other hand the TSS and gypsum content were found to vary from 2.23 to 10.27 % and 0.88 to 3.74%, respectively. We suggest to use sulfate resistance Portland cement (SRPC) for foundation and all concrete in contact with soil covered all sides of concrete with bitumen layer with a thick according to choice the designer or minimum cement content is 410 kg/m³, maximum free water/ cement ratio is 0.50 by weight and special precautions should be adopted for concrete reinforcement below ground level due to high percent of chloride content. Protection of the foundation with three layers by bitumen materials highly recommended.

Table -12- Results of chemical analysis for soil

No. of BH	Depth (m)	SO_3 (%)	Gyp. (%)	TSS (%)	ORG (%)	CaCO3 (%)	PH %	Cl%
BH.1	1-1.5	0.41	0.88	2.23	0.67	5.0	7.8	0.054
=	2.5-3	0.69	1.48	4.15	0.61	6.0	8.0	0.049
=	4.5-5	0.75	1.61	4.37	0.52	3.0	7.9	0.044
BH.2	5.5-6	0.91	1.95	5.12	0.46	7.0	7.7	0.041
=	7.5-8	1.68	3.61	7.54	0.40	7.0	7.8	0.038
BH.3	9.5-10	1.53	3.30	8.93	0.34	4.0	8.0	0.032
=	11.5-12	1.74	3.74	10.27	-	9.0	-	-
BH.4	12.5-13	1.38	2.97	8.41	-	5.0	-	-
=	14.5-15	1.64	3.52	9.18	-	3.0	-	-

5-3-2- Water chemical test

According to ASTM D-4750, chemical analysis for ground water is listed in Table (13). The water is shown to be of high alkalinity, medium to high in salts content and it has harmful amount of sulfates (according to ASTM specifications). Precaution should be taken in concreting.

Table -13- Chemical test for ground water

SO4 mg/l	Cl mg/l	PH	EC * 10³ mm hos/cm	TDS mg/l	Depth water (m)	BH .No
1073	394	7.9	1.23	1256	2.60	1
1072	391	7.8	1.19	1251	2.60	2
1069	388	7.8	1.22	1253	2.65	3
1074	395	7.8	1.25	1258	2.60	4

6- Conclusion

Geotechnical investigations have been carried out for the site. In-situ standard penetration tests have been carried out. Laboratory tests have been undertaken to determine Atterberg limits, grading, shear strength parameters, consolidation test and chemical tests for soils (sulphate, organic content, total soluble salts and chloride) and chemical analysis for water (pH, Cl, SO4 and TDS). From the field observation and test results the following conclusions are gathered:

1-The allowable bearing capacity at shallow depth may be taken as (5.87T/m²) at depth 1.0 m, (7.10T/m²) at depth 2.0 m , (8.23T/m²) at depth 3.0 m and (9.92T/m²) at depth 4.0 m .below natural ground level.

2-Ground conditions encountered in the exploratory holes showed that the soil profile consists of the following layers: The soil profile can be described as a layers stratification of different soil types. The cohesive soil of brown to gray silty clay to clayey silt is the most soil abundant at the site. According to USCS; the cohesive soil can be classified as lean (CL) to fat clay (CH). As well as thin layers of cohesion less soil of silty sand soil (SW,SP) poorly graded .

3-Groundwater levels have been recorded. The groundwater table is about 2.60 m.b.g.l below existing ground level .Water flow around the foundations may cause scouring under the foundations so foundation type must be chose carefully. Dewatering is required for the part of structure below the water table level.

7- Recommendations

1- Study of the G.W. in the study area with the possibility to make use of it when establishing a green spaces, and this high level of G.W. (2.6m b. g.l.)can be reduce
2- Study of the mineral elements for the study area with possibility of benefit from it as an economic feasibility after additions.

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APPENDIX (1)

Physical properties & field test for soil for Private Hilla University building project . (BH.1)

