Geotechnical evaluation of some properties of the physical and chemical soil selected sites in Najaf – Iraq

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Abstract

This study was conducted on selected soil in the governorate of Al- Najaf, for the purpose of identifying some of the physical and chemical properties and its importance to the establishment of engineering at the site, and based on the investigation of the engineering. For soil investigation, with a 10-borehole test.

It was found from the results obtained from field and laboratory work that soil study area like the soil Mesopotamian plain areas where silty clay is high plasticity interspersed with shallow sandy soils of some sites, which need some engineering treatments to improve their quality.

Key words: Al- Najaf Al-Ashraf governorate, soil investigation, properties of soil.

الخلاصة

تم اجراء هذة الدراسة على ترب مختارة في محافظة النجف لغرض التعرف على بعض الخواص الفيزيائية والكيميائية لها وذلك لاهميتها عند اقامة منشأ هندسي عليها ، وبالاعتماد على تحريات التربة ، حيث تم اجراء 10حفرة اختبارية.

وقد تبين من النتائج المستحصلة من العمل الحقلي والمختبري ان تربة منطقة الدراسة كباقي تربة مناطق السهل الرسوبي حيث هي طينية غرينية عالية اللدونة تتخللها تربة سطحية رملية لبعض المواقع ، وهي بحاجة الى بعض المعالجات الهندسية لتحسين نوعيتها لمقاومة الاحمال المقامة عليها.

الكلمات المفتاحية : محافظة النجف الاشرف ، تحريات تربة ، خواص التربة .

1- Introduction:

Usually the soil minerals and organic materials consist plus a set of salts and oxides represent free hard part of it, while the water in the soil and contain the dissolved material in the water, this is the liquid part,

The presence of varying concentrations of dissolved.

For the purpose of knowledge of the physical, chemical, engineering and mineral properties, which is a reflection of the components above, it should be an investigation of the soil, in this research has been to rely on mechanical machine type "Flight Auger" drill method because it is one of the best drilling operations to identify the compositions and layers below the surface (Khalidi, 2002).

The presence of groundwater his influence on the engineering properties of the soil, including the bearing capacity of the loads inflicted by causing consolidation addition to the erosion of the foundations of facilities as a result contain salts

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, 1984).

For accessing to geological study of the subsurface based on drilling as a way to optimal geotechnical testing (khalaf, 2010).

The purpose of the study of the geotechnical properties of the soil will help in the design of buildings, facilities and process to give significant for these engineering.

2- Site location & Description

The site is located (163Km) southern of Baghdad is part of Quaternary sediments. The site in general is flat area. The boreholes coordinates are as shown in Table(1), and site plan for ten boreholes location is shown in Fig.(1) .

Table (1) boreholes coordination

B.H. No	Coordination			Block Location
	E(m)	N(m)	Z(m)	
1	44 18 21.1	31 59 51.1	not available	not available
2	44 18 20.4	31 59 51.9	=	=
3	44 18 19.3	31 59 52.6	=	=
4	44 18 18.1	31 59 51.1	=	=
5	44 18 19.3	31 59 50.2	=	=
6	44 18 19.3	31 59 50.5	=	=
7	44 18 19.7	31 59 51.6	=	=
8	44 18 16.8	31 59 50.8	=	=
9	44 18 15.1	31 59 52.5	=	=
10	44 18 16.4	31 59 52.2	=	=

Figure (1): Satellite image of the investigation area

3-Method of Research

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

3-1 Field Work:

3-1-1 Drilling and sampling

Ten boreholes have been bored during September -2014 by using mechanical machine type "Flight Auger" drill method. 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 extension to underneath the zone of influence of significant foundation pressure to materials that were relatively incompressible. The depth of boring was 10 m from the existing Natural Ground Surface (N.G.S) ,and Groundwater levels recorded in the boreholes shown in table(2),and table(3)

The underground water level (actually it is at the same of level the river water) was measured at end of boring at the time of sub-soil investigation (September, 2014) from the natural ground surface (+0.00m) shown in Table (2). The specified depth was fixed after 24 hours of boring termination. However, the depth September fluctuate during the seasons of the year. According to ASTM D-4750, chemical analysis for ground water is listed in Table (3). 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 (2) the underground water level of study area

BH.NO	The date of measurement	under ground water elevation (m) from drilling	Bored method	Bored Depth (m)	Bored Diameter (m)
1	September-2014	1.10	Flight Augers	10	0.10
2	=	1.00	=	10	0.10
3	=	1.10	=	10	0.10
4	=	1.20	=	10	0.10
5	=	1.10	=	10	0.10
6	=	1.10	=	10	0.10
7	=	1.10	=	10	0.10
8	=	1.10	=	10	0.10
9	=	1.50	=	10	0.10
10	=	1.10	=	10	0.10
10					

Table (3) Chemical analysis for ground water of study area

BH .No	$SO4^{//}$ mg/l	$Cl^{/}$ mg/l	PH	EC * 10^3 mm hos/cm	TDS mg/l	Depth (m)
1	1042	312	7.8	1.21	1259	1.10
2	1045	298	7.7	1.24	1257	1.00
3	1041	295	7.8	1.26	1261	1.10
4	1040	307	7.8	1.25	1264	1.20
5	1044	213	8.0	1.27	1258	1.10
6	1043	208	7.9	1.24	1260	1.10
7	1040	301	7.9	1.28	1263	1.10
8	1043	297	7.7	1.23	1259	1.10
9	1042	304	7.8	1.27	1261	1.50
10	1045	310	7.8	1.28	1265	1.10

3-2-Laboratory work

After completing the first phase above, and after transferring samples to the lab , 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 for soil study area, and required tests were specified on each sample depending on the type of examination sample Disturbed sample (DS),Undisturbed sample (US),and in accordance with ASTM and BS for each test. Test program included the following laboratory tests:

3-2-1- Physical properties of soil

* Natural moisture content.
* Grain size analysis.
* Atterberg Limits.
* Specific gravity.
* Unit weight (natural and dry)
*Soil Activity

3-2-2 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).

4- Results and discussion

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

5-1 Physical properties of soil

5-1-1 grain size Result:

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. The sieving method consists of sorting soil grains by size by passing the soil sample through a stack of sieves. Percent fraction by weight according to USCS and ASTM D-2488 and ASTM D-2487, engineering soil classification systems for the samples are given. The experiments were successfully carried out. Little soil was lost in the sieving process.

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), (Bowles,1984).

Referring to the results of the SPT results, the sand and silty sand can be described as dense to very dense since SPT values are in general greater than 50. It is worthy to mention that the relatively high values of SPT may be attributed to the

absence of ground water within the drilled depths and the presence of some natural chemical components that cemented the sand particles together (Al Asho, 1997).

