Geotechnical Evaluation to the Soil of Tikrit University Using Seismic Refraction Method

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Abstract

Seismic refraction survey is conducted for geotechnical evaluation to the soil of Tikrit university at allocated site to construct a new building for housing the professors of the university . The measurements of compressionnal and shear waves velocities are conducted along six profiles at the study area . Four main layers were recognized from the results of the seismic data interpretation . Depending on the (Vs/Vp) ratio, three geotechnical properties were calculated for geotechnical evaluation to the different layers, these are Poisson's ratio(σ), Material index (Im) ,Plasticity index (P.i). The contour maps for different layers are plotted to show the distribution of geotechnical properties at the study area. These maps are divided into two zones, Zone A represents the area which has good geotechnical properties ,and Zone B represents the area which has weak geotechnical properties such as loose unconsolidated sediments or weak zones. The results of evaluation show that the first and third layers are fairly competent to intermediate competent layers because they have good geotechnical properties by comparing with second and fourth layers which have poor geotechnical properties which represent incompetent layers. Depending on the values of plasticity index , the sediments of the study area ranges between low plasticity to intermediate plasticity sediments except some of the places characterized by high values of plasticity index representing high plasticity sediments.

Key Words:- Seismic refraction, Geotechnical evaluation , Poisson's ratio, Material index, Plasticity index , Weak Zones.

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التقييم الجيوتكنيكي لتربة جامعة تكريت باستخدام الطريقة الزلزالية الانكسارية

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المستخلص

اجري المسح الزلزالي ألانكساري لغرض التقييم الجيوتكنيكي لتربة جامعة تكريت في الموقع المقترح لإنشاء بناية جديدة لإسكان أساتذة الجامعة. تم تنفيذ قياسات الموجات الطولية والمستعرضة على طول ستة مسارات موزعة ضمن منطقة الدراسة. أظهرت نتائج التفسير للبيانات الزلزالية تمييز أربع طبقات مختلفة في منطقة الدراسة. اعتماداً على النسبة (Vs/Vp) تم حساب ثلاثة خواص جيوتكنيكية لغرض التقييم الجيوتكنيكي للطبقات المختلفة, وهي نسبة بوزان (σ) ,معامل المادة(Im) ومعامل اللدونة (P.i). رسمت الخرائط الكنتورية لإظهار توزيع الخواص الجيوتكنيكية في منطقة الدراسة, حيث قسمت هذه الخرائط الى نطاقين مختلفين هما نطاق A الذي يمثل المنطقة التي تمتاز بخصائص جيوتكنيكية جيدة ونطاق B ويمثل الرواسب التي لها خواص جيوتكنيكية غير جيدة كانطقة الضعف او الرواسب غير متماسكة. أظهرت نتائج التقييم الجيوتكنيكي لطبقات منطقة الدراسة بان الطبقتين الأولى والثالثة مؤهلتان لإنشاء المشروع السكني بسبب خصائصها الجيوتكنيكية الجيدة مقارنة بالطبقتين الثانية والرابعة اللتان تمتازان بخصائص جيوتكنيكية غير جيدة (غير مؤهلة), كما بينت الدراسة وبالاعتماد على قيم معامل اللدونة بان رواسب منطقة الدراسة تتراوح بين واطئة الى متوسطة اللدونة باستثناء بعض المناطق التي بمعامل لدونة عال تمثل رواسب عالية اللدونة.

الكلمات المفتاحية:ـ الزلزالية الانكسارية , التقييم الجيوتكنيكي , نسبة بوزان , معامل المادة, معامل اللدونة , أنطقة الضعف

Introduction

The statistics of failures of structures such as buildings, dams and bridges increased geometrically. The need for pre-foundation studies have therefore become very imperative so as to prevent loss of valuable lives and properties that always accompany such failure. Foundation study usually provides subsurface information that normally assists civil engineers in the design of foundation of civil engineering structures [1]

Geophysical methods such as the Electrical Resistivity (ER), Seismic Refraction, Electromagnetic (EM), Magnetic and Ground Penetrating Radar are used singly or in combinations for engineering and geotechnical site investigation,[2] . The applications of such geophysical investigation are determination of depth to bedrock, structural mapping and evaluation of subsoil competence.