Depth m	Type of Sample	Soil classification				Soil Description	Plasticity Index			Unit weight gm/cm³		G.S	SPT(N)
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-0.5	DS	49	24	27	0	Grayish silty sandy clay soil , medium consistency , with organic matter , CL	-	45.0	26.0	-	-	-	-
1-1.5	SS	46	25	29	0		-	-	-	-	-	-	16
1.5-2	US	51	28	21	0	Greenish sandy silty clay soil , medium consistency , CL	8.9	49.0	30.0	1.67	1.82	2.73	-
2.5-3	SS	52	31	17	0		-	-	-	-	-	-	15
3.5-4	DS	6	34	60	0	Greenish , medium dense , fine to medium , silty sand soil	-	-	-	-	-	2.65	-
4.5-5	SS	41	26	33	0	Greenish silty sandy clay soil , medium consistency , CL	-	-	-	-	-	-	22
5.5-6	US	46	23	31	0		25.2	41.0	25.0	1.47	1.84	2.70	-
6.5-7	DS	49	27	24	0	Reddish sandy silty clay soil , stiff consistency , CL	-	-	-	-	-	-	-
7.5-8	SS	53	25	22	0		-	-	-	-	-	-	43
8.5-9	US	48	29	23	0		22.7	45.0	26.0	1.55	1.91	2.72	-
9.5-10	DS	44	30	26	0		-	-	-	-	-	-	-
10.5-11	SS	7	32	61	0	Greenish ,very dense , fine to medium , silty sand soil	26.8	-	-	1.60	2.03	2.65	52
11.5-12	DS	3	29	68	0		-	-	-	-	-	-	-
12.5-13	SS	2	25	73	0		26.0	-	-	1.62	2.04	-	61
13.5-14	DS	2	24	74	0		-	-	-	-	-	2.65	-
14.5-15	SS	3	26	71	0		-	-	-	-	-	-	75

Physical properties & field test for soil for Private Hilla University building project . (BH.2)

Depth m	Type of Sample	Soil classification				Soil Description	Plasticity Index			Unit weight gm/cm³		G.S	SPT(N)
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-0.5	DS	47	24	29	0	Grayish silty sandy clay soil , medium consistency , with organic matter , CL	-	42.0	25.0	-	-	-	-
1-1.5	SS	52	27	21	0	Brownish sandy silty clay soil , medium consistency , CH	-	-	-	-	-	-	12
2-2.5	US	49	29	22	0		26.7	48.0	30.0	1.54	1.80	2.73	-
2.5-3	SS	44	31	25	0		-	-	-	-	-	-	16
3.5-4	DS	7	30	63	0	Greenish , loose dense , fine to medium, silty sand soil	-	-	-	-	-	2.65	
4.5-5	SS	4	32	64	0		29.3	-	-	-	-	-	10
5.5-6	US	45	30	25	0	Grayish sandy silty clay soil , medium consistency , CL	25.5	-	-	1.45	1.82	-	-
6.5-7	DS	49	29	22	0		-	45.0	27.0	-	-	2.73	-
7.5-8	SS	46	23	31	0	Reddish silty sandy clay soil , stiff consistency , CL	-	-	-	-	-	-	38
8.5-9	US	44	26	30	0		22.7	41.0	25.0	1.54	1.89	2.71	-
9.5-10	DS	41	25	34	0		-	-	-	-	-	-	-
10.5-11	SS	7	31	62	0	Greenish , dense to very dense , fine to medium , silty sand soil	27.1	-	-	-	-	-	45
11.5-12	DS	4	33	63	0		-	-	-	-	-	2.65	-
12.5-13	SS	3	29	68	0		26.7	-	-	-	-	-	58
13.5-14	DS	3	27	70	0		-	-	-	-	-	2.65	-
14.5-15	SS	2	31	67	0		-	-	-	-	-	-	91