Examining the tests results, it can be seen that the range of sulphate (SO4) in water between (1039-1047) mg/l, while the range of chloride content is between (297-313) mg/l [For water samples]. On the other hand it also noted that the range of pH value for water samples were (7.7-8.0) It can be seen that the TDS of water samples is high and varies from (1257-1265) mg/l.

5-1-2- Permeability test results:

The results of coefficient of permeability K= for layers it varies from (7.10x 10^{-3} to 3.92 x10^{-6}) cm/sec. The permeability of this soil is poor to good , and this is caused by variation of increasing the sand percentages in the sub-soil.

5-1-3-Moisture 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(28.6% to 17.3%),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 (28.6% to 17.3%) 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.

6- Soil Layer Description or soil profile:

According to the in site and some of laboratory testing carried out on the soil of site, the subsoil strata encountered at the investigated location is detailed on the borehole logs. The Unified Soil Classification System for sediments is used for the classification of this soil as shown in Appendix (1) results from this Table [Appendix (1)], it is clear that the soil consists of the following layers:

a-The sub -soil strata starting from natural ground surface consisting of fill material (0.0-0.05m) in BH.1 and a layer consists of brownish , greenish , reddish , grayish silty clay soil (CL ,CH) with sand, medium to stiff to very stiff consistency. This layer extends from the boring end depth of (0.0-10) m. and greenish silty sand soil (SW,SP), very dense . in BH.5 and silty sand (SW,SP ,SM ,SC) with clay, fine gravel and content gypsum , loose to medium to very dense This layer extends from the depth of (0.0-7.0) m in BH. 8, and 9,.

This consequent changes or sub-soil strata is related to way of deposition.

6-1- Soil Activity:

With 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 (1).

The average ratio of plasticity index to clay content equal (0.57) which release that this soil have poor clay activity according to ASTM specifications, so this soil has

low swelling tendency. The results generally indicate that the value of moisture content is closer to the plastic limit than to the liquid limit. This trend suggests that the cohesive less layer is loose dense and cohesive layer and cohesive layer is consolidation.

Linear shrinkage results are from 12.0 to 17.0 percent which indicate that the cohesive layer might exhibit swelling and shrinkage potential.

Table (4)Show result Atterberg limits of soil study area

A	LI	Mc	Properties index			System of classification Sieve &Hydrometer				Depth (m)	B.H. No	Type of sample
			PI %	LL %	PL %	Grave. %	Sand %	Silt %	Clay %			
0.566	-0.088	19.0	34.0	56.0	22.0	0	16	24	60	3-3.5	1	DS
0.557	-0.096	19.2	29.0	510	22.0	0	27	21	52	7.5-8	2	US
0.600	-0.077	19.0	39.0	61.0	22.0	0	12	23	65	9-9.5	4	DS
0.620	0.016	20.3	44.0	65.0	21.0	0	3	26	71	14.5-15	5	US
0.582	-0.031	19.0	32.0	52.0	20.0	0	20	25	55	5-5.5	7	US
0.600	0.874	24.1	15.0	26.0	11.0	2	52	21	25	1-1.5	10	DS

The Liquidity Index (LI) has been proposed as a measure of quantifying liquefaction problem. Values of LI $\geq$ 1 are indicative of a liquefaction or quick potential. As long as most calculated values of LI shown in Table (4) is less than and equal to one, so the samples have no liquefaction potential. Values of LI in Table (4) with less than zero indicate also that the consistency of the soil is in a semi-solid or solid state, while other values indicate that the soil is in a plastic state. The value of LI with less than or equal zero indicates that the soil is over consolidated. Activity of clay given in Table (3), which is the ratio of Plasticity Index to clay content, is a measure of degree to which soil will exhibit colloidal behavior.

Values of Activity (A) in Table (4) less than 0.75 are termed inactive clays. Normally active clays have activities between 0.75-1.25. The samples with activity more than 1.25 are active clays. The test results indicate that most of the soil samples have activity of less than 0.75. This means that the samples are of inactive clay.

LI: Liquidity Index (L.I=Mc-P.L./P.I) …….1

Where:

A: Activity (A=P.I./clay fraction)

LL: Liquid Limit

PL: Plastic Limit

PI: Plasticity Index

Mc : Natural moisture Content (water content)

6-2 determining the physical/Index properties of the soil

Specific Gravity, Water Content (to determine natural water content of the soil), Atterberg Limits (LL, PL and PI values), Sieve Analysis test (to determine grain size analysis) were made to SPT and UD samples.. Soil classification according to index properties is given below.

Natural water content Mc: varies between % 15.3-26.2

Gravel rate: varies between % 0.00-0.00

According to USCS classification; the material on the sieve No: 10 (+) is coarse material and called Gravel.

Sand rate: varies between % 3-29

Specific Weight (Gs) :2.73 -2.76

According to USCS classification Clay rate : varies between % 48-79

; material passing thorough the sieve No: 200 (-) is fine grained and consistency limits were made for classification.

Liquid Limit LL : % 50 -67

Plastic Limit PL : % 19-23

Plasticity Index PI : % 29-44

Liquid Limit and plasticity Index values put on Casagrande Chart table (5) ,and **Appendix 2** to make material classification as a result of Atterberg Limit Test and CH "medium-high plasticity clay" is determined from table (6).

Table (5). Casagrande plasticity Chart

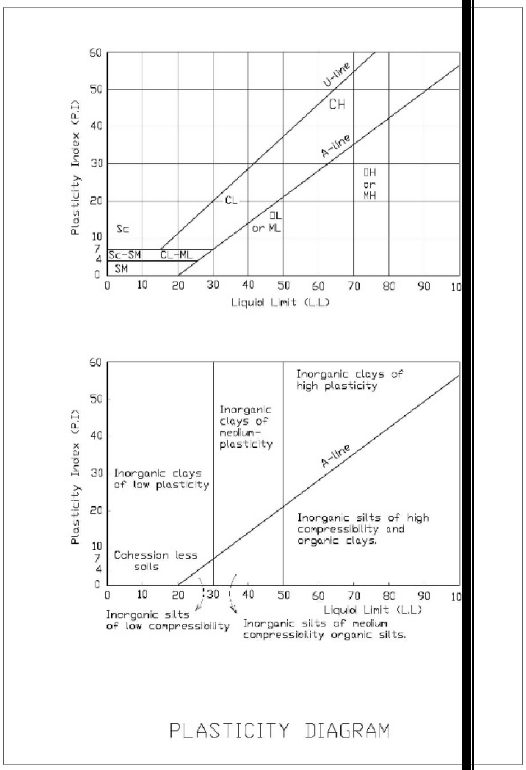
Grain size (No.200 >%50)	**Low Plasticity Silts and Clays (W_L < %50)**	**ML**	**Low plasticity inorganic silts and clayey silts**	
		CL	**Low plasticity inorganic Clays and Silty Clays**	
		OL	**Low plasticity organic Silts and Clayey Silts**	
	High plasticity Silts and Clays (W_L > % 50)	**MH**	**High 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**	

