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Geotechnical Assessment of Hilla City – Iraq

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Abstracts

Establishing a realistic working profile of soil properties has been, and is still, one of the most challenging problems facing geotechnical engineers. Geotechnical assessment are important and plays a critical role in all construction works particularly in projects involved substantial amount of ground improvement, so, it was helped in suggesting design for appropriate control measures. This study can provide and use as a reference and guidance to estimate site characterization of Hilla city that can be used as potential inputs for designing structures by the city planner, civil and geotechnical engineers. In order to make a geotechnical evaluation and make a general description to determine types of the subsoil of the study area, Five boreholes was drilled to a depth of (15m) from existing ground surface at several sites and laboratory tests were carried out in each area of Hilla city, in addition to large existing data as a results of in-site and laboratory tests from previous geotechnical studies taken from 110 boreholes distributed over different area in Hilla city.

Chemical Analysis for soil and ground water were conducted and the results shows that ground water is small alkalinity, medium to high in salts and it has contain harmful amount of sulfates. Result of chemical tests of soil shows that the sulphat contact of soil between (0.2-1.9)%, Percentage of Organic Matter Content (ORG) is between (0.03-0.06)%, Total soluble salts (T.S.S.) between (0.9-2.7)%, Gypsum content between (0.25-0.67)% and chloride content between (0.034-0.08)%.

The results shows that number of vales (N) of standard penetration test (SPT) is between (4-48) blow and elevation of water table is between (0.3-1.3)m below natural ground surface (N.G.S). The moisture content (M.C) is between (19%-34%) of samples weight. Specific gravity is between (2.67-2.76). Results of analysis of grain size distribution indicate that the majority contents of soil profile consist of silt, sand and clay and this ratios are fluctuating with depth , also results indicates that the percentages of gravel content is between (0-7)%, clay content is between (10%-66%), silt content is between (14%-70%), and sand content is between (4%-74%). Liquid limit (L.L)of soil is between (28%-6١%),Plastic limit (PL) is between (20-39)% and the plasticity index (P.I) is (4%-26%). The average value of soil activity was between (0.56-0.7) and the soil is classified to non active soil. Results from engineering properties of soil indicates the soil have permeability ranging between(6.1x 10^{-4} to 3.3 x10^{-3})cm/sec , compression index (Cc) between (0.06-0.3) for shallow depths, unconfined compression test (qu) between (47-155) Kn/m and the value of (cu) is between (2.6-4.4) ton/m2, and (Φu) is between (7-11) degree. The dynamic and static methods was used to evaluate bearing capacity of soil and the results indicate that the allowable bearing capacity of soil are ranging between (4.3-7) Ton/m2 in different location in Hilla city . The geotechnical assessment of Hilla city showed that the soil profile consist of clay-silt to silt-clay with small amount of sand below natural ground surface for shallow depths ,therefore soil classified to clay with high and low plasticity limits, and silt with high and low plasticity limits fluctuating with depth and soil needs engineering treatments which depends on project type in some places in Hilla .

الخلاصة

عملية وضع مخطط تفصيلي شامل لهيكلية طبقات التربة لمنطقة معينة تعد من اكبر التحديات التي لا تزال تواجه المهندس الجيوتكنيكي حيث يعتبر التقييم الجيوتكنيكي من العوامل المهمة والتي تعلب الدور الرئيسي في الإعمال الإنشائية وخصوصا تلك التي تتضمن عمليات معالجة مختلفة للتربة حيث تساعد من خلال اقتراح التصاميم المناسبة وبما يتلائم مع حاجة المشروع. تضمنت الدراسة حفر خمسة حفر اختبارية موزعة على موقع الدراسة بعمق ١٥م لغرض عمل تقييم جيوتكنيكي وصف عام لطبقات التربة وخصائصها إضافة إلى نتائج الفحوصات المختلفة من الدراسات الجيوتكنيكة السابقة والتي تضمنت ١١٠ حفرة اختباريه سابقة توزعت على مختلف مناطق مدينة الحلة حيث تم الاعتماد في التقييم على المعلومات المستحصلة من العمل الحقلي وعلى نتائج الفحص المختبري للنماذج المشوشة وغير المشوشة المأخوذة من تربة منطقة الدراسة. تم إجراء تحليل كيميائي للتربة وللماء الجوفي في منطقة الدراسة حيث أشارت النتائج الى ان الماء الجوفي ذو قاعدية قليلة اما الأملاح فكانت النسبة تتراوح بين متوسط إلى عالي ويحتوي على نسبة ضارة من الكبريتات . كما وأشارت نتائج الفحوصات الكيميائية للتربة ان محتوى الكبريتات يتراوح بين (٠.٢-١.٩) % ، وبلغت قيمة النسبة المئوية لمحتوى المواد العضوية (٠.٠٣-٠.٠٦)%، وقيمة الأملاح الذائبة الكلية القابلة للذوبان ٠.٩-٢.٧) % في حين بلغت قيمة محتوى الجبس بين (٠.٢٥-٠.٦٧)% ومحتوى الكلوريدات (٠.٠٣٤-٠.٠٠٨)%. تراوحت معدل عدد الضربات (N) لفحص الاختراق القياسي (SPT) بين (٨-٤٨)

ضربة، مستوى المياه الجوفية من (٠.٣-١.٣)م تحت مستوى سطح الأرض الطبيعي، محتوى الرطوبة (M.C) بين (١٩%-٣٤) % من وزن النماذج . النوعي للتربة تراوح بين (٢.٦٧-٢.٧٦) . أما التوزيع الحبيبي فقد تراوحت نسبة الحصى بين (٠-٧) % وتراوحت نسبة الطين بين (١٠%-٦٦%) ونسبة الغرين بين (١٤%-٧٠%)م ونسبة الرمل بين (٤%-٧٤%). اما حد السيولة (LL.) فقد تراوحت قيمته بين (٢٨%-٦١%) وحد اللدونة (PL.) بين (٢٠%-٣٩%) ودليل للدونة (PI) بين (٤%-٢٦%)، في حين كان معدل قيمة فعالية التربة بحدود (٠.٥٦- ٠.٧) حيث على أساسها صنفت التربة بأنها غير فعالة. قابلية تحمل التربة تم احتسابها بطريقتي التحمل الاستاتيكي والداينميكي حيث أشارت الى ان قابلية تحمل التربة تتراوح بين (٤.٣-٧) طن/م٢ في مختلف مناطق مدينة الحلة. نتائج الفحوصات الهندسية اشارت الى ان معامل النفاذية للتربة يتراوح بين (6.1x 10-4 to 3.31 x10-3) سم/ثانية ومؤشر الانضغاطية للتربة تراوحت بين (Cc) (٠.٠٣-٠.٠٦)، كما تراوحت قيم فحص الانضغاط اللامحصور بين (٤٧-١٥٥) كن/م٢ ، كما وتراوحت قيمة التماسك (Cu) للتربة بين (٢.٦-٤.٤) طن/م٢ وزاوية الاحتكاك الداخلي للتربة بين (٧-١١) درجة. وقد تبين من خلال التحري ونتائج الفحص المختبري بأن التربة في موقع الدراسة تحتاج الى معالجات هندسية لغرض إقامة المنشآت الهندسية عليها.

Keywords: Hilla City, Chemical Properties ,Physical Properties , Geotechnical Assessment, Geotechnical Properties.

Introductions

Site investigation and estimation of soil characteristics are essential parts of a geotechnical design process. Geotechnical Engineers must determine the average values and variability of soil properties.

Soil profile is a convenient description of the subsurface conditions. In almost every geotechnical project, there is a need to establish a working soil profile, a profile that is simple enough for the subsequent geotechnical analysis and design and yet accurate enough to represent the subsurface conditions of the site.

There are many published experimental and theoretical investigations dealing with soil assessment and evolution of soil properties problem in Iraq and other regions in the words, but relatively few of them deal with the geotechnical assessment of Hilla city.

Ghaidaa Al-Naimi, 1996, presenting geotechnical and evaluation studies about soil parameters and shear strength of soil of Baghdad city , middle region of Iraq, and presenting many charts showing variations of different types pf soil properties liquid limit, plastic limits, soil activity and other factors with death

Bakir, 1998 , studied different types of soil properties of southern region of Iraq and presenting many geotechnical maps showing variations of different types pf soil properties liquid limit, plastic limits, soil activity and other factors with death soil for this area.

Al Ani (2001), presenting geotechnical maps for soil of Dyalaa governorate and middle region of Iraq . the study included different soil properties liquid limit, plastic limits, shear strength and other factors with death

AlJubory, Hamed Hassan (2002), studies the geotechnical properties of Babil governorate and another areas and presenting a geotechnical maps. The study includes are effect of different soil properties (mechanical, physical and chemical) with depth .