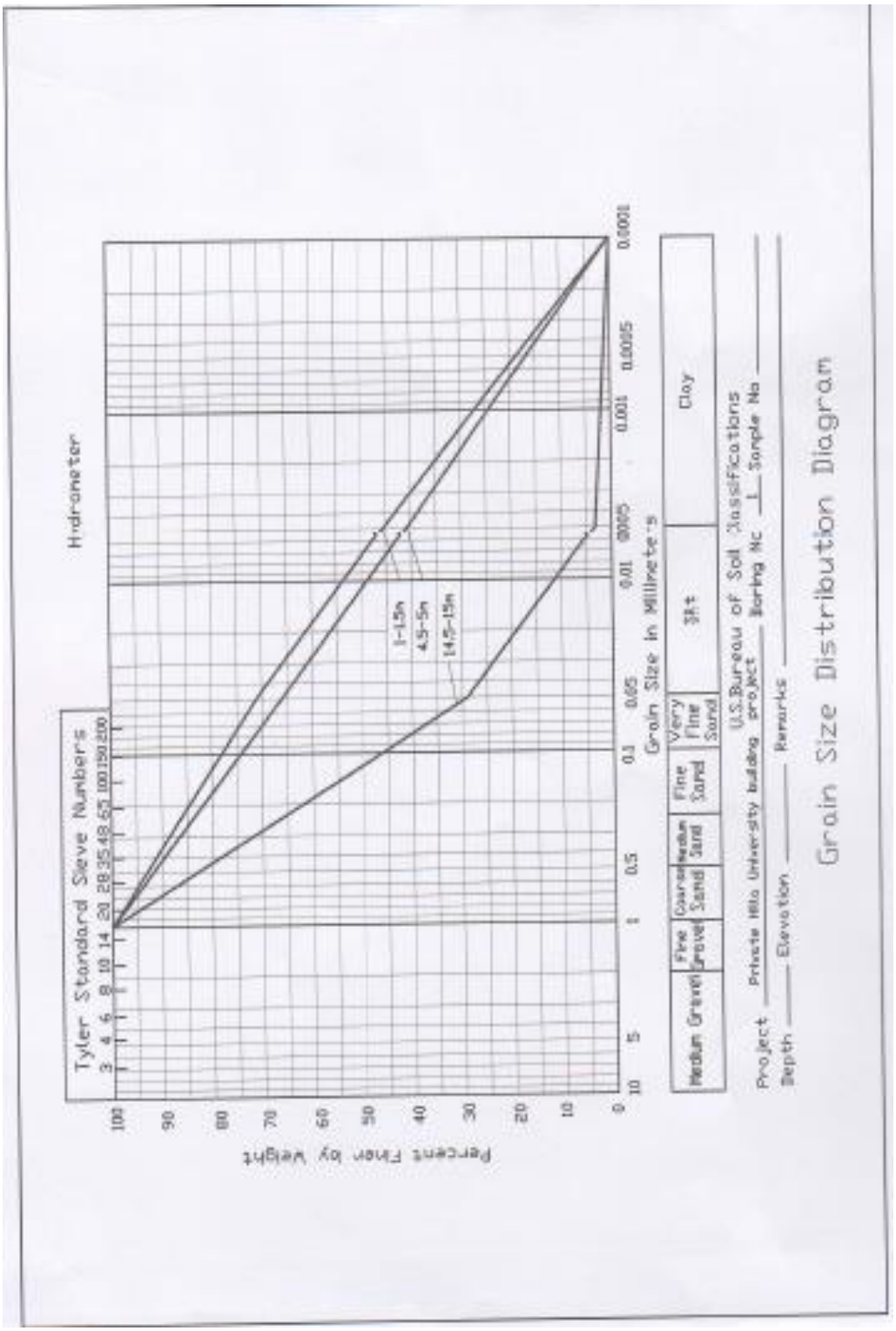
Physical properties & field test for soil for Private Hilla University building project . (BH.3)