Table (6). 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-2	**3.5-4**	**20.0**	**CH**	**3**	**97**	**64**	**23**	**41**	**2.76**
BH-5	**20.5-21**	**20.7**	**CL**	**30**	**70**	**41**	**18**	**23**	**2.72**
BH-8	**6.5-7**	**24.1**	**CH**	**5**	**95**	**67**	**23**	**44**	**2.76**

7- Chemical Test :

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 (7). It is clears that the highest value of sulfate as SO_3 % is in the range of (0.37-1.88%) for soil and the range of chloride content is (0.039-0.055) %. Organic matter of soil samples is varied from 0.33 to 0.71 %. On other hand the TSS and gypsum content were found to vary from 5.68 to 16.35 % and 3.41 to 11.23 %, 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 (7) Results of chemical analysis for soil

No. of BH	Depth (m)	SO_3 (%)	Gyp. (%)	TSS (%)	ORG (%)	CaCO3 (%)	PH %	Cl%
BH.10	9-9.5	1.10	6.27	12.38	0.38	13.0	-	-
=	10-10.5	1.26	7.11	14.40	-	15.0	-	-
BH.9	11.5-12	1.35	4.65	8.12	-	16.0	-	-
=	12.5-13	1.44	5.72	10.25	-	20.0	-	-
BH.6	14-15	1.59	9.12	14.61	-	17.0	-	-
=	16.5-17	1.62	10.54	15.28	-	19.0	-	-
=	18.5-19	1.67	7.28	12.95	-	22.0	-	-
BH.4	21.5-22	1.75	10.41	16.35	-	21.0	-	-
=	23.5-24	1.84	11.23	15.09	-	25.0	-	-
=	25.5-26	1.88	8.15	13.24	-	28.0	-	-
BH.3	2-2.5	0.39	4.24	6.53	0.66	7.0	7.8	0.055
=	4-4.5	0.52	6.45	9.47	0.51	8.0	7.8	0.051
=	6-6.5	0.66	5.13	8.70	0.47	11.0	7.9	0.048
=	8-8.5	0.74	5.70	9.45	0.42	9.0	8.0	0.043
BH.1	9.5-10	0.89	8.22	12.12	0.33	7.0	7.8	0.039
=	11.5-12	1.16	5.46	10.34	-	14.0	7.9	-
=	13.5-14	1.35	7.21	11.70	-	15.0	7.7	-
=	15.5-16	1.41	6.53	10.92	-	17.0	7.8	-

8- In-site testing and measurement (SPT):

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).

9- 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, 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- Groundwater levels ranging from 1.0 m to 1.5 m below the surface of the Earth's natural after the measurement.
2- The study area soil is silty sandy clay high plasticity, interspersed with clay and a low-plasticity with a sandy clay.
3- Depending on the grain size analysis of soil, clay ratio from 71% to 6% range and the percentage of silt from 32% to 14% and the proportion of sand 61% to 2% and gravel from 4% to zero.
4- Atterberg limits, the liquid limit 67% higher value of either plastic index 44%.
5- Dry density ranging from 1.67gm/cm^3 to 1.45 gm/cm^3 either wet density ranges from 2.13 gm/cm^3 to 1.da gm/cm^3 **.**
6- The moisture water content it 28.6% to 17.3%.
7- The average ratio of plasticity index to clay content equal (0.57) which release that this soil have poor clay activity according to ASTM specifications, so this soil has low swelling tendency.
8- The results generally indicate that the value of moisture content is closer to the plastic limit than to the liquid limit. This trend suggests that the cohesive less layer is loose dense and cohesive layer and cohesive layer is consolidation.
9- The chemical properties as SO_3 % is in the range of (0.37-1.88%) for soil and the range of chloride content is (0.039-0.055) %. Organic matter of soil samples is varied from 0.33 to 0.71 %. On other hand the TSS and gypsum content were found to vary from 5.68 to 16.35 % and 3.41 to 11.23 %, respectively

10-Recomondation:-

1-study of the fluctuation of groundwater levels of the study area and its effect on the proposed engineering facilities to establish.
2-study the effect of the percentage salts Chemical in the soil and water on the foundations facilities.
3-a comparative study with other regions to comple investigations soils region.
4. study to install and treatment of mechanical and chemical of the soil in the study area in order to ensure the safety of engineering structures.

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APPENDIX (1)

Physical properties & field test for soil . (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	-	-	-	-	Fill material	-	-	-	-	-	-	-
0.5-1	DS	53	21	26	0	Brownish , silty sandy clay soil , stiff consistency , CH	-	51.0	30.0	-	-	2.73	-
1.5-2	SS	55	20	25	0		-	-	-	-	-	-	41
2-2.5	US	59	18	23	0		22.7	-	-	1.54	1.89	-	-
3-3.5	DS	60	24	16	0	Brownish , sandy silty clay soil , very stiff consistency , CH	-	56.0	34.0	-	-	2.75	-
4-4.5	SS	63	22	15	0		-	-	-	-	-	-	50/4"
5-5.5	US	58	23	19	0		19.0	-	-	1.63	1.94	2.75	-
6-6.5	DS	54	21	25	0	Greenish , silty sandy clay soil , very stiff consistency , CH ,	-	52.0	32.0	-	-	-	-
7-7.5	SS	52	22	26	0		-	-	-	-	-	-	70
8-8.5	US	47	24	29	0	Greenish , silty sandy clay soil , very stiff consistency , CL	20.8	-	-	1.59	1.92	2.72	-
9.5-10	DS	48	25	27	0		-	45.0	26.0	-	-	-	-

Physical properties & field test for soil. (BH.2)