Mohammed Abdul – Zahra Turkie (2005) presenting geotechnical maps for the soil of Baghdad, Diyala, Wasit and Babylon governorates through collecting data, tabulating the information & analyzing them, then maps were drawn for each property for different depths. He studied different types of soil properties Atterberg limits (liquid limit & plasticity index), dry unit weight, initial void ratio, fine particle percent, strength of soil in term of (number of blows in S.P.T and unconfined compression strength), compression index, organic matter percent, sulphate content and water table.

Muhsen O'bead Khalaf Al-Khakani (2006) studied swelling problems of clay soils in Hilla city based on the results from laboratory and field tests of samples taken from fifteen locations in the study area. Physical and mechanical properties of soil are also studied. The results indicates to low-high swelling degree for Hilla city.

Jiang Jianping, (2011) , studying physical and mechanical characteristics of soft soil (including clay and silty clay) in the foundation of Sutong large bridge in lower reaches of

Yangtze River, Jiangsu province, China, based on large numbers of geotechnical tests. He found variation coefficient of natural density, dry density, specific gravity of soil grain, saturation are small; the variation coefficient of natural water content, naturalhole ratio, liquid limit, plastic limit are generic; and the variation coefficient of plasticity index, compress module, compress coefficient, coherent strength, inner friction angle, the standard penetration test (SPT) are big.

Ali Hooshmand and others (2011) studied the mechanical and physical characterization of Tabriz Marls, Iran to investigate the strength and deformation characteristics of Tabriz marls. stress–strain behavior are investigated by various in situ and laboratory tests. The results indicates The parameters qu (uni-axial compressive strength), NSPT, and Es (Young's modulus) have good correlation with depth, Among the three types of Tabriz marls, yellow and gray/black marls have the lowest and the highest strengths, respectively.

The purposes of this study were to explore subsurface conditions for Hilla city and to provide recommendations for geotechnical aspects of design and construction of different projects. We accomplished these purposes by:

1. Reviewing readily-accessible geologic and geotechnical information in the general site vicinity;
2. Drilling five geotechnical soil borings to explore subsurface conditions and to obtain samples for laboratory testing.
3. Conducting geotechnical laboratory tests to assess pertinent soil engineering properties ;
4. Collect useful information and data to help the designer of foundations
5. Find profile section and allowable bearing capacity for the soil.
6. Analyzing the field and laboratory data to develop conclusions and recommendations

Site Description and Map of Study Area

Iraq is located between two Latitudes (N ٢٩˚٥´) and (N٣٧˚١٥´) and between two Longitudes (E ٣٨˚٤٥´) and (E ٤٨˚٤٥´) (Buringh 1960), while the site of study area is located in Babylon Governorate, Hilla city, between two Latitudes (**N 32º 34` 00``**) and (**N 32º 25` 00``**) and between two Longitudes (E **44º 23` 00``)** and (**E 44º 31` 00``**). The site which located southern of Baghdad (100Km) is part of Quaternary sediments. The site in general is flat area. The location of the boreholes was distributed over the site. A general map of study area , locations of boreholes with different depths of boring and the coordination of study area (Latitude (N) and longitude (E)) are shown in Figure (1).

Brief Geological History of the Steady Area

Hilla city in Babylon governorate is part of flood plain region, which represent the recent surface formation of Iraq geology, since it contains the resent alluvial sedimentation deposit from the two rivers, Tigers and Euphrates.

However, the site is free from erosion old rock surface. The formation of this flood plain is belonging to Pleistocene period. On the other hand there is depression fill deposits which accumulate due to successively floods .It consist primary soft layers of fine sand and silt, clay and silty clay.

Methodology of Study

The scope of work of the study include reviewing pervious geotechnical and environmental studies of the city, conducting additional test pit explorations in areas not previously explored, and presenting our findings. Geotechnical investigation program included studying physical, chemical and engineering properties of the soil. In the present study , a geotechnical assessment of Hilla city was carried out in four phases as below:

Phase One: Reconnaissance Phase

The scope of work of this phase are representing in collect available information from pervious geotechnical studies , find a location of each boreholes in Hilla city in addition to getting GPS coordination (Latitude (N) and longitude (E)) for each borehole by using GPS Equipments

and preparing a general map of study area putting borehole coordinate on it as shown in Fig. (1) .

In the present study, the total number of boreholes are (115) boreholes distributed over Hilla city, (110) boreholes from pervious geotechnical studies and (5) boreholes from present study. Distribution of boreholes in Hilla city are showing in Figure (1) . Total depth of boring of each borehole and number of boreholes are presented in table (1)

Table (1) Number of Boreholes with depths for Hilla city

Total Depth of Borehole below natural ground surface (m)	10	12	15	20	
Number of Boreholes in present study	22	12	20	8	Total Boreholes 115

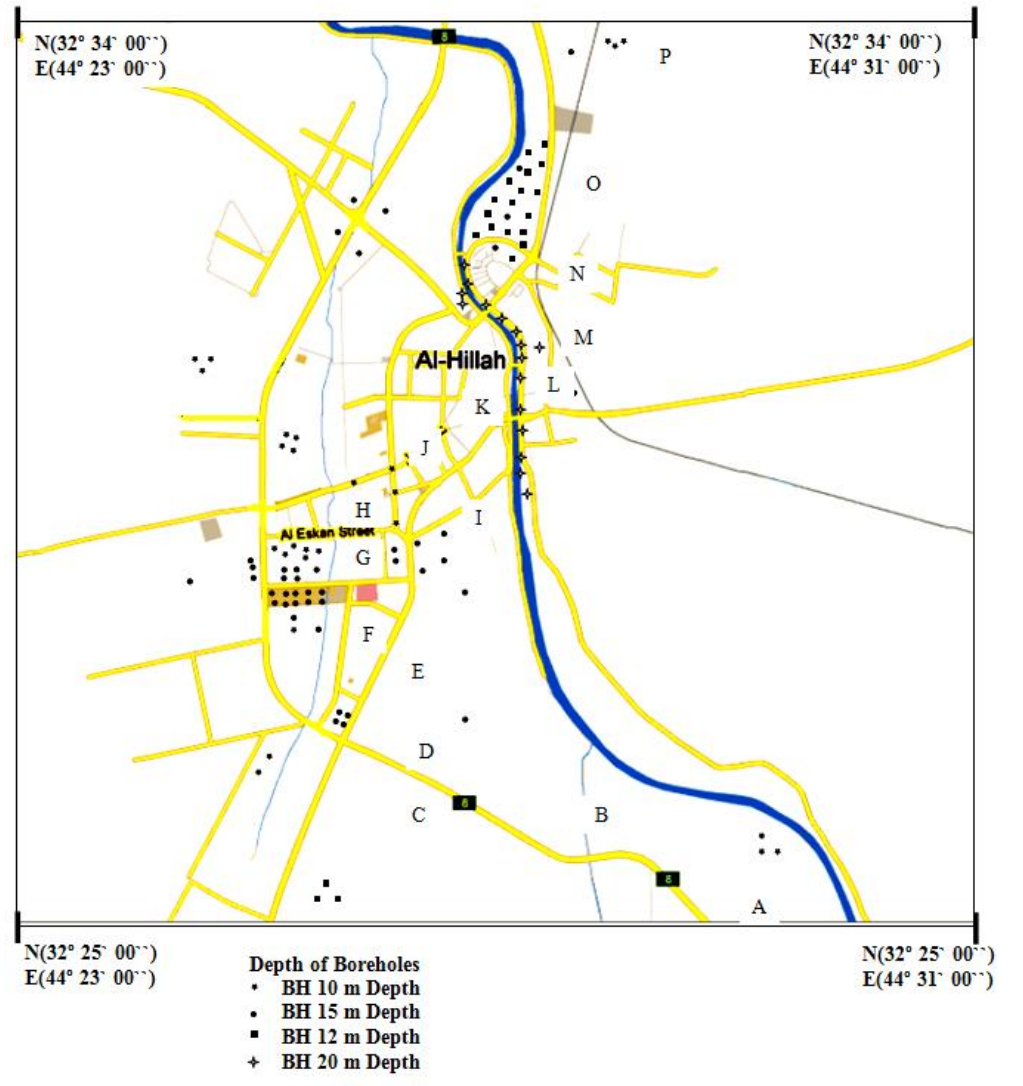


Figure (1) Satellite Map of Hilla City with location of boreholes and GPS coordination of map

Phase Two : Field Work

The scope of work emphases on a location of drilled boreholes and in-site tests which are doing during drilling works. During this phase, the work is divided to two parts:

A- Allocation of Studding Area and Boreholes

The scope of work emphases on find a suitable location and drilling works for each boreholes. Five boreholes have been drilled to a depth 15 m below natural ground surface by using mechanical machine type Flight Augers drill method with diameter (10cm) . Hydraulic drilling rig machines mounted on a four-wheel vehicle were used for drilling the boreholes adopting rotary bit drilling method. The method of drilling was in accordance with procedures specified in the code of practice for site investigation of 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 detecting to extend to underneath the zone of influence of significant foundation pressure to materials that were relatively incompressible.The samples recovered were examined, labeled, described and classified by a geotechnical engineer, placed in proper sequence in wooden boxes. Soil samples were put in plastic bags and transferred to laboratory for testing. Table (2) showing types of collecting samples

Table (2) Types of Sample and Tests

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

B- In-situ Testing, Standard Penetration Test (S.P.T.)