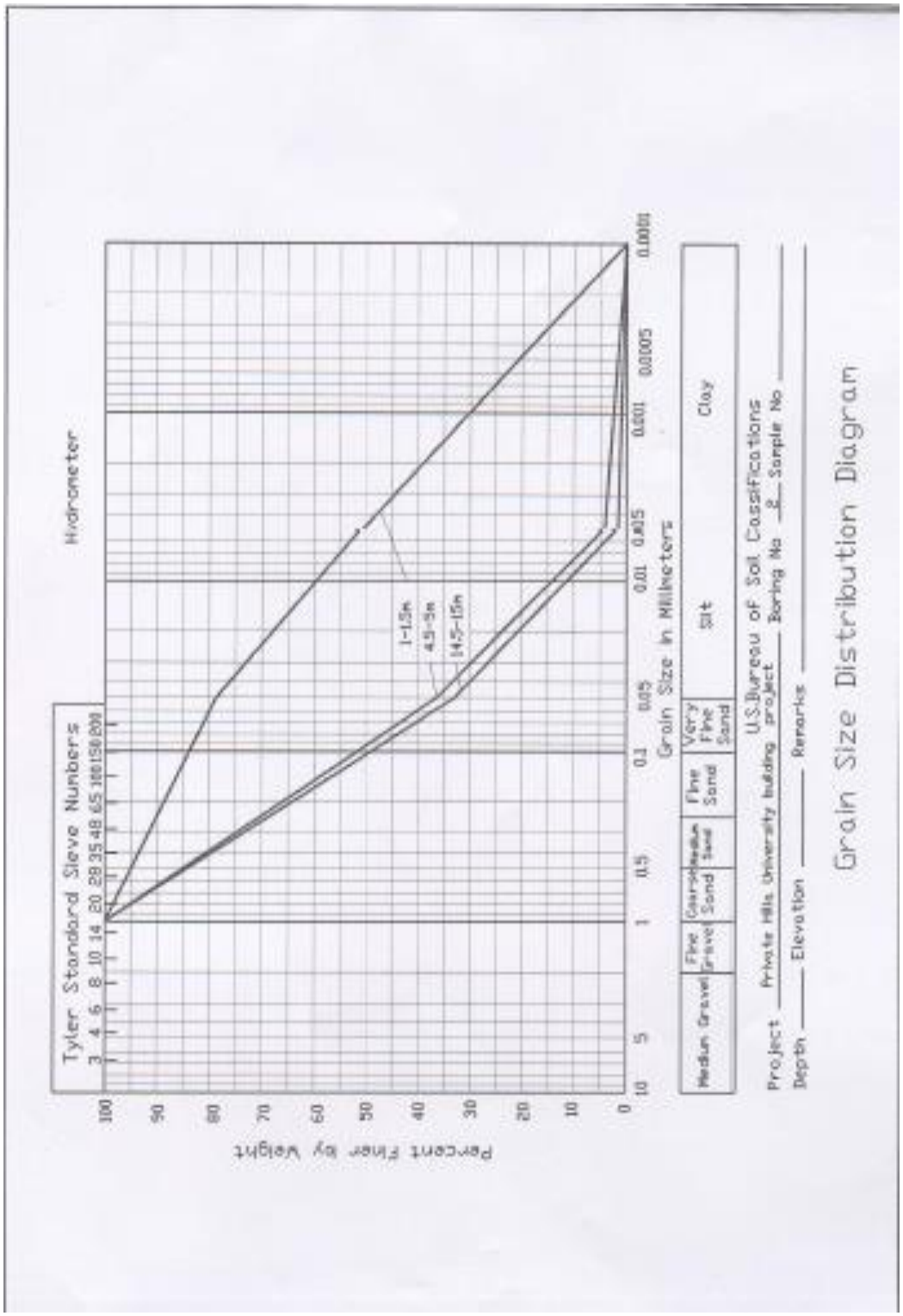
Depth m	Type of Sample	Soil classification				Soil Description	Plasticity Index			Specific Gravity gm/cm³		G.S	SPT(N)
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-0.5	DS	56	28	16	-	Grayish sandy silty clay soil , medium consistency , with organic matter , CH	-	-	-	-	-	-	-
1-1.5	US	61	24	15	0		4.5	55.0	37.0	1.77	1.85	2.75	-
2-2.5	SS	54	29	17	0	Brownish sandy silty clay soil , medium consistency , CL	-	-	-	-	-	-	17
3-3.5	DS	47	32	21	0		25.3	43.0	25.0	1.46	1.83	2.72	-
3.5-4	SS	8	31	61	0	Greenish , medium dense , fine to medium , silty sand soil	28.7	-	-	-	-	-	14
4.5-5	DS	5	28	67	0		-	-	-	-	-	2.65	-
5.5-6	US	44	32	24	0	Grayish –greenish sandy silty clay soil , medium consistency , CH	25.1	-	-	1.47	1.84	-	-
6.5-7	SS	51	29	20	0		-	-	-	-	-	-	20
7.5-8	DS	54	27	19	0		-	52.0	33.0	-	-	2.75	-
8.5-9	US	52	22	26	0	Brownish silty sandy clay soil , very stiff consistency , CH	21.2	49.0	31.0	1.58	1.92	2.73	-
9.5-10	SS	47	23	30	0		-	-	-	-	-	-	52
10.5-11	DS	6	32	62	0	Greenish , very dense , fine to medium , silty sand soil	-	-	-	-	-	2.65	-
11.5-12	SS	2	31	67	0		26.5	-	-	1.62	2.05	-	61
12.5-13	DS	3	29	68	0		-	-	-	-	-	-	-
13.5-14	DS	5	25	70	0		-	-	-	-	-	2.65	-
14.5-15	SS	4	27	69	0		26.0	-	-	1.66	2.09	-	70