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	52	23	25	0	Brownish , silty sandy clay soil , stiff consistency ,CH	-	-	-	-	-	-	-
0.5-1	US	53	20	27	0		22.0	51.0	30.0	1.55	1.89	2.73	-
1.5-2	SS	57	19	24	0		-	-	-	-	-	-	43
2.5-3	DS	62	30	8	0	Brownish , silty clay soil , very stiff consistency ,CH	-	-	-	-	-	-	-
3-3.5	SS	69	27	4	0		-	-	-	-	-	-	82
3.5-4	US	71	26	3	0		20.0	64.0	41.0	1.60	1.92	2.76	-
4.5-5	DS	67	31	2	0		-	-	-	-	-	-	-
5.5-6	SS	65	29	6	0		-			-	-	-	50/6"
6.5-7	DS	54	22	24	0	Reddish , silty sandy clay soil , very stiff consistency ,CH	-	-	-	-	-	-	-
7.5-8	US	52	21	27	0		19.2	51.0	29.0	1.62	1.93	2.73	-
8.5-9	SS	53	22	25	0		-	-	-	-	-	-	50/6"
9.5-10	DS	56	20	24	0		-	-	-	-	-	-	-

Physical properties & field test for soil . (BH.3)

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	we t		
0-0.5	DS	54	22	24	0	Brownish , silty sandy clay soil , stiff consistency , CH	-	-	-	-	-	-	-
1-1.5	DS	53	20	27	0		-	50.0	31.0	-	-	2.73	-
2-2.5	SS	55	24	21	0	Reddish , sandy silty clay soil , very stiff consistency , CH	-	-	-	-	-	-	50/6"
3-3.5	US	58	23	19	0		20.0	-	-	1.61	1.93	2.75	-
4-4.5	DS	63	25	12	0		-	59.0	37.0	-	-	-	-
5-5.5	SS	61	24	15	0		-	-	-	-	-	-	50/4"
6-6.5	DS	57	20	23	0	Greenish , silty sandy clay soil , very stiff consistency , CH	-	-	-	-	-	-	-
7-7.5	US	54	19	27	0		18.3	-	-	1.64	1.94	2.74	-
8-8.5	DS	59	17	24	0		-	55.0	34.0	-	-	-	-
9-9.5	SS	63	14	23	0		-	-	-	-	-	-	50/3"
10-10.5	US	61	18	21	0		17.5	-	-	1.66	1.95	2.76	-

Physical properties & field test for soil. (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	65	27	8	0	Brownish – reddish , silty clay soil , very stiff consistency , CH	-	-	-	-	-	-	-
1-1.5	SS	69	26	5	0		-	-	-	-	-	-	41
2-2.5	US	73	23	4	0		23.5	-	-	1.53	1.89	2.76	-
3-3.5	DS	70	27	3	0		-	-	-	-	-	-	-
4-4.5	SS	68	28	4	0		-	-	-	-	-	-	50/5"
5-5.5	US	71	26	3	0		19.7	64.0	41.0	1.62	1.94	2.76	-
6-6.5	DS	70	25	5	0		-	-	-	-	-	-	-
7-7.5	US	67	27	6	0		19.0	-	-	-	-	2.76	-
8-8.5	SS	69	26	15	0	Greenish – grayish , sandy silty clay soil , very stiff consistency , CH	-	-	-	-	-	-	50/4"
9-9.5	DS	65	23	12	0		-	61.0	39.0	-	-	-	-
10-10.5	US	63	24	13	0		18.3	-	-	1.64	1.94	2.76	-

Physical properties & field test for soil . (BH.5)

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	59	25	16	0	Brownish , sandy silty clay soil , medium stiff consistency ,CH	-	-	-	-	-	-	-
0.5-1	DS	58	27	15	0		-	54.0	36.0	-	-	2.75	-
1.5-2	SS	62	26	12	0		-	-	-	-	-	-	14
2.5-3	US	65	22	13	0	Reddish , sandy silty clay soil , very stiff consistency , CH	26.2	-	-	1.45	1.83	-	-
3.5-4	DS	64	21	15	0		-	60.0	39.0	-	-	2.76	-
4.5-5	SS	61	23	16	0		-	-	-	-	-	-	50/6"
5.5-6	US	59	22	19	0		20.0	-	-	1.60	1.92	-	-
6.5-7	DS	54	24	21	0		-	51.0	33.0	-	-	2.74	-
7.5-8	SS	55	25	20	0		-	-	-	-	-	-	50/5"
8.5-9	US	53	22	25	0	Greenish , silty sandy clay soil , very stiff consistency , CH	19.0	-	-	1.63	1.94	-	-
9.5-10	DS	56	21	23	0		-	52.0	32.0	-	-	2.74	-

Physical properties & field test for . (BH.6)

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	59	27	14	0	Grayish , sandy silty clay soil , stiff consistency , CH	-	-	-	-	-	-	-
0.5-1	DS	61	24	15	0		-	57.0	36.0	-	-	2.76	-
2-2.5	SS	64	23	13	0		-	-	-	-	-	-	45
3-3.5	US	62	21	17	0	Reddish , sandy silty clay soil , very stiff consistency , CH	22.7	-	-	1.53	1.88	2.75	-
4-4.5	DS	63	25	12	0		-	59.0	38.0	-	-	-	-
5-5.5	US	66	24	10	0		-	-	-	-	-	-	-
6-6.5	SS	64	25	11	0		-	-	-	-	-	-	50/6"
7-7.5	DS	65	22	13	0		-	61.0	41.0	-	-	2.76	-
8-8.5	US	68	21	11	0		20.0	-	-	1.61	1.93	-	-
9-9.5	SS	66	24	10	0	Grayish , sandy silty clay soil , very stiff consistency , CH	-	-	-	-	-	-	86
10-11	DS	69	23	8	0		-	64.0	42.0	-	-	2.76	-

Physical properties & field test for soil . (BH.7))

Depth m	Type of Sample	Particle size distribution				Soil Description	Plasticity Index			Specific Gravity gm/cm³		G.S	SPT
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-0.5	SS	44	24	32	0	Brownish , silty sandy clay soil , medium consistency , CL	-	-	-	-	-	-	13
1-1.5	DS	46	25	29	0		-	-	-	-	-	-	-
2-2.5	US	49	23	28	0		25.2	45.0	26.0	1.47	1.84	2.72	-
3-3.5	SS	50	26	24	0	Reddish , sandy silty clay soil , very stiff consistency , CH	-	-	-	-	-	-	50/6"
4-4.5	DS	52	27	21	0		-	-	-	-	-	-	-
5-5.5	US	55	25	20	0		19.0	52.0	32.0	1.64	1.95	2.73	-
6-6.5	SS	57	26	17	0		-	-	-	-	-	-	50/4"
7-7.5	DS	58	24	18	0		-	-	-	-	-	-	-
8-8.5	US	55	23	22	0		17.5	-	-	1.66	1.95	2.73	-
9-9.5	SS	53	24	23	0		-	-	-	-	-	-	50/5"
10-10.5	DS	52	21	27	0	Reddish , silty sandy clay soil , very stiff consistency , CH	-	51.0	30.0	-	-	-	-