During the drilling operations, Standard penetration tests (SPT) were performed in accordance with ASTM D-1586 at regular intervals using Standard Penetration Sampler to evaluate the relative density/consistency of the soils encountered and to retain soil samples for laboratory testing. The penetration tests were performed by initially driving the sampler a 50 mm external diameter thick walled tube ((Split spoon sampler)) into the bottom of the borehole using a 63.5 kg hammer falling freely from a height of 760 mm (automatic trip-hammer falling). The sampler was driven the first 150 mm to penetrate loose soil cuttings and "seat" the sampler. Thereafter, the sampler was progressively driven an additional 300mm with the results recorded as the corresponding number of blows required "N" value to advance the sampler 300mm. Soil samples obtained from the borings were packaged and sealed in the field to reduce moisture loss and disturbance and brought to laboratory for testing.

Phase Three: Laboratory Testing:

Laboratory tests were performed on selected samples from each boreholes. The tests were carried out in accordance with British Standard (BS) and American Society for Testing and Materials (ASTM) in order to determine the physical, mechanical and chemical properties of studying areas.

A summary of all laboratory tests performed is presented below:

1- Physical Properties of Soil

- Consistency & Atterberg Limits (ASTM D-4318)
- Water Content (ASTM D-2488)
- Clay Activity
- Grain Size Analysis (ASTM D-422)
- Specific gravity. (ASTM D-854)
- Unit weight (natural and dry) (ASTM D-4318)

2- **Engineering Properties of Soil**

- Standard Penetration Test (S.P.T) (ASTM D 1586-99)
- Permeability Test (ASTM D2434)
- Unconfined compression test. (ASTM D-2266)
- Direct shear. (ASTM D-2850, D-4767)
- Consolidation test (ASTM D-2435-02)

3- Chemical Properties of Soil and Ground Water

- Sulphate Content (SO3 % (B.S. 1377: 1990 Part 3)
- Organic Matter (ORG %) (B.S. 1377: 1990 Part 3)
- Total soluble salts (T.S.S) (B.S. 1377: 1990 Part 3)
- Gypsum content (B.S. 1377: 1990 Part 3)
- Chloride Content (B.S. 1377: 1990 Part 3)

Phase Four: Analyzing the Results of Pervious Geotechnical Studies

The scope of work emphases on analyzing large existing data from pervious geotechnical studies of Hilla city, the total number boreholes are 110 boreholes distributed over area of study. The locations of boreholes are shown in Figure (1). Pervious geotechnical studies which used in the present study are taken from different places; Babil construction laboratory, consultant bureau of Engineering collage - Babylon University, consultant bureau of science collage - Babylon University and consultant bureau of Engineering collage - Baghdad University.

Results and Discussion

Results of present study are evaluating according to ASTM and B.S specifications.

First: Physical Properties of Soil

1-Grain size and hydrometer analysis :

Soils consist of a mixture of particles of different size, shape and mineralogy. Because of the size of the particles obviously has a significant effect on the soil behavior, the grain size and grain size distribution are used to classify soils. The grain size distribution describes the relative proportions of particles of various sizes.Tests were performed in general accordance with ASTM Test Method D 422.

Hydrometer analysis were performed to determine the grain size distribution of fine – grained soils having particle sizes smaller than 0.075 mm and when percentage of finer is greater than 12% with weight approximately equal to 50 gm. Results of grain size and hydrometer analysis of five boreholes indicate well-graded soil of five boreholes as presented in Fig. (2)

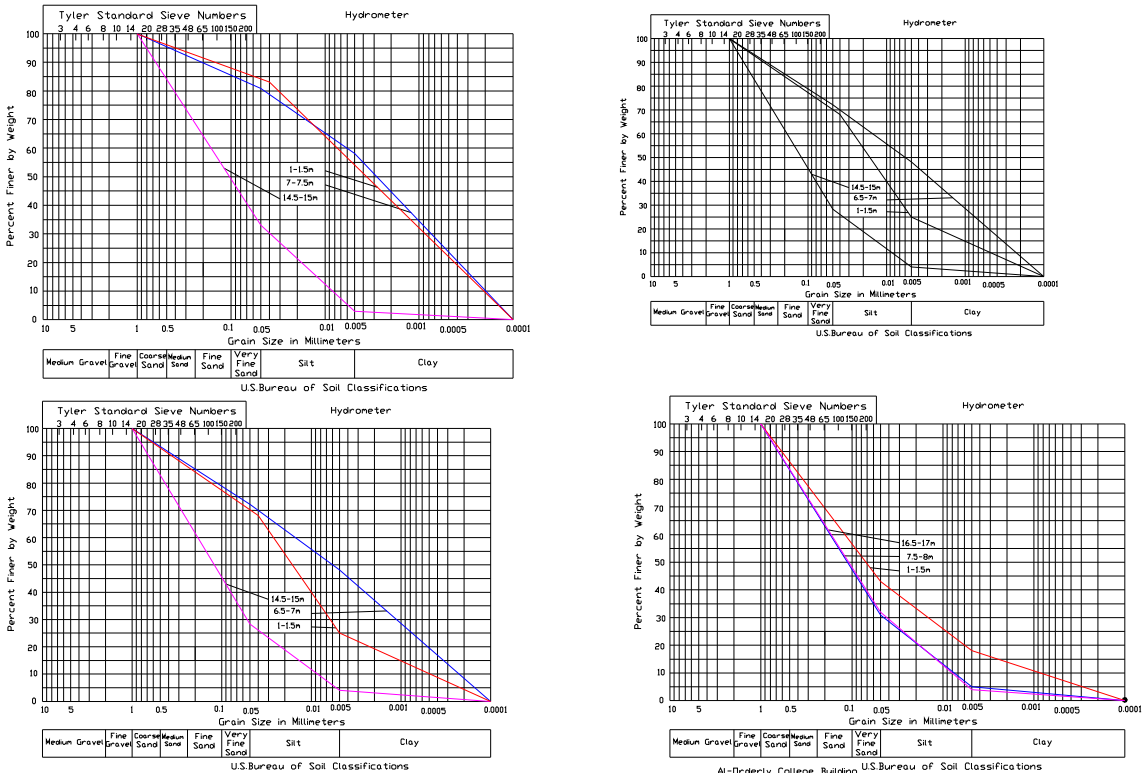


Figure (2) Results of Grain Size analysis for different boreholes in present study

Form the results of present study and pervious studies, results of grain size analysis indicates that the most of soil profile materials consist of silt ,clay and sand , while some places have gravel content with small ratios especially in shallow depths. The maximum values of gravel content is (7%) by weight and show in one to three places and did not show in other places from area of study. From the Fig (3) , results indicate a very little amount of gravel content in soil profile of present study, which can be neglecting on taking the effect of gravel content on soil profile of studying area. From the analysis , the major contents of soil profile are silt, clay and sand materials in different depth below natural ground surface as shown in Fig (4) . According to these results, the majority of soil profile consist of silt -clay to clay -silt with a trace of sand especially for shallow depth. Then, after 6 m depth below natural ground surface, the amount of sand content has become increased and become more effective like clay and silt in most of places of studying area. Also we noted that the effect of sand become decreases after 9 m depth below natural ground surface and the majority of soil profile consist of silt-clay to clay- silt in most places of studying area.