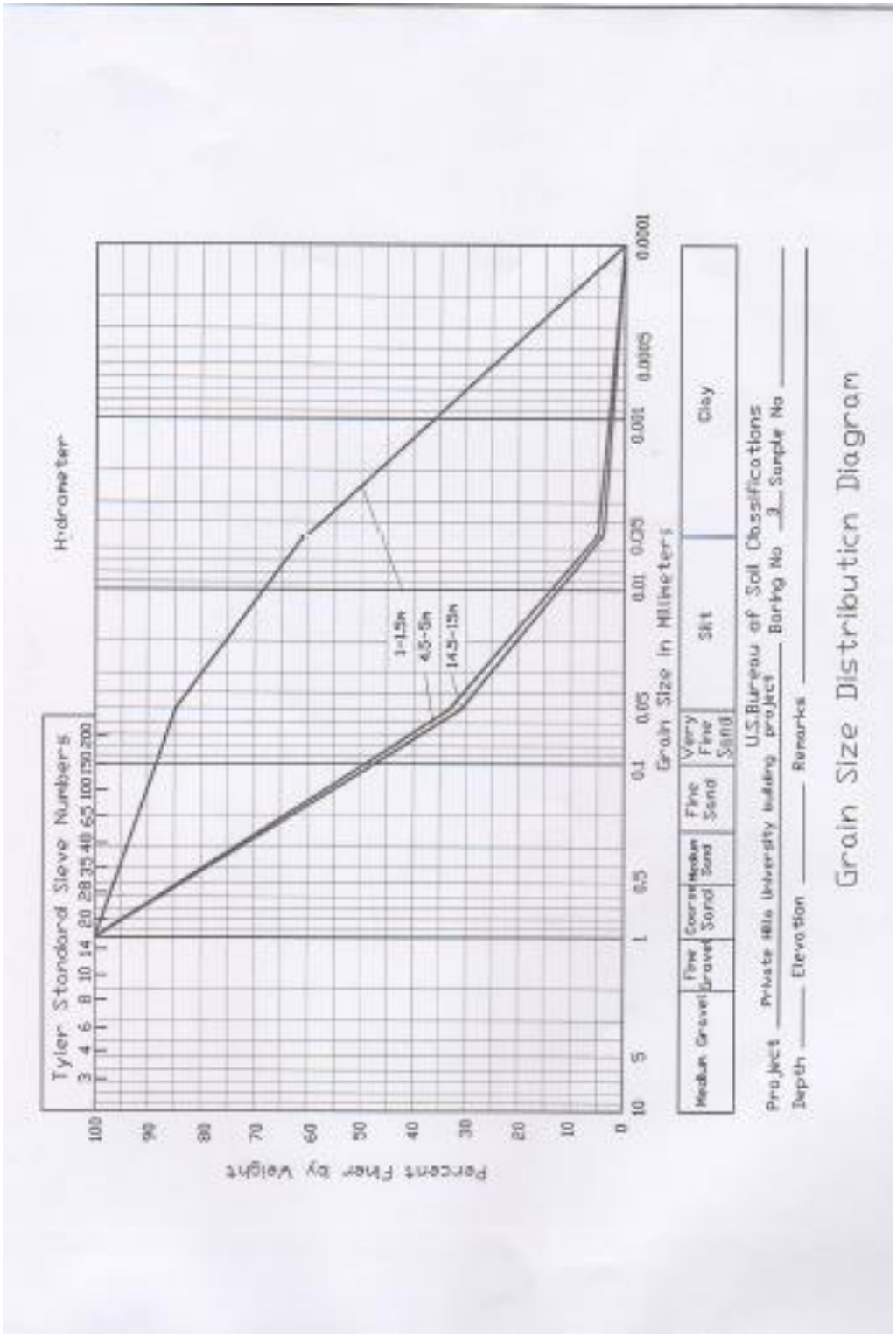
Physical properties & field test for soil for Private Hilla University building project . (BH.4)