Physical properties & field test for soil . (BH.8)

Depth m	Type of Sample	Soil classification				Soil Description	Plasticity Index			Unit weight gm/cm³		G.S	SPT
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-1	DS	50	23	27	0	Brownish , silty sandy clay soil , medium consistency , CH	-	-	-	-	-	-	-
1.5-2	SS	53	21	26	0		-	-	-	-	-	-	17
2.5-3	US	54	22	24	0		26.2	52.0	33.0	1.45	1.83	2.73	-
3.5-4	DS	65	28	7	0	Reddish , silty clay soil , medium consistency , CH	-	-	-	-	-	-	-
4.5-5	SS	68	29	3	0		-	-	-	-	2.13	-	25
5.5-6	US	72	25	3	0	Reddish , silty clay soil , very stiff consistency , CH	24.1	-	-	1.48	1.84	-	-
6.5-7	DS	71	24	5	0		-	67.0	44.0	-	-	2.76	-
7.5-8	SS	67	27	6	0		-	-	-	-	-	-	69
8.5-9	US	60	18	22	0	Greenish , silty sandy clay soil , very stiff consistency , CH	21.7	-	-	1.56	1.90	-	-
9.5-10	DS	55	19	26	0		-	53.0	32.0	-	-	2.73	-

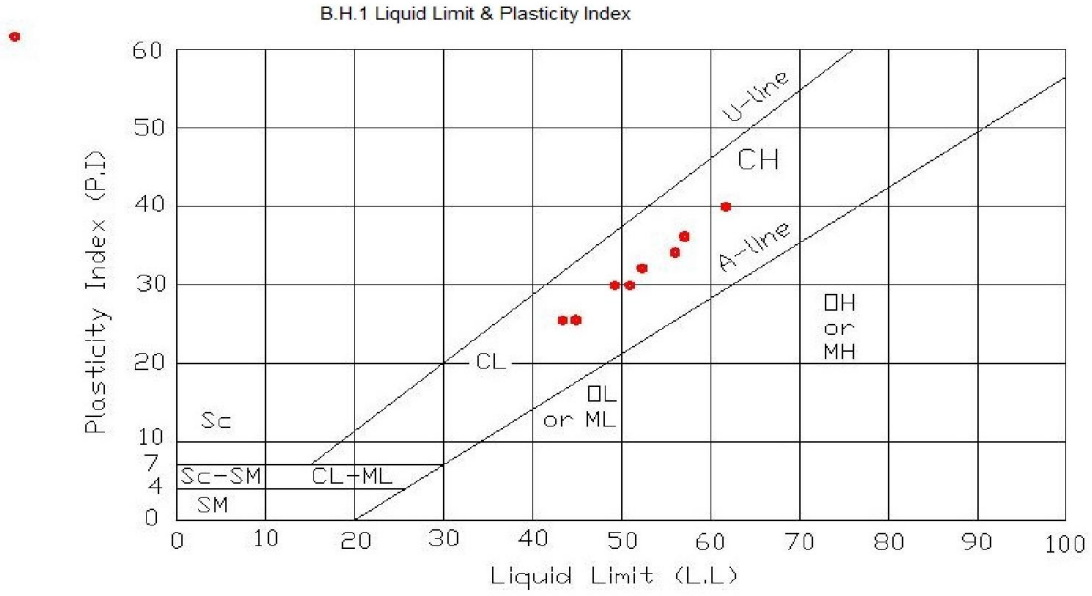
Physical properties & field test for soil. (BH.9)

Depth m	Type of Sample	Soil classification				Soil Description	Plasticity Index			Unit weight gm/cm³		G.S	SPT
		Clay %	Silt %	Sand %	Grave. %		M.C %	L.L %	P.I %	Dry	wet		
0-0.5	DS	18	23	59	0	Grayish , loose dense , medium clayey silty sand soil , SM	-	-	-	-	-	2.67	-
0.5-1	SS	17	25	58	0		-	-	-	-	-	-	11
1.5-2	DS	20	26	54	0		28.6	15.0	3.2	-	-	2.68	-
2.5-3	DS	26	21	53	0	Greenish , very dense ,fine silty clayey sand soil with gypsum content , SC	-	28.0	16.0	-	-	-	-
3.5-4	SS	28	22	50	0		27.0	-	-	-	-	-	63
4.5-5	DS	29	20	51	0		-	-	-	-	-	2.68	-
5.5-6	US	48	23	29	0	Greenish silty sandy clay soil , very stiff consistency , CL	21.0	-	-	1.57	1.90	-	-
6.5-7	SS	51	22	27	0		-	-	-	-	-	-	50/5"
7.5-8	DS	50	24	26	0		-	48.0	27.0	-	-	2.72	-
8.5-9	US	52	21	27	0	Reddish , silty sandy clay soil , very stiff consistency, CH	18.3	-	-	1.64	1.94	-	-
9.5-10	SS	56	20	24	0		-	-	-	-	-	-	50/5"

Physical properties & field test for soil. (BH.10)

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	7	32	58	3	Greenish , medium dense , fine to medium silty sand soil with fine gravel	-	-	-	-	-	2.64	-
0.5-1	SS	6	30	61	3		-	-	-	-	-	-	13
1-1.5	DS	25	21	52	2	Greenish , very dense , fine silty clayey sand soil with fine gravel , SC	24.1	26.0	15.0	-	-	2.68	-
2-2.5	DS	26	17	53	4		-	-	-	-	-	-	-
3-3.5	SS	29	18	51	2		23.5	-	-	-	-	-	50/ 6"
4-4.5	DS	28	20	50	2		-	-	-	-	-	2.68	-
5-5.5	SS	47	23	30	0	Greenish , silty sandy clay soil , very stiff consistency, CH	-	-	-	-	-	-	74
6-6.5	US	49	22	29	0		21.0	-	-	1.58	1.91	-	-
7-7.5	DS	50	24	26	0		-	49.0	31.0	-	-	2.73	-
8-8.5	SS	52	21	27	0		-	-	-	-	-	-	50/ 3"
9-9.5	US	55	21	24	0		17.3	-	-	1.67	1.96	-	-
10-10.5	DS	59	18	23	0		-	-	-	-	-	2.75	-

APPENDIX (2)