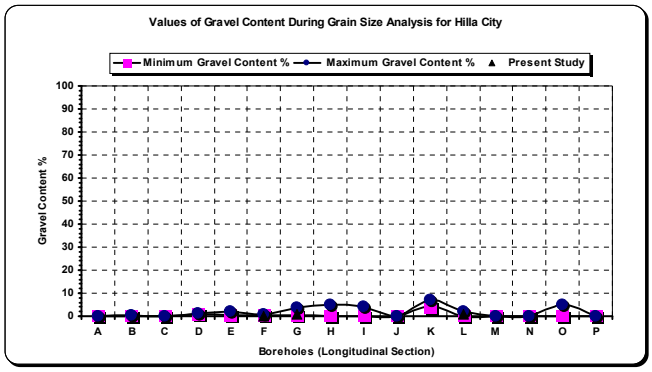


Figure (3) Gravel Content in different location in Hilla city from pervious studies

The percentage by weight of silt, clay and sand contents with different depths in different locations in area of study are presents in Fig. (4)

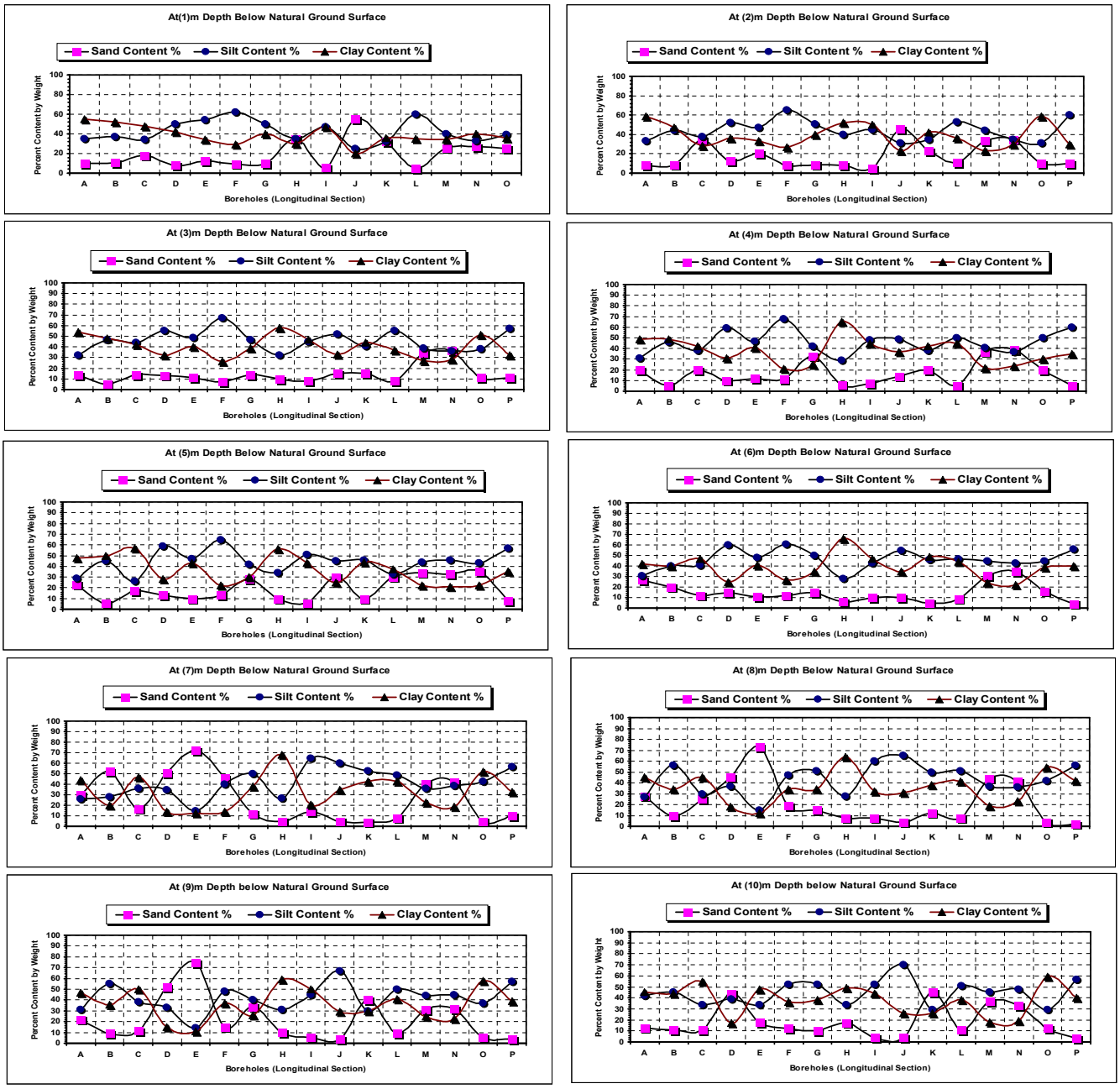
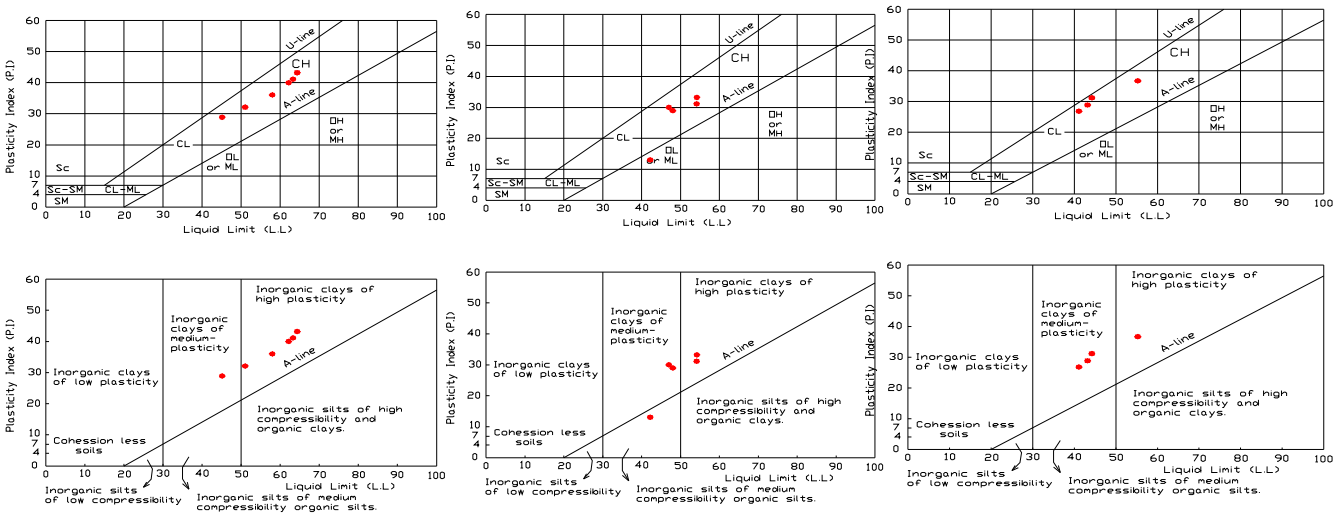


Figure (4) Analysis of soil profile content (Silt, Clay and Sand) in different location in Hilla city

2- Consistency & Atterberg Limits

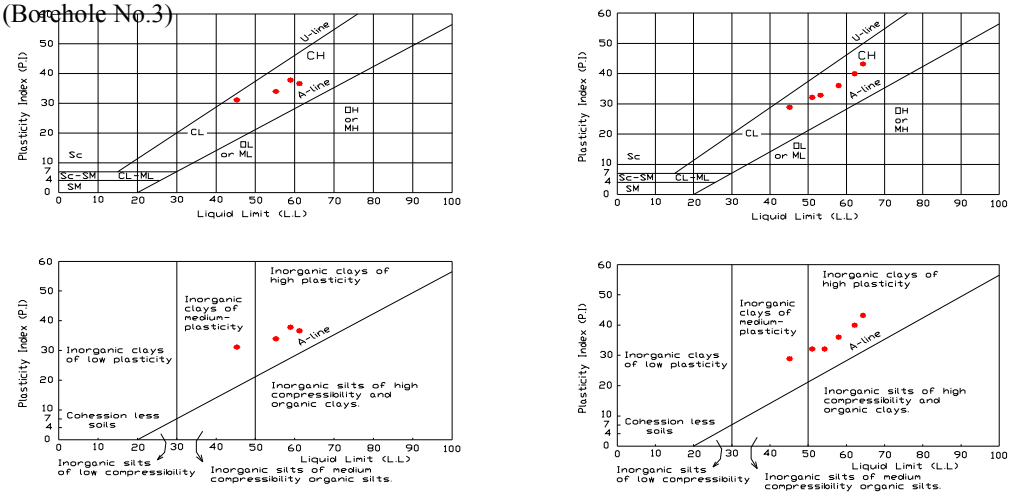
Atterberg Limits tests were performed to classify soils and evaluate the plasticity characteristics of the soil. Tests were performed in general accordance with ASTM Test Method D 4318. Twenty six samples from five boreholes in different depth showed (43–62)% for liquid limits and (19–42%) for plastic limits. All samples have

plasticity index between (13–42) and are classified as CL, CH in the plasticity chart, results indicates the cohesive soil have wide range of plasticity CL (clays of medium plasticity),CH (clays of high plasticity) and one sample test have OL or ML (silts of medium or high compressibility and clay. Fig. (5) showing plasticity chart of present study.



(Borehole No.1) (Borehole No.2)

(Borehole No.3)



(Borehole No.4) (Borehole No.5)

Figure (5) Plasticity Chart of five boreholes of present study

Form analysis of the results of present study and pervious studies , the average values of liquid limits, plastic limits and plasticity index in different location of Hilla city

with different depths are presented in Fig (6). According to these results, we can see that the liquid limit have the upper values in all of locations of Hilla city in all depths, while Plastic limit and plasticity index values are quite closer in some locations of Hilla city particularly in shallow depths.The average values of liquid limits, plastic limits and plasticity index with different depths in different locations in Hilla city are presents in Fig.(6). Result from pervious studies indicates that the linear shrinkage results are between 11.0 to 14.0 percent which indicate that the cohesive layer might exhibit swelling and shrinkage potential.