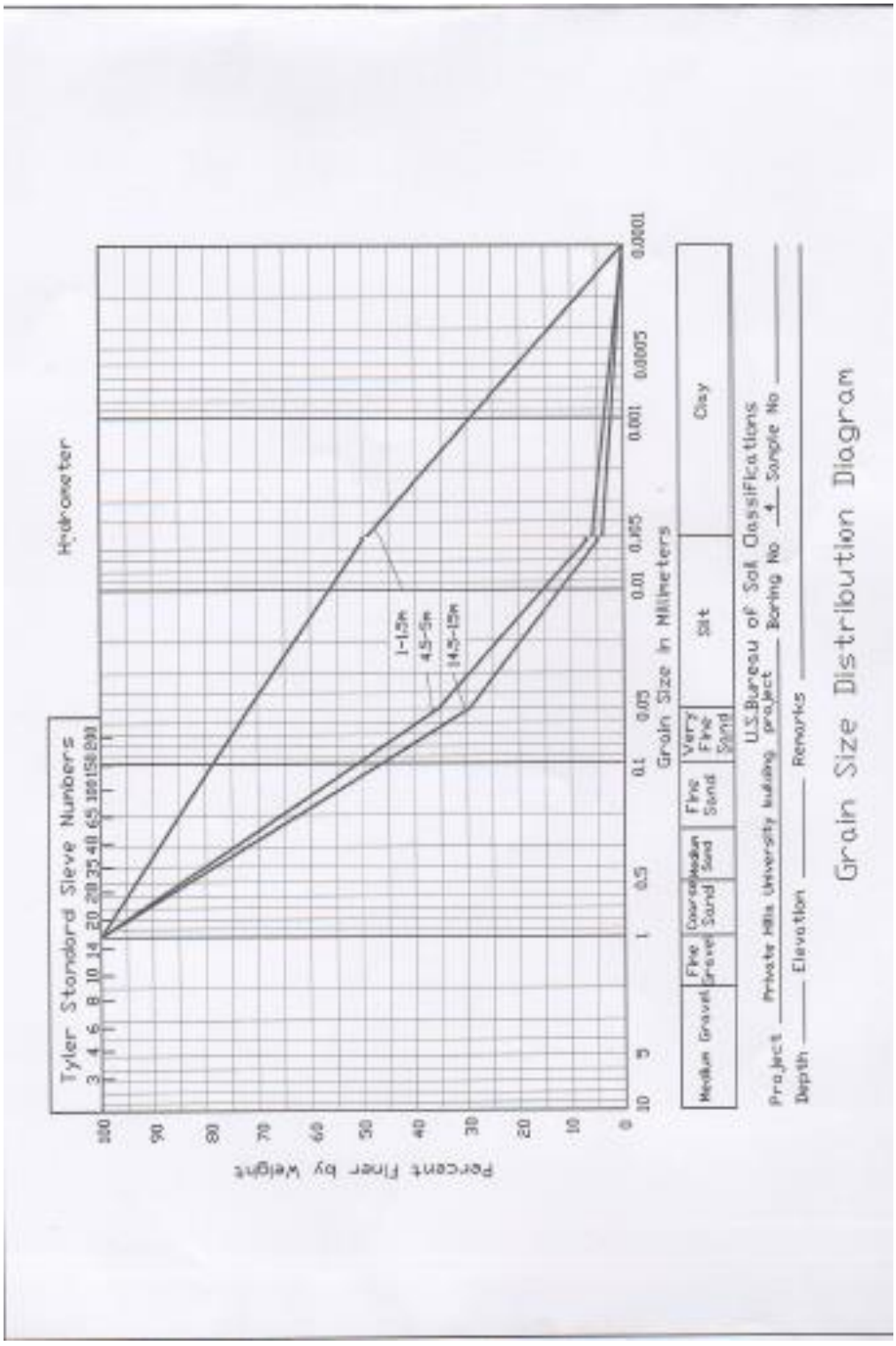
Depth m	Type of Sample	Soil classification				Soil Description	Plasticity Index			Unit weight gm/cm³		G.S	SPT(N)
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-0.5	DS	45	24	31	0	Grayish silty sandy clay soil , medium consistency , with organic matter , CL	-	42.0	22.0	-	-	2.71	-
1-1.5	SS	49	23	28	0		-	-	-	-	-	-	17
1.5-2	US	55	26	19	0	Brownish sandy silty clay soil , medium consistency , CH	11.5	53.0	34.0	1.65	1.84	2.74	-
2.5-3	SS	51	28	21	0		-	-	-	-	-	-	25
3.5-4	DS	44	32	24	0		25.2	-	-	-	-	2.71	-
4.5-5	SS	6	31	63	0	Greenish , medium dense , fine to medium, silty sand soil	29.0	-	-	-	-	-	13
5.5-6	DS	5	33	62	0		-	-	-	-	-	2.65	-
6.5-7	US	45	30	25	0	Grayish sandy silty clay soil , stiff consistency , CL	23.1	43.0	23.0	1.51	1.86	2.72	-
7.5-8	SS	43	31	26	0		-	-	-	-	-	-	31
8.5-9	DS	44	24	32	0	Reddish silty sandy clay soil , stiff consistency , CL	-	41.0	22.0	-	-	2.71	-
9.5-10	US	40	25	35	0		24.8	-	-	1.49	1.86	-	-
10.5-11	SS	7	27	66	0	Greenish , dense to very dense , fine to medium , silty sand soil	27.1	-	-	1.55	1.97	-	47
11.5-12	DS	4	29	67	0		-	-	-	-	-	2.65	-
12.5-13	DS	2	28	70	0		-	-	-	-	-	-	-
13.5-14	SS	2	24	74	0		26.0	-	-	1.66	2.09	-	81
14.5-15	DS	4	25	71	0		-	-	-	-	-	2.65	-

APPENDIX (2)