The management of Tikrit university proposed to allocate a site to build a new building for housing the professors of the university. The site is located at Salah-Eldin governorate ,175 Km. north Baghdad city ,at Tikrit university site , between longitudes (43º-38′-30″ 43º-38′-43″ E) and latitudes (34º-40′-16″-34º-40′-22″ N,) figure(1). At Tikrit university site there are some buildings are settled and its walls are cracked due to the presence of weak zones in the soil beneath the buildings, therefore it is necessary to provide subsurface information by using geophysical methods that normally assist the civil engineer in the design of foundations of the structures. Three geotechnical properties are measured for geotechnical evaluation to the soil of Tikrit university , these are

Poisson's Ratio (σ):- It is a fundamental parameter usually estimated in engineering studies It is the ratio of fractional transverse contraction to the fractional longitudinal extension [3]. A suggested range for the values of Poisson's ratio is from (0.0) for very hard material to (0.5) for liquids , and about (0.25) for elastic material [4]. In soil mechanics works, the Poisson's ratio often ranges between (0.2 – 0.4) , and about (0.5) for saturated soil [5].

Material Index(Im):- is the more important geotechnical index, it represents the degree of materials efficiency because of depending it on numbers of elastic moduli, where it is derived according to the ratios of (μ/ K) and (λ / K), . The limits of this index lie between (-1) when (μ=0.0) for liquid material and (1) when $\lambda = 0.0$ for very solid material, and (0.0) when $\mu = \lambda$ for elastic material. The competence of soil as a foundation materials can be classified according to the values of Poisson's ratio and material index as illustrated in table-1-

Table-1- Classification of soil's competent according to Poisson's ratio and material index values , after ,(6)

Soil description	Incompetent to slightly competent	Fairly to moderately competent	Competent material	Very high competent materials
Poisson's Ratio (σ)	o.41-o.49	0.35-0.27	0.25-0.16	0.12-0.03
Material Index(Im)	(-0.5) – (-1)	(-0.5)-(0.0)	(0.0)- (0.5)	>0.5

Plasticity index (P.I):- it is the moisture content , in percent , at which the soil remains at plastic state . or it is defined as the difference between the liquid limit and the plastic limit of the soil. The soil properties can be classified according to the plasticity index as illustrated in table - 2 -

Table -2- soil classification by its plasticity index after (7)

Plasticity Index	Plasticity
0-1	Non Plastic soil
1-5	Slight plastic soil
5-10	Low plastic soil
10-20	Medium plastic soil
20-40	High plastic soil
>40	Very high plastic soil

Methodology

Shallow seismic refraction measurements are carried out along three parallel profiles (AA', BB', CC') , each profile consists of three spreads. Three additional profiles (DD' ,EE' , FF') perpendicular to the previous profiles, are conducted , each profile consists of one spread. The measurements for both P-wave and S-wave are conducted along these profiles, figure (1). Twenty-four (24) geophones for each seismic spread are used, they are separated from each other by ten meters, thus the seismic spread is 230 m in total length. Each 12 geophones are attached to a geode through a cable, finally the geode is connected to the recording unit.

The source used is a hammer , attached to a sensor that signals to the system to record when the hammer hits the ground. Generation of elastic waves is carried out at three positions for each spread, two shots at the beginning and ending of spread line between geophones 1 and 2 at distance 5m, and between geophones 23 and 24 at distance 225m (Direct and Reverse shooting respectively) , and one shot is at the middle of the spread line between geophones 12 and 13 at distance 115m (Central shooting).The overlapping distance between each adjacent spreads is 70 m.