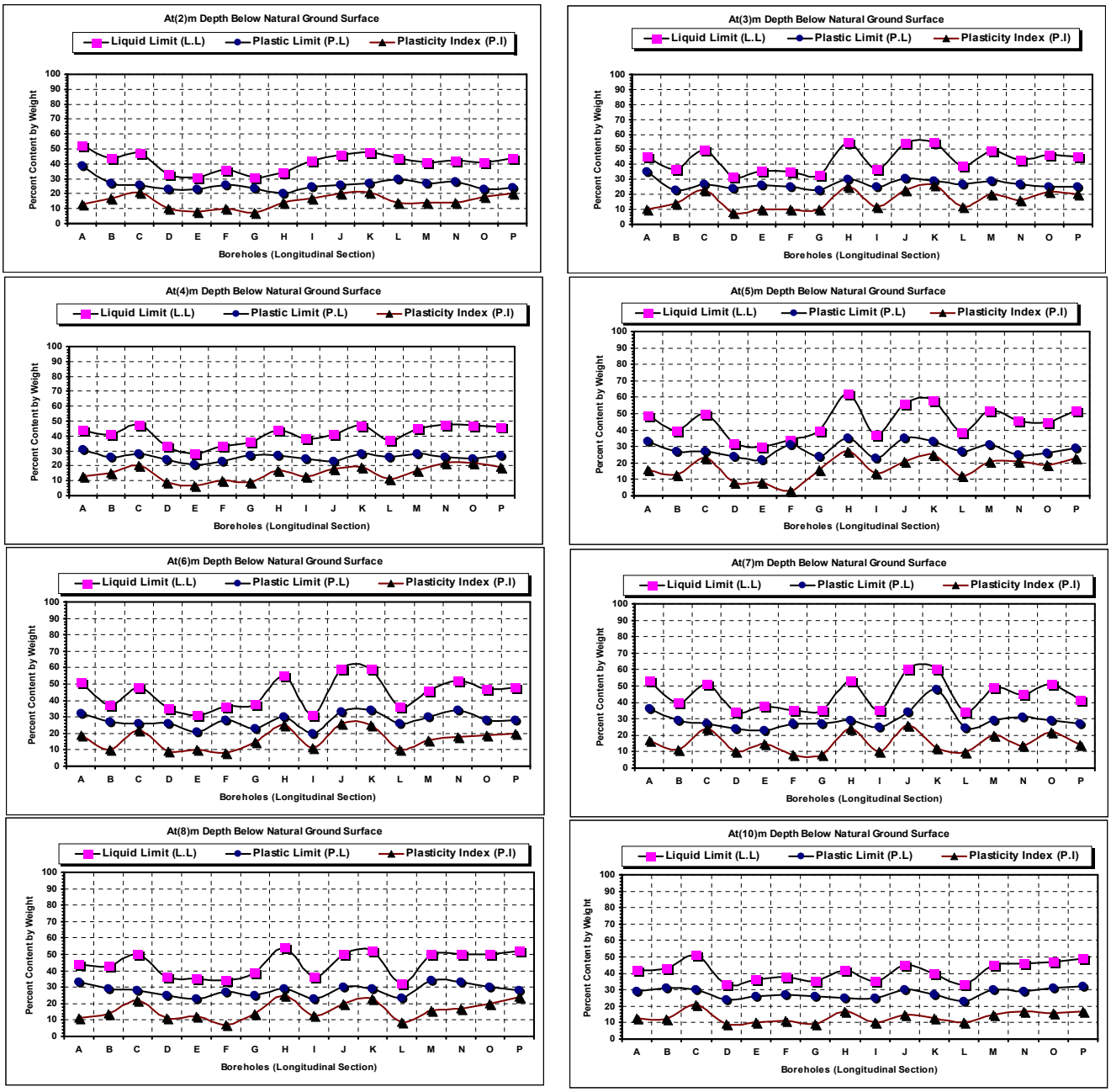


Figure (6) Analysis of average values of Atterberg limits in different location in Hilla city

3- Soil Activity

Bowles ,1984, defined soil activity as a relation between plasticity index to finer clay content, which can expressed as a: Soil Activity = PI/finer less than 0.002 mm

In the present study, according to the results of Atterberg limits and grain size analysis, The average ratio of plasticity index to clay content (soil activity) is (0.62).Form analysis of the results of present study and pervious studies , the average values of soil activity in different location of Hilla city with different depths are presented in Fig (7). The results indicates that this soil have poor clay activity according to ASTM specifications, so this soil of Hilla city has low swelling tendency.

4-Specific Gravity(Gs)

The specific gravity of soil, Gs, is defined as the ratio of the mass in air of a given volume of soil particles to the mass in air of an equal volume of gas free distilled water at a stated temperature (typically 68° F {20° C}). Specific gravity was evaluated in general accordance with ASTM Test Method D 854. The specific gravity of soils is needed to relate a weight of soil to its volume, and it is used in the computations of other laboratory tests.

Form analysis of the results of present study and pervious studies , the average values of specific gravity of soil, Gs in different location of Hilla city with different depths are presented in Fig (8). The results indicates a range of specific gravities from a minimum of 2.67 to a maximum of 2.76 for Hilla city as a show in Fig.(8). The little variation between values of specific gravity because of the nature of the soil formation in the area are almost similar and have the same formative resources.

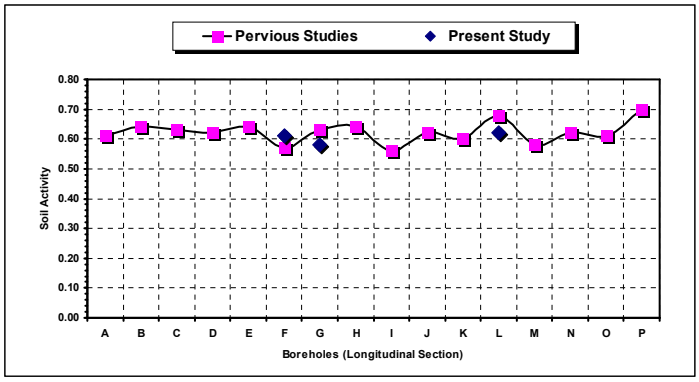


Figure (7) Average values of Soil Activity in different location in Hilla city

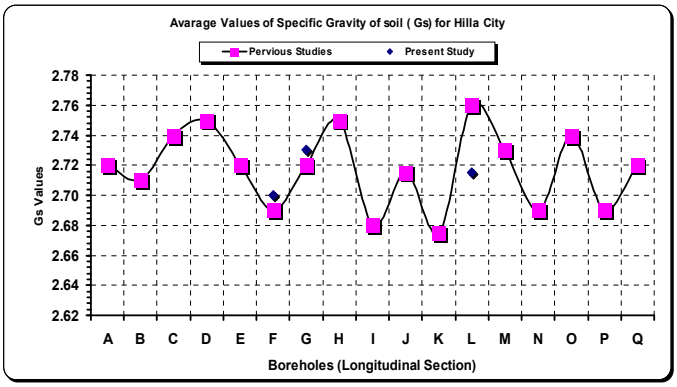


Figure (8) Average values of specific gravity of soil, Gs ,in different location in Hilla city

4- Moisture Content and Dry Unit Weight of Soil

Moisture content and dry unit weight tests were performed to evaluate moisture conditioning requirements during site preparation and earthwork grading, soil overburden, and active and passive earth pressures, and relative soil strength and compressibility. Moisture content was evaluated in general accordance with ASTM Test Method D 2216. Dry unit weight was evaluated using procedures similar to ASTM Test Method D 2937.

Form analysis of the results of present study and pervious studies , the average values of Moisture content of soil, in different location of Hilla city with different depths are presented in Fig (9). The results indicates average value of moisture content from a minimum of 19% to a maximum of 33% for Hilla city as a show in Fig.(9). The results generally indicate that the value of moisture content is closer to the plastic limit than to the liquid limit and that maybe refer to the cohesive layer is over consolidated .

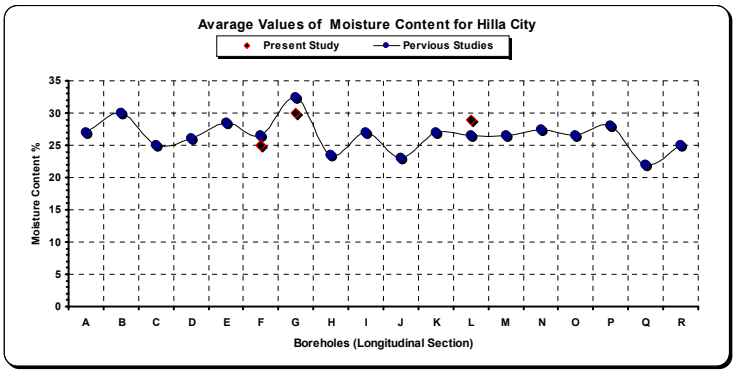


Figure (9) Average values of Natural Moisture Content of soil in different location in Hilla city

Second: Engineering Properties of Soil

1- Permeability Test:

Laboratory falling permeability test was carried out for cohesive soil and no cohesive soil samples and the test was performed in general accordance with ASTM Test Method D 2434. In the present study, three falling permeability tests are done in three different samples, the results indicates that coefficient of permeability was varied from (6.1×10^{-4} to 3.3×10^{-3}) cm/sec.