B.H.1 Liquid Limit & Plasticity Index
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Liquid Limit (L.L)
U-line
A-line
CH
OH or MH
CL
OL or ML
Sc
Sc-SM
SM
CL-ML
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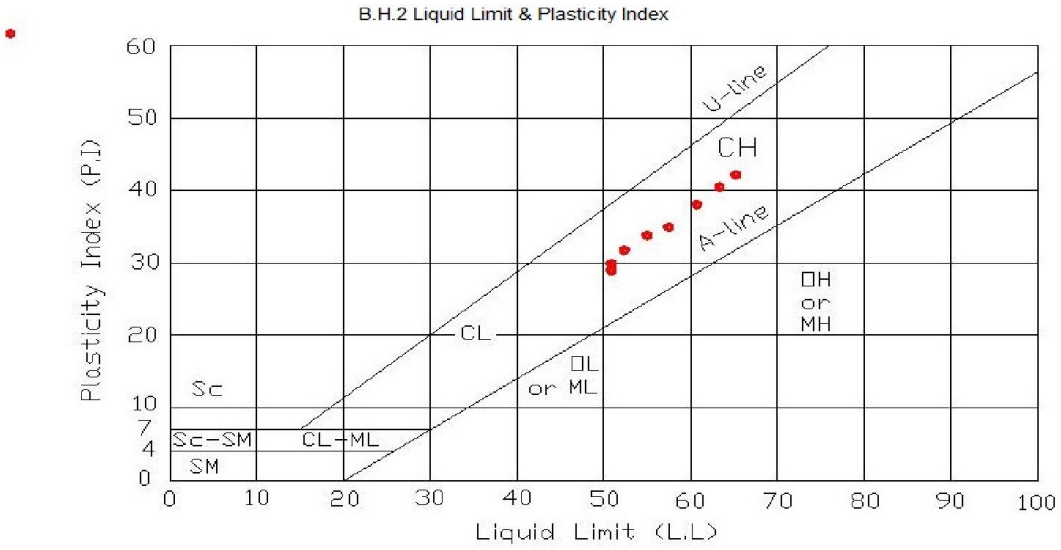
10
20
30
40
50
60
70
80
90
100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Liquid Limit (L.L)
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A-line
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OH or MH
CL
OL or ML
Sc
Sc-SM
SM
CL-ML
0
4
7
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40
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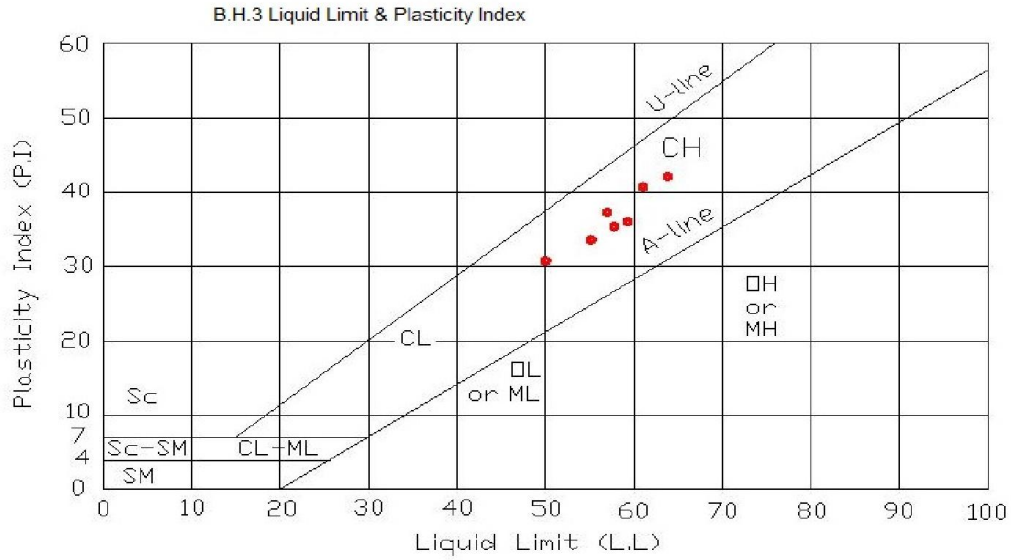
60
70
80
90
100


B.H.3 Liquid Limit & Plasticity Index
Plasticity Index (P.I)
Liquid Limit (L.L)
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A-line
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CL
OL
or ML
OH
or
MH
Sc
Sc-SM
CL-ML
SM
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30
20
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4
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30
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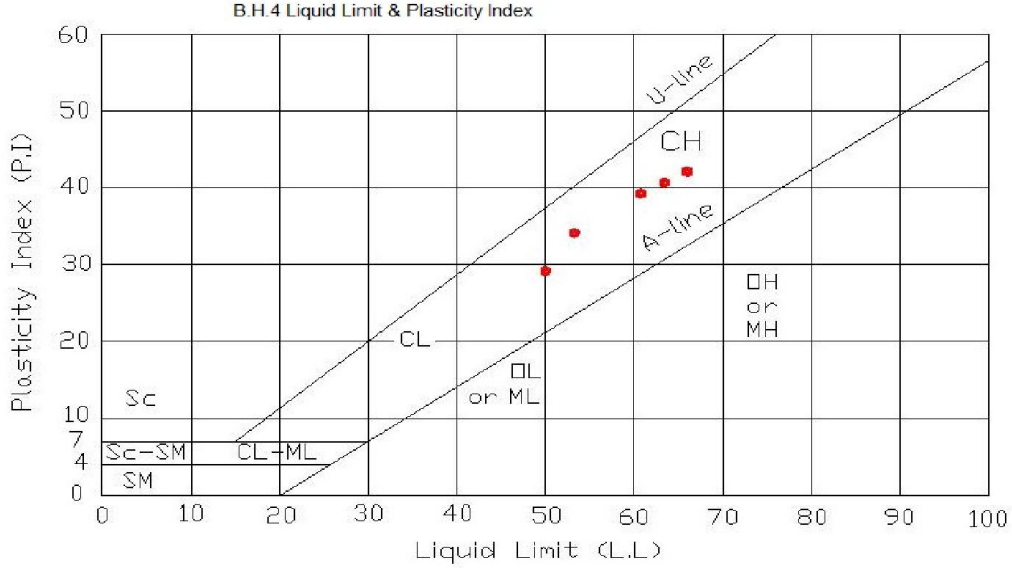
90
100