The length of the first three profiles (AA', BB', CC') is 1650 m in total , 550 m for each profile, and for the other profiles(DD' ,EE' , FF') is 690 m in total, 230 m for each profile. The total number of spreads is (12) with a total length of 2340 m. The total number of shots recorded at the study area is 36 shots, each shot is recorded five times to increase the signal to noise ratio.

Compressional waves are recorded along all profiles by using geophones with vertical coil ,while shear waves are recorded by using geophones with horizontal coil and hitting the hammer horizontally on the steel plate at two perpendicular directions to the spread line direction. .

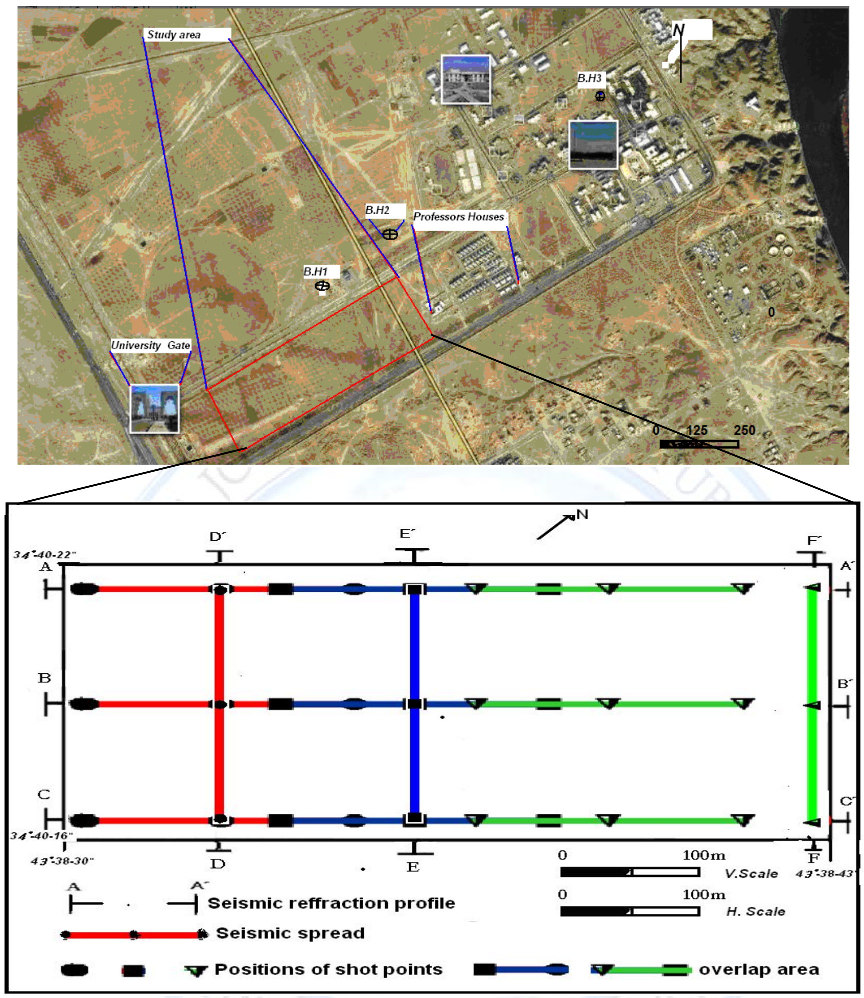

Figure (1) location of the study area , seismic refraction spreads and shot points positions along seismic profiles

The Results and discussion

Least square method is used to determine compressional wave and shear wave velocities , table -3-. The results of this method show four layers, the first layer represent top soil , second layer represent wetted sand silt clay mixture ,third layer consist of gravel to sandy gravel sediments ,while the fourth layer represents saturated gravel to sandy gravel sediments.