From pervious studies, The average value of coefficient of permeability for Hilla city are varied from (4.2×10^{-4} to 4.7×10^{-3})cm/sec. Form analysis of the results of present study and pervious studies , results indicate the permeability of soil is poor to medium in different areas in Hilla city. This range from poor to medium in permeability of soil because of increasing percentage of sand content in some soil layers in different locations and depths. Medium degree of permeability for non-cohesive soil and low permeability for cohesive soil.

2- Consolidation Test

Consolidation test was carried out for three undisturbed soil samples, and the test was performed in general accordance with ASTM Test Method D-2435-02. The results of consolidation test from the present study and the variations between overburden (Po) pressure and preconsolidation (Pc) pressure with depth which are presenting in Table (3), the consolidation results indicate that the cohesive soil layer is over consolidated

Table (3) consolidation parameters with depth.

Boreholes No.	Depth (m)	Parameters of Consolidation Test				
		Initial Void Ratio (e_0)	Compressibility Index (Cc)	Swelling Index (Cr)	Po Kn/ m^2	Pc Kn/ m^2
BH.1	3-3.5	0.585	0.189	0.046	36	100
BH.2	5-5.5	0.75	0.25	0.076	54	140
BH.3	9.5-10	0.589	0.192	0.042	95	140

Form analysis of the results of present study and pervious studies , the average values of compression index Cc of soil, in different location of Hilla city with different depths are presented in Fig (10). The results indicates that average values of compression index Cc are increasing with increasing depth to approximately 5 meter depth below natural ground surface, after that compression index Cc will be decreasing with increase

the depth. Generally, the soil layers are over consolidated soil in different location in Hilla city. Values of compression index Cc for depth 2 and 3 m are presented in Fig (10).

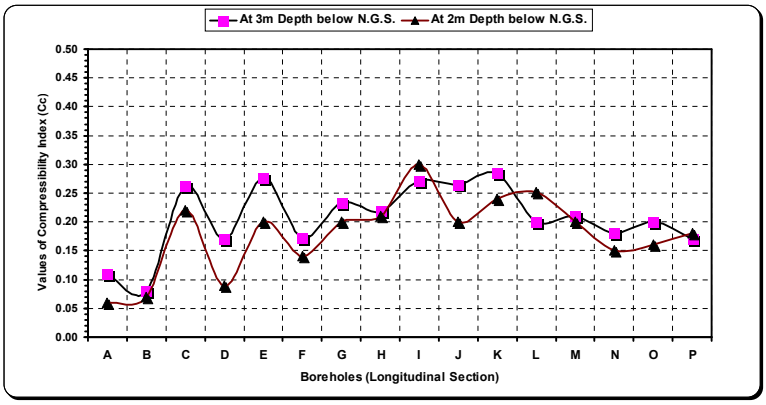


Figure (10) Average values of compression index Cc of soil in different location in Hilla city

3- Shear Strength of Soil

The shear strength of a soil is the maximum shearing stress the soil structure can resist before failure. Soils generally derive their strength from friction between particles (expressed as the angle of internal friction, φ), or cohesion between particles (expressed as the cohesion, c in units of force/unit area), or both. In the present study, tow types of laboratory shear tests was used according to soil types:

- **Unconfined Compression test:** An unconfined compression test was performed on a four selected, undisturbed samples from five boreholes at different depth to evaluate the undrained shear strength of the sample. Test procedures were in general accordance with ASTM Test Method D 2166. Result of test are presenting in table (4) and indicate that the consistency of the cohesive soil layer is soft to medium to stiff with increasing depth below natural ground surface.
- **Direct shear Test :** Four soil samples from five boreholes at different depth were tested by using direct shear strength The tests were conducted following ASTM D3080. The shear box used for testing has an area of 36 cm2 (60 * 60 * 20 mm dimensions, with a volume of 72 cm3). Shearing was conducted at a rate of 0.6 mm/min. Results of direct shear tests are presenting in table (4) and indicate that the relative density of this soil layer is loose to medium dense to very dense with increasing depth below natural ground surface.

Table (3) Results of unconfined compression test and direst shear test

BH No.	Depth m	Unconfined compression test (qu) Kn/m2	Direct shear test		Unit weight gm/cm³	
			C Kn/m2	Ø 0	γ_{wet}	γ_{dry}
BH.1	1-1.5	105			1.93	1.56
	3-3.5	250			2.09	1.75
	10-10.5		0	34		
BH.2	2-2.5	235			1.975	1.64
	4-4.5	336			1.99	1.6
BH.3	2-2.5	230			1.97	1.64
	2.5-3		0	31		

BH No.	Depth m	Unconfined compression test (qu) Kn/m2	Direct shear test		Unit weight gm/cm³	
			C Kn/m2	Ø 0	γ_{wet}	γ_{dry}
BH.4	11-11.5		0	35		
BH.5	1.5-2	60			1.96	1.54
	2.5-3		0	33		

Form analysis of the results of present study and pervious studies , the average values of unconfined compression test, qu, of soil, in different location of Hilla city with different depths are presented in Fig (11). The results indicates average value of unconfined compression test, qu are generally increase with increase depth below natural ground surface. Values of unconfined compression test, qu for depth 2 , 3 and 5 m are presented in Fig (11).

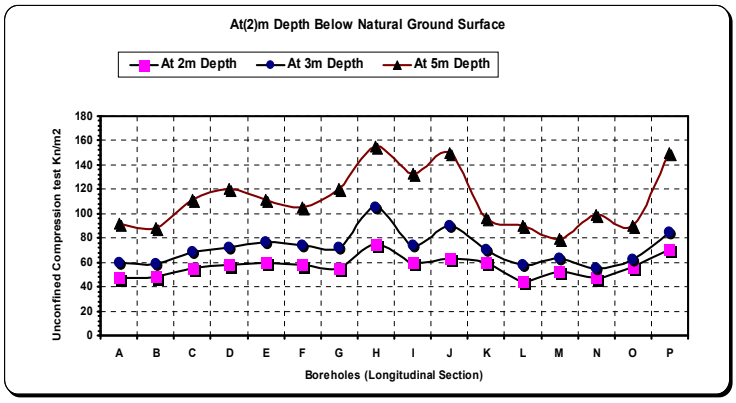


Figure (11) Average values of unconfined compression test of soil in different location in Hilla city

1- Standard Penetration Test (S.P.T.)

In the present study, In-situ Standard penetration tests (SPT) were performed in accordance with ASTM D-1586 at regular intervals between (1.5-2)m depth below natural ground surface using Standard Penetration Sampler to evaluate the relative density/consistency of the soils. 32 Standard penetration test (SPT) was did in five boreholes in different location in Hilla city with different depths.

The penetration tests were performed by initially driving the sampler a 50 mm external diameter thick walled tube ((Split spoon sampler)) into the bottom of the borehole using a 63.5 kg hammer falling freely from a height of 760 mm (automatic trip-hammer falling).

Form analysis of the results of present study and pervious studies , the average values of standard penetration tests (SPT) of soil of Hilla city with depth are presented in Fig (12). All

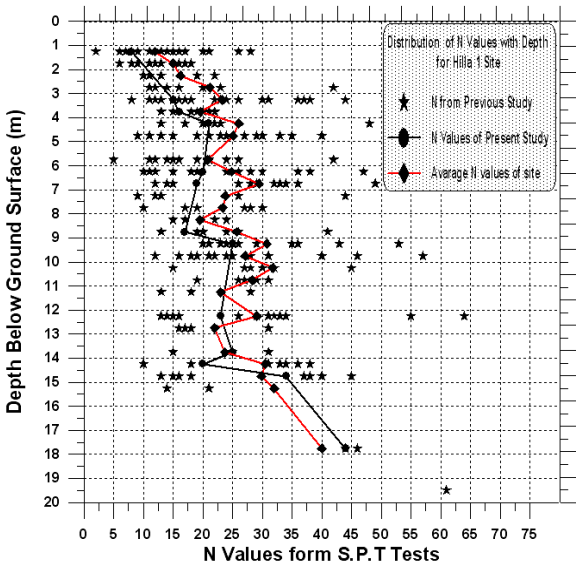


Figure (12) Average values N values of S.P.T tests with different depth in different location in Hilla city

SPT tests are done under water table in present study and from results of pervious studies. The results indicates a wide variation between N values from Standard penetration tests (SPT) in same depths , this variation maybe happened because of using different hammer types in doing SPT test. In present study, SPT test are done by using automatic trip-hammer falling. From pervious studies ,SPT tests was did by using hand-lifted hammer in some boreholes and automatic trip-hammer in other boreholes. therefore , this is maybe a main reason in variation of N values in same depth below natural ground surface. Generally, The result indicate that N values of SPT test are increase with increasing the depth to approximately 5 meter below natural ground surfaces. , after that N values will be decreasing with increase the depth until 8 m depth, then N values will be increased with increasing depth below 8m.