B.H.4 Liquid Limit & Plasticity Index
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Liquid Limit (L.L)
U-line
A-line
CH
CL
OL
or ML
OH
or
MH
Sc
Sc-SM
CL-ML
SM
60
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4
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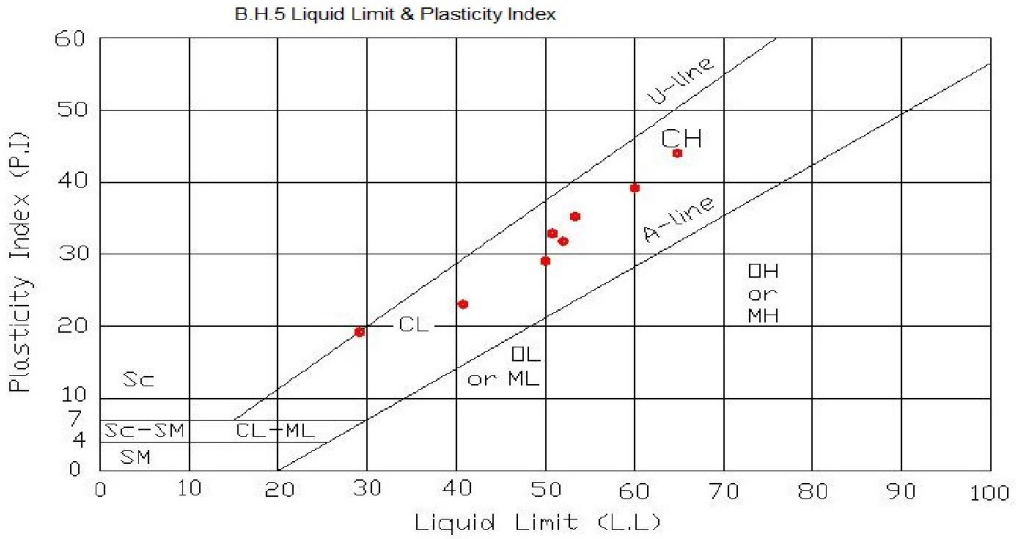
80
90
100


B.H.5 Liquid Limit & Plasticity Index
Plasticity Index (P.I)
Liquid Limit (L.L)
U-line
A-line
CH
CL
OH or MH
OL or ML
Sc
Sc-SM
CL-ML
SM
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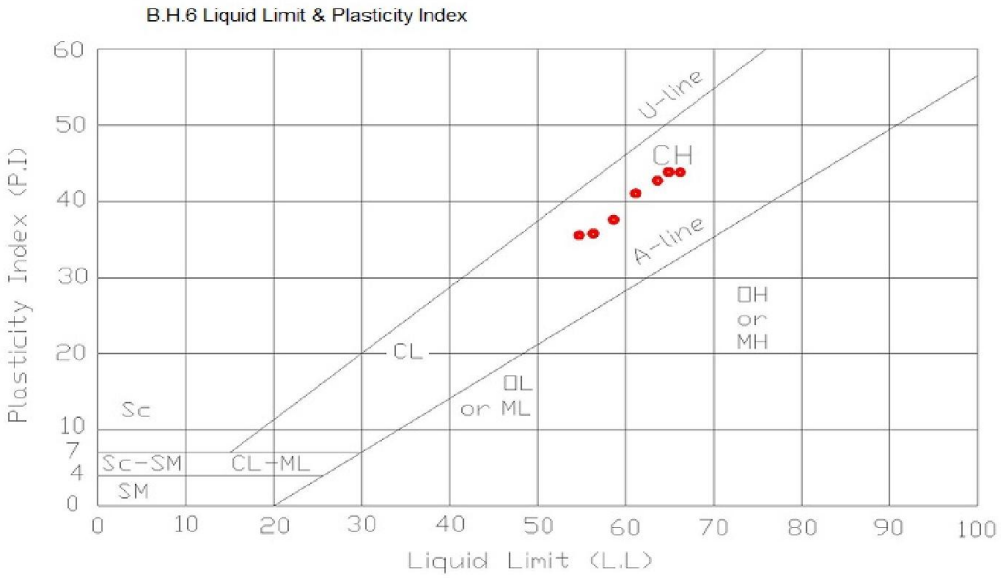
B.H.6 Liquid Limit & Plasticity Index
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Liquid Limit (L.L)
U-line
A-line
CH
CL
OH or MH
OL or ML
Sc
Sc-SM
CL-ML
SM
60
50
40
30
20
10
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4
0
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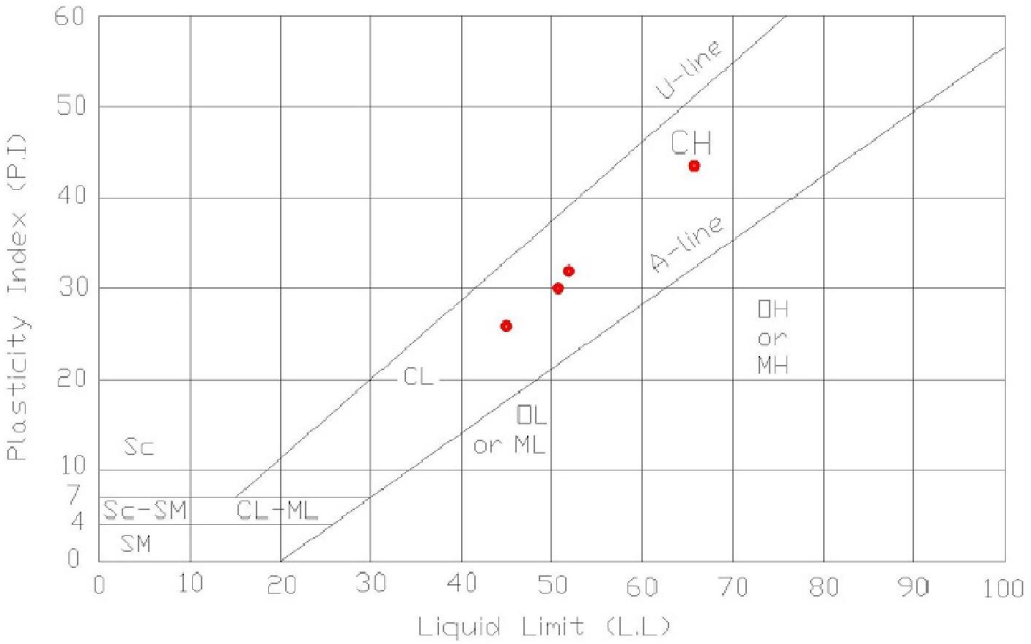
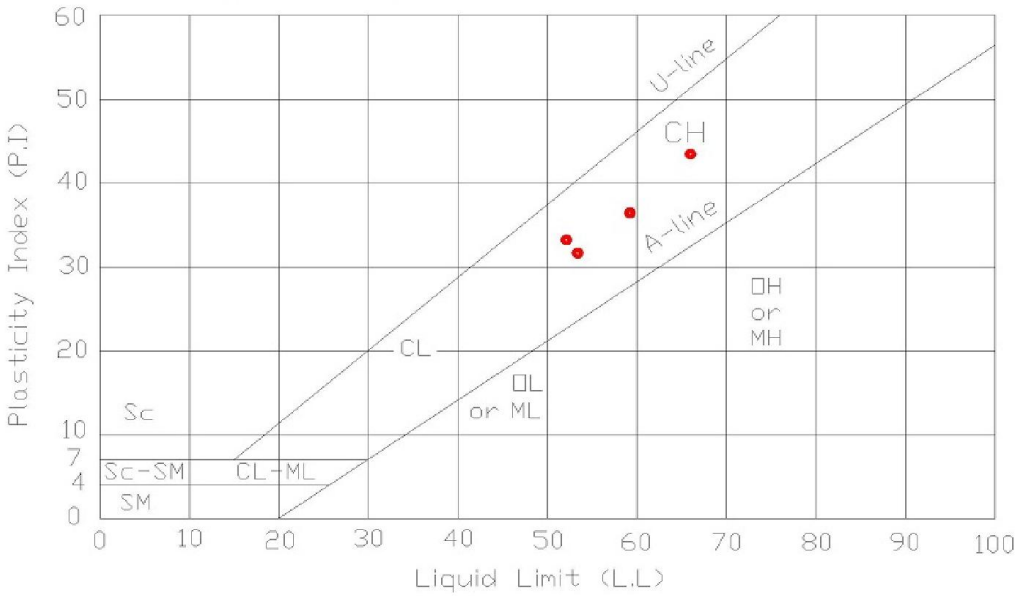
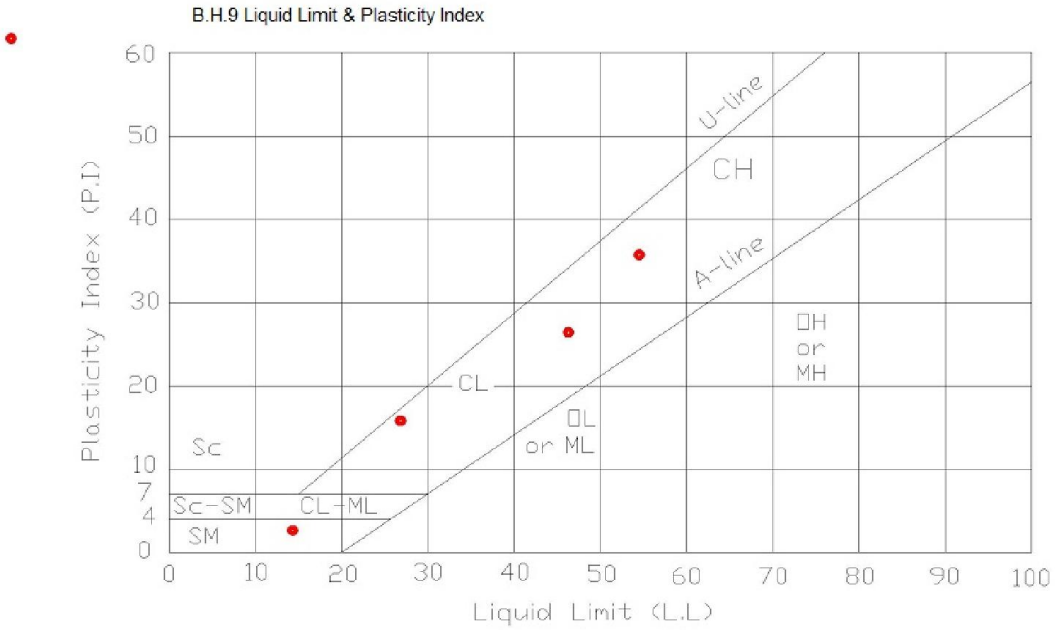
10
20
30
40
50
60
70
80
90
100