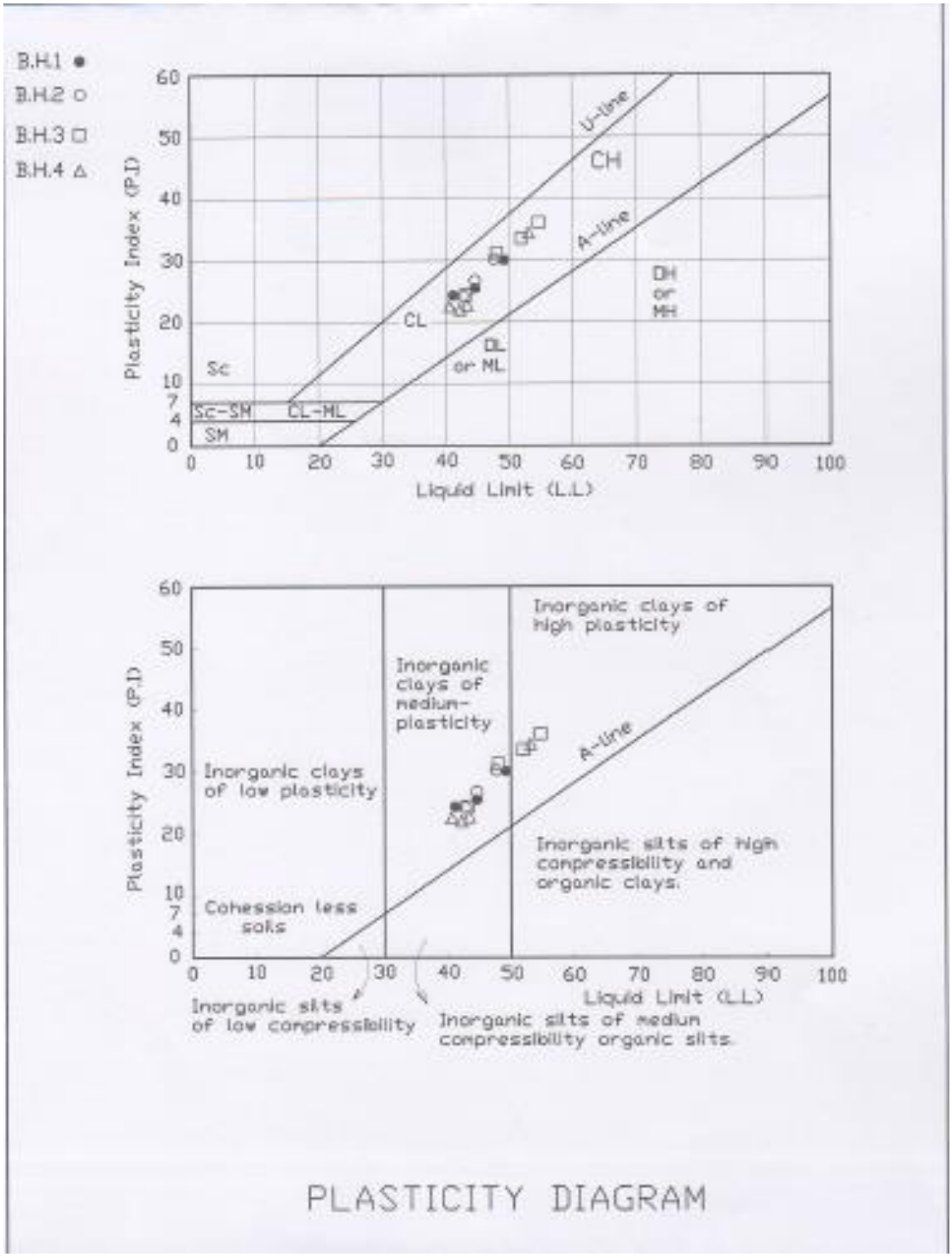

Grain Size Distribution Diagram
Project ____ Private Hilla University building project ____ Boring No ____ Sample No ____
Depth ____ Elevation ____ Remarks ____
U.S.Bureau of Soil Classifications
Medium Gravel
Fine Gravel
Coarse Sand
Medium Sand
Fine Sand
Very Fine Sand
Silt
Clay
Grain Size in Millimeters
10
5
1
0.5
0.1
0.05
0.01
0.005
0.001
0.0005
0.0001
Percent Finer by Weight
100
90
80
70
60
50
40
30
20
10
0
Tyler Standard Sieve Numbers
3 4 6 8 10 14 20 28 35 48 65 100 150 200
Hydrometer
1-15h
4.5-5h
14.5-15h


Grain Size Distribution Diagram
Project Private Hills University building project Boring No 2 Sample No
Depth Elevation Remarks
U.S.Bureau of Soil Classifications
Medium Gravel
Fine Gravel
Coarse Sand
Medium Sand
Fine Sand
Very Fine Sand
Silt
Clay
Grain Size in Millimeters
Hydrometer
Tyler Standard Sieve Numbers
3 4 6 8 10 14 20 28 35 48 65 100 150 200
Percent Finer by Weight
1-1.5m
4.5-5m
14.5-15m


Grain Size Distribution Diagram
Percent Finer by Weight
Tyler Standard Sieve Numbers
3 4 6 8 10 14 20 28 35 48 65 100 150 200
Hydrometer
1-1.5m
4.5-5m
14.5-15m
Grain Size in Millimeters
Medium Gravel
Fine Gravel
Coarse Sand
Medium Sand
Fine Sand
Very Fine Sand
Silt
Clay
U.S.Bureau of Soil Classifications
Project Private Hilla University building project Boring No 3 Sample No
Depth Elevation Remarks


Grain Size Distribution Diagram
Project _____ Private Hills University building project Boring No 4 Sample No _____
Depth _____ Elevation _____ Remarks _____
U.S.Bureau of Soil Classifications
Medium Gravel
Fine Gravel
Coarse Sand
Medium Sand
Fine Sand
Very Fine Sand
Silt
Clay
Grain Size in Milimeters
Hydrometer
Tyler Standard Sieve Numbers
3 4 6 8 10 14 20 28 35 48 65 100 150 200
1-1.5m
4.5-5m
14.5-15m
Percent Finer by Weight

APPENDIX (3)



PLASTICITY DIAGRAM

COSOLIDATION TEST

Project: Private Hilla University building project

Location: Al-Ranjya1Al-Kfel District, Babylon Gov.