In order to attempt stratification of soil layers of Hilla city, variation of N values with different depths and location are studied, also comparison between the results from present study and pervious studies are made as shown in Figure (13). The results indicates a wide differences between N values near ground surface especially for depths (0.5-2.5)m below ground surface, that refer to the soil layer is not have same properties from strength side because of majority of surface layers maybe consist of filling materials added to the surface. After (2.5-5)m depth, results of the N values of SPT tests are converged between them in most of area in Hilla city and that indicate to the soil layer have same properties from strength side. After (5.5-7) m depth, the differences between N values are found. After 8 m depth, the variation between N values of SPT test are become lesser and converging between them are found.

5- Bearing Capacity:

In the present study, Two methods are used to determinate a allowable bearing capacity of soil of Hilla city as shown below:

A- Dynamic Method

In this method, bearing capacity of soil depend on N values from Standard penetration test (SPT) . From the results, the allowable bearing capacity of the soil from N-SPT test for depth from (1.5 -15 m) is ranging from (4 – 9.5) T /m² for all boreholes depending on formula(Meyerhof ,1965) , which is suitable for cohesionless soil for (25mm) of settlement.

B- Static Method

In this method, bearing capacity of soil are accounting from results of laboratory tests of that's show engineering properties of soil. The results shows that the value of (cu) is (2.6-4.4) ton/m2, and (Φu) is (7-11) degree . Form analysis of the results of present study and pervious studies , the average values of soil bearing capacity in different location of Hilla city are presented in Fig (14). The results indicates average value of bearing capacity from a minimum of 4.3 Ton/m2 to a maximum of 7 Ton/m2 for Hilla city for shallow depth.

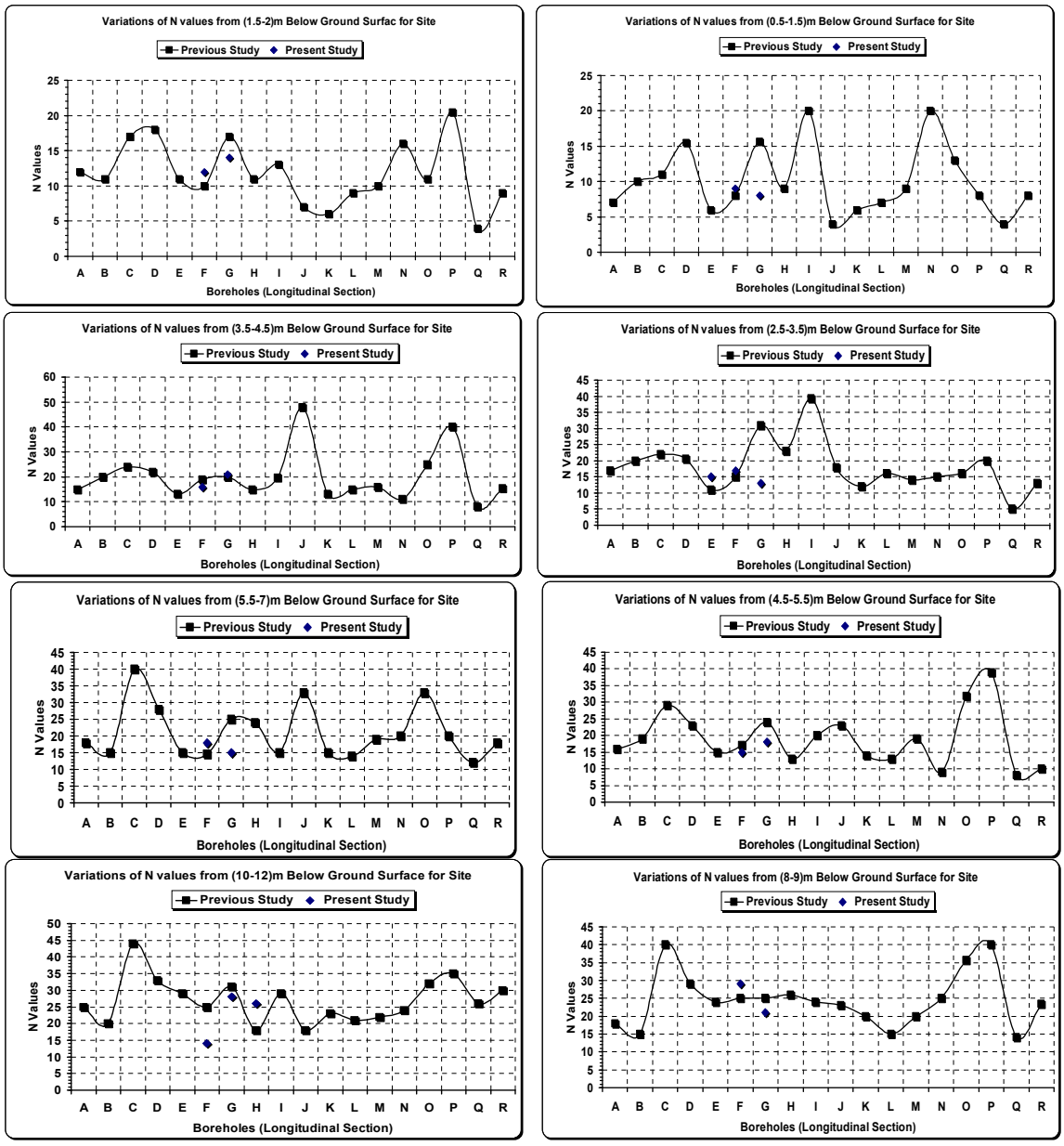


Figure (13) Average values S.P.T tests with depth in different location in Hilla city

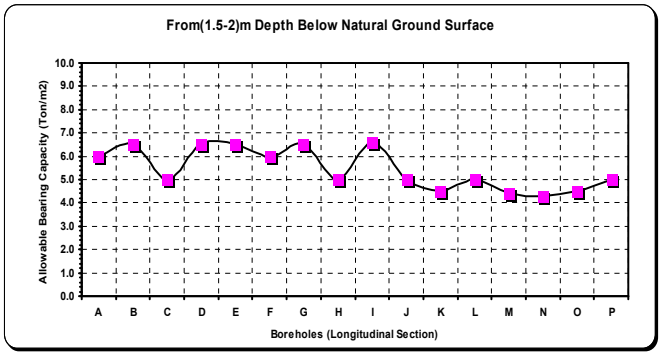


Figure (14) Average values of allowable bearing capacity of soil in different location in Hilla city

Third: Chemical Properties of Soil

1- Sulphat Content SO3 %

Form analysis of the results of chemical test from present study and pervious studies , the average values of sulfate content (SO3%) of soil in different location of Hilla city are presented in Fig(15). The results indicates average value of sulfate content from a minimum of 0.2 % to a maximum of 1,9 % particularly for shallow depths. Therefore, sulfate resistance Portland cement (SRPC) should be used for all concrete works that have contact with soil.

2- Organic Content (ORG %)

Form analysis of the results of chemical test from present study and pervious studies , the average values of Organic Content (ORG %) of soil in different location of Hilla city are presented in Fig (16). The results indicate average value of Organic Content (ORG %) between (0.03-0.06)% for shallow depths in different location in Hilla city.

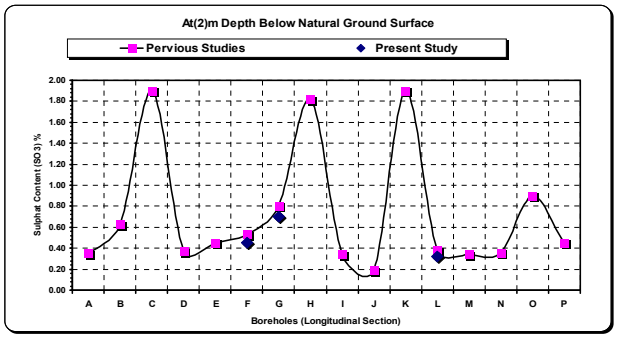


Figure (15) Average values of Sulphat Content SO3% of soil in different location in Hilla city

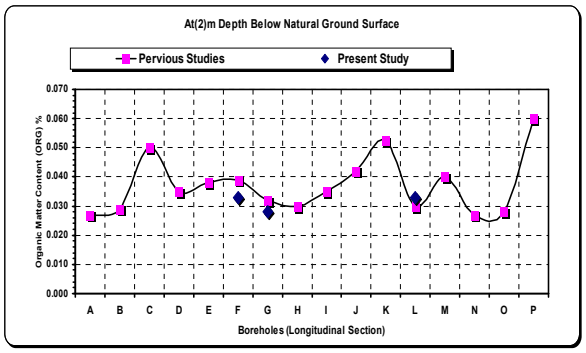


Figure (16) Average values of Organic Content ORG % of soil in different location in Hilla city

3- Total soluble salts (T.S.S)

Form analysis of the results of chemical test from present study and pervious studies , the average values of total soluble salts (T.S.S %) of soil in different location of Hilla city are presented in Fig (17). The results indicate average value of total soluble salts (T.S.S %) is between (0.9-2.7) % for shallow depths.