In this study three geotechnical properties are selected to evaluate the geological layers, depending on seismic waves velocity as described below. The contour maps for different layers are plotted to show the distribution of geotechnical properties at the study area. These maps are divided into two zones, Zone A represents the area which has good geotechnical properties ,and Zone B represents the area which has weak geotechnical properties such as loose unconsolidated sediments or weak zones.

Poisson's Ratio (σ)

The values of poisson's ratio are calculated according to its relation with the ratio (Vs/Vp) by the following equation:-

$$\sigma = \frac{0.5-(vs/vp)^2}{1-(vs/vp)^2} \quad \text{-----------------------} (8)$$

The ranges and mathematical mean of the poisson's ratio for different layers along all profiles at the study area are illustrated in table(4) . The contour maps are plotted for different layers to show the distribution of poisson's ratio values, as shown in figure (2). The first layer is characterized by wide range of values of poissons' ratio lies between (0.28-0.37) because of the lithological changes and the variations in degree of consolidation . This range indicates that , the sediments of this layer lie between fairly to moderate competent sediments. The contour map for the first layer (figure,2a) is divided into two zones, the first zone is Zone A, which consists of the consolidated to intermediate consolidated sediments , while the second zone is Zone B,which consists of the sediments which has less consolidation by comparing with Zone A.

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Profile No.	Shot point distance(m)	Compressional wave velocity (m/sec)				Shear wave velocity (m/sec)			
		V_{P1}	V_{P2}	V_{P3}	V_{P4}	V_{S1}	V_{S2}	V_{S3}	V_{S4}
	5 D	1000	1600	2800	4000	550	608	1500	-----
	115 C	794	1786	2544	3820	420	684	1428	------
	165 D	555	1846	2720	4000	250	772	1500	-------
	225 R	588	1846	3000	4000	270	681	1666	------
	275 C	648	1605	2700	3719	340	625	1500	-------
	325 D	555	1818	2500	3600	263	800	1240	-------
	385 R	833	1555	2750	3800	454	720	1420	1580
	435C	590	1718	2533	3732	290	653	1250	-----
AA'	545 R	909	1666	2222	4000	500	681	1053	1500
	5 D	910	1619	2500	3636	500	725	1177	------
	115 C	588	1612	2450	4000	294	465	1200	-------
	165 D	625	1650	2400	3818	300	611	1200	-------
	225 R	625	1650	2625	3636	303	571	1385	-------
	275 C	625	1667	2828	4000	333	510	1500	1666
	325 D	910	1833	2600	3818	500	636	1333	1580
	385 R	714	1583	2500	3700	385	666	1222	1500
	435 C	910	1775	2450	3636	457	673	1200	1500
BB'	545 R	625	1545	2727	4000	333	620	1500	------