Sample Description:

Sample Dimentions			
Dia.	mm	Height	mm

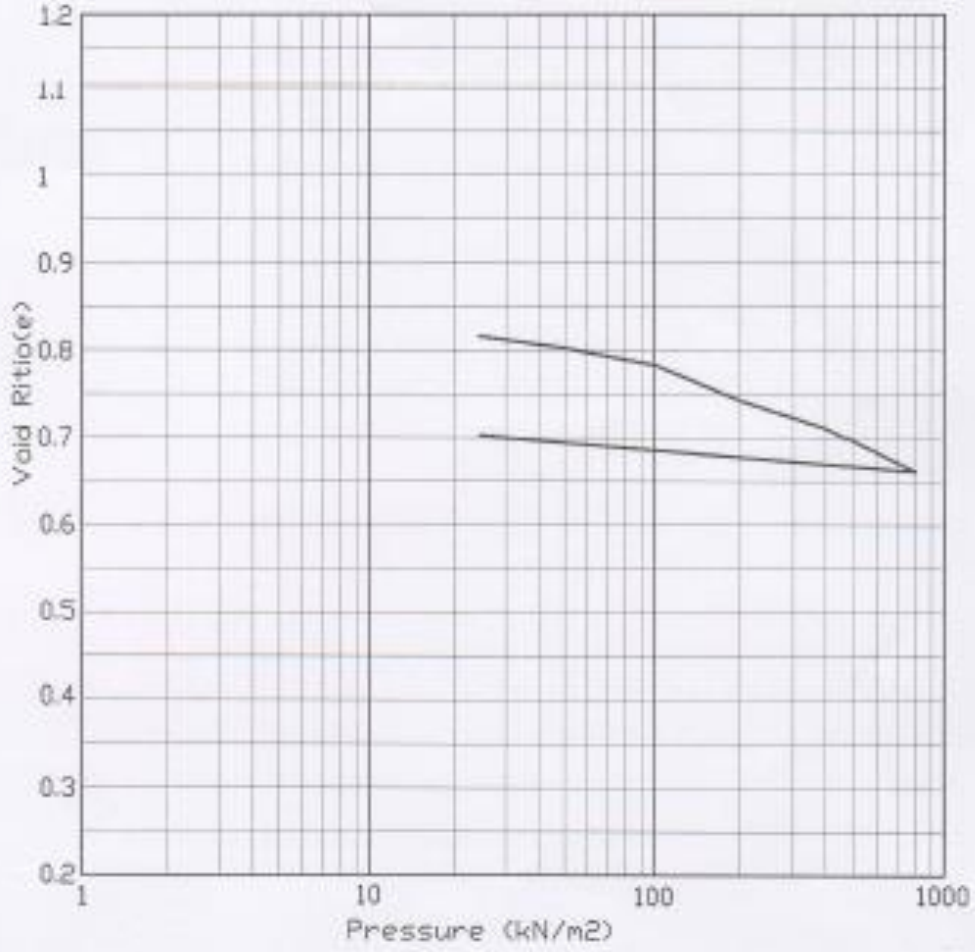
Bore hole	1
Sample	No.
Depth	5.5-6m

Void Ratio	Initial	0.841
	Final	

Specific Gravity Assumed/ 2.7

Effective Overburden Pressure	(Po)	
Preconsolidation kg/cm2	(Pc)	1.30
Compression Index	(Cc)	0.13
Swelling Index	(Cr)	0.024
Swelling Pressure		

Pressure kN/m2	Void Ratio e
25	0.818
50	0.803
100	0.788
200	0.747
400	0.710
800	0.660
25	0.702



COSOLIDATION TEST

Project: Private Hilla University building project

Location: Al-Ranajiya?Al-Kfel District, Babylon Gov.

Sample Description:

Sample Dimentions		Bore hole	3
Dia. mm	Height mm	Sample	No.
		Depth	3-3.5m

Void Ratio	Initial	0.709
	Final	

Specific Gravity Assumed/ 2.7

Effective Overburden Pressure	(Po)	
Preconsolidation kg/cm2	(Pc)	1.15
Compression Index	(Cc)	0.174
Swelling Index	(Cr)	0.031
Swelling Pressure		

Pressure kN/m2	Void Ratio e
25	0.681
50	0.660
100	0.625
200	0.573
400	0.523
800	0.470
25	0.522