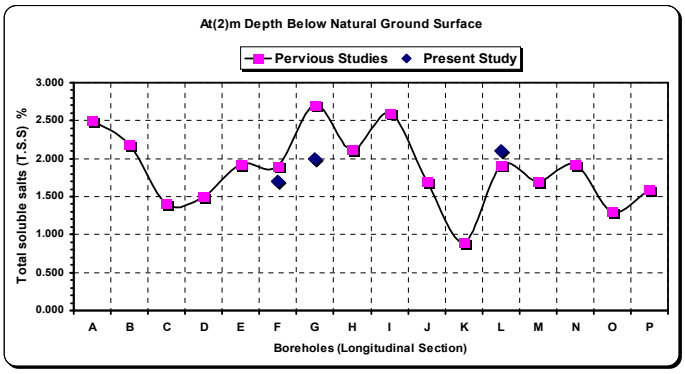


Figure (17) Average values of total soluble salts (T.S.S %) of soil in different location in Hilla city

4- Gypsum Content

The presence of gypsum in soil affects its engineering properties and behavior in a degree which is greatly dependant on the amount of gypsum present in the soil. Form analysis of the results of chemical test from present study and pervious studies, the average values gypsum content in soil in different location of Hilla city are presented in Fig (18). The results indicate average value of gypsum content is between (0.25-0.67) % for shallow depths.

5- Chloride Content

Form analysis of the results of chemical test from present study and pervious studies , the average values Chloride content in soil in different location of Hilla city are presented in Fig (19). The results indicate average value of Chloride content is between (0.034-0.08)% for shallow depths

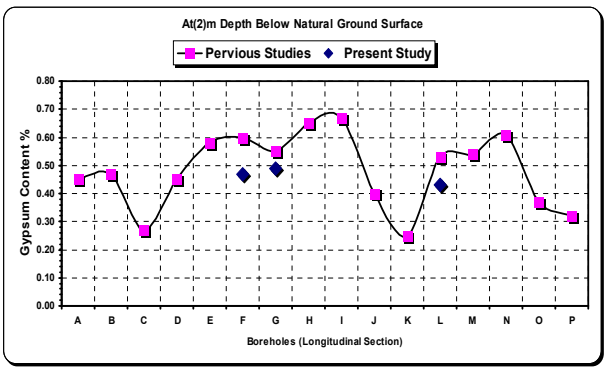


Figure (18) Average values of gypsum content% of soil in different location in Hilla citv

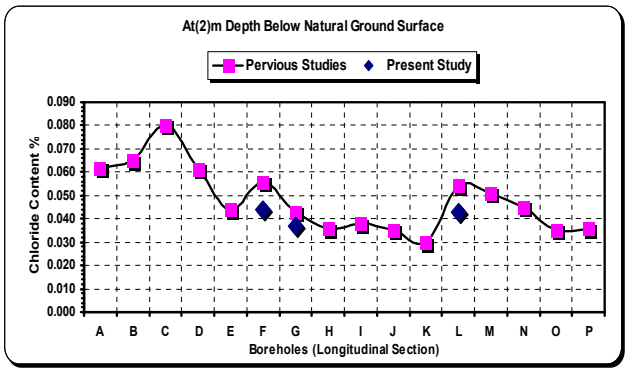


Figure (19) Average values of Chloride content % of soil in different location in Hilla citv

6- Ground water table observation and water chemical analysis:

The underground water level was measured at end of boring at the time of sub-soil investigation from the natural ground surface. The specified depth was fixed after 24 hours of boring termination. Form analysis of the results of present study and pervious studies, the average values water table below natural ground surface in different location of Hilla city are presented in Fig (20). The results indicate average value of water table between (0.3-1.3)m below natural ground surface in different location in Hilla city. Form analysis of the results of chemical test from present study and pervious studies , the average values of sulfate content (SO3%) of ground water in different location of Hilla city are presented in Fig(21). Generally, ground water is harmful amount of sulfates especially for any concrete works

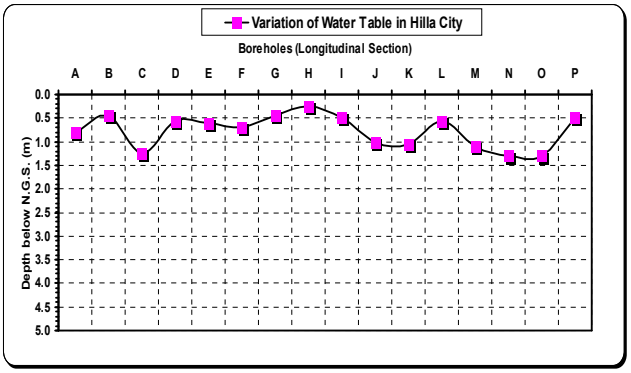


Figure (20) Average values of water table below natural ground surface in different location in Hilla

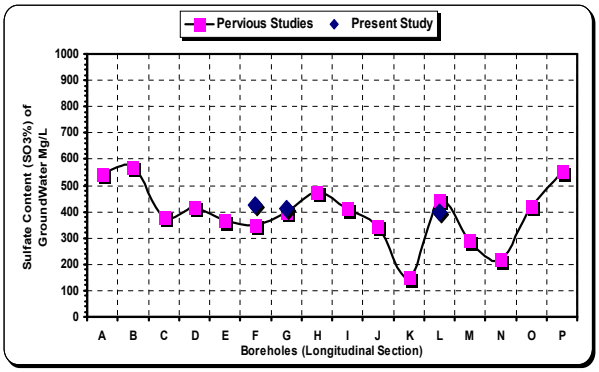


Figure (21) Average values of Sulphat Content SO3 % of ground water in different location in Hilla city

Conclusions:

The purposes of this study were to explore subsurface conditions for Hilla city and to provide recommendations for geotechnical aspects of design and construction of different

projects. Geotechnical assessment of Hilla city during in situ and laboratory tests are generally indicate:

1.The permeability of sub-soil ranges between poor to good depending on variation of sand percentages in the sub-soil .

2.Allowable bearing capacity of soil ranged between (4.3-7) T/m² at depth 1.5 m below natural ground surface for different locations in Hilla city.

3.The majority of soil profile consist of silt -clay to clay -silt with a trace of sand especially for shallow depths to approximately 6 m depth. Then, after 6 m below natural ground surface, the amount of sand content has become increasing and be more effective like clay and silt in most of places of studying area. Sand content become decreases after 9 m depth below natural ground surface and the majority of soil profile consist of silt-clay to clay- silt in most places of studying area.

4.Liquid limit have the upper values in all of locations of Hilla city in all depths, Plastic limit and plasticity index values are quite closer in some locations of Hilla city particularly in shallow depths, while linear shrinkage is between 11.0 to 14.0 percent which indicate that the cohesive layer might exhibit swelling and shrinkage potential. Also, Natural moisture content of soil is closer to the plastic limit than to the liquid limit.

5.The soil have poor clay activity according to ASTM specifications, so it has low swelling tendency.

6.The soil have a little variation between values of specific gravity Gs ,the values of Gs is range between (2.67-2.76).

7.Compression index Cc of soil are increasing with increasing depth to approximately 5.5 meter below natural ground surface, after that compression index Cc will be decreasing with increase the depth.

8.Generally, result of SPT test indicate Soil layer from depth (0.5-2.5)m is not have same properties from strength side because of majority of surface layers maybe consist of filling materials added to the surface. After (2.5-5)m depth, result of SPT test indicate soil layer have same properties from strength side. After 8 m depth, the soil layer have same properties from strength side in most places in Hilla city .

9.According to the chemical tests, generally, soil have high value of soluble salts , gypsum and sulphat contents in the soil, therefore any concrete works which be in touch with soil should be protected by using coating all the faces by a layer of hot bitumen type 20/30 with 8.0 mm thickness.

10. For projects have earth works under ground water table, dewatering of water table during the construction period should be done by filter by using well point system for dewatering or boring deep wells with filter to avoid pumping fine particles of soil which effects of structure of soil .

11. Elevation of ground water is ranging between (0.3-1.3)m below natural ground surface in different locations in Hilla city and have harmful amount of sulfates especially for any concrete works**.**

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