B.H.7 Liquid Limit & Plasticity Index



B.H.8 Liquid Limit & Plasticity Index




B.H.9 Liquid Limit & Plasticity Index
Plasticity Index (P.I)
Liquid Limit (L.L)
U-line
A-line
CH
CL
OH or MH
OL or ML
Sc
Sc-SM
CL-ML
SM
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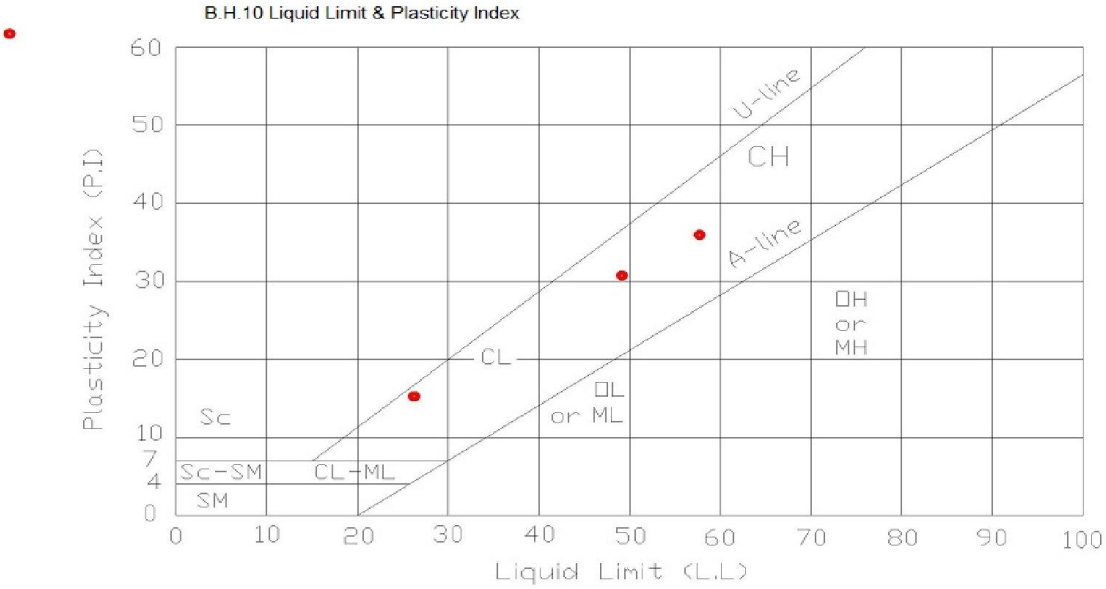
B.H.10 Liquid Limit & Plasticity Index
Plasticity Index (P.I)
Liquid Limit (L.L)
U-line
A-line
CH
CL
OH or MH
OL or ML
Sc
Sc-SM
CL-ML
SM
60
50
40
30
20
10
7
4
0
0
10
20
30
40
50
60
70
80
90
100