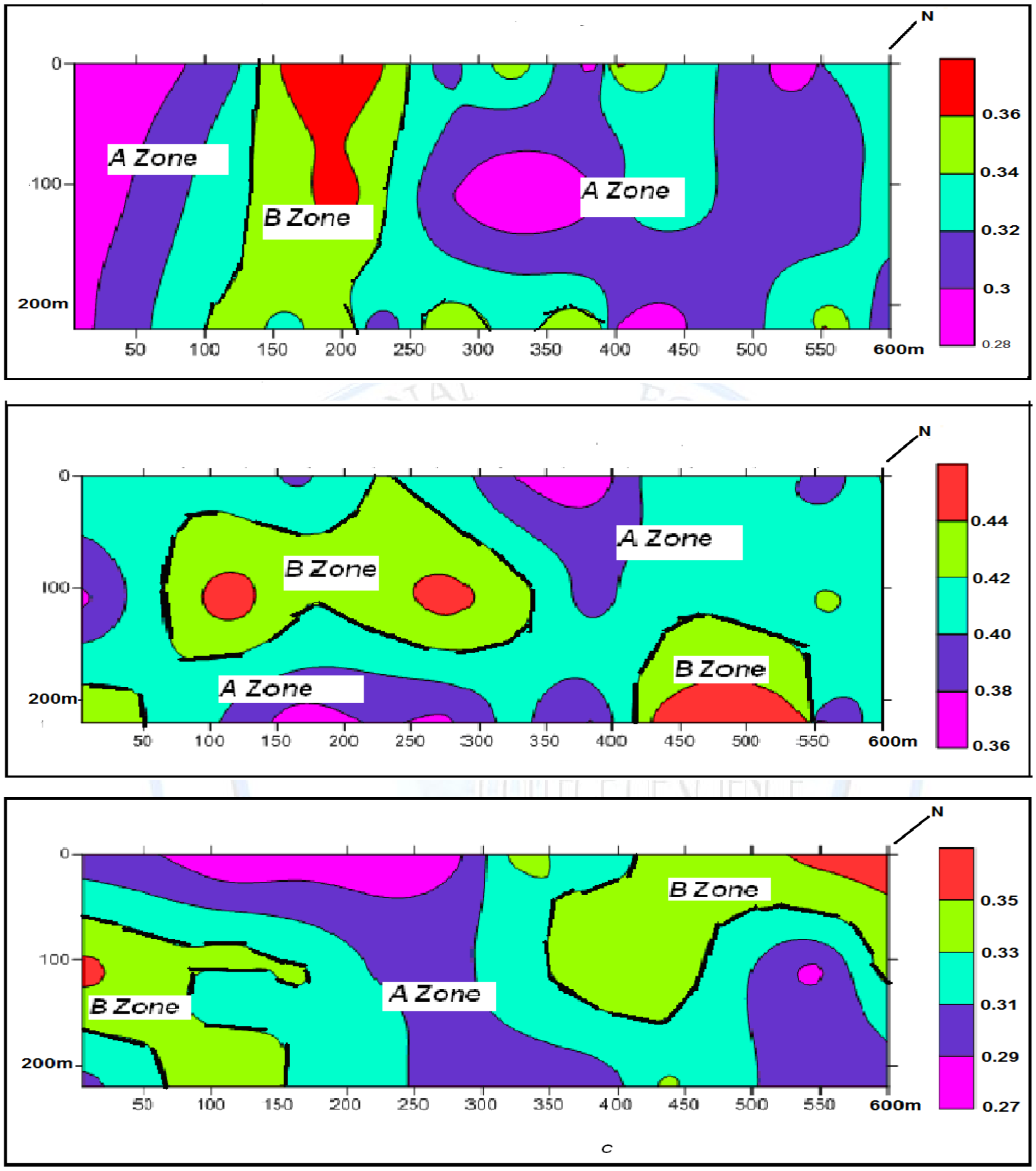
'CC	5 D	833	1500	2600	4000	450	500	1385	1600
	115 C	500	1772	2450	3818	242	735	1181	1540
	165 D	833	1588	2525	3800	416	725	1285	------
	225 R	625	1714	2800	4000	333	750	1333	1600
	275 C	625	1690	2878	3875	294	757	1560	------
	325 D	714	1764	2500	4000	357	700	1333	1770
	385 R	666	1550	2777	3666	312	687	1500	1655
	435 C	555	1844	2665	3718	300	556	1333	-------
	545 R	769	1714	2800	3818	384	500	1500	------
DD'	5 D	909	1739	2666	4000	448	720	1333	1666
	115 C	625	1850	2633	4000	333	810	1380	------
	225 R	785	1760	2566	3818	389	688	1240	1555
EE'	5 D	588	1416	2500	4000	294	690	1333	------
	115 C	625	1695	2675	3900	345	535	1428	1653
	225 R	769	1538	2636	3800	384	681	1428	-------
FF'	5 D	714	1500	2500	3715	380	585	1333	------
	115 C	641	1550	2433	3732	322	600	1200	1428
	225 R	600	1428	2470	3800	300	523	1150	1600

Table(3) The values of compressioonal wave velocity (Vp) and shear wave velocity(Vs)

D: Direct Shooting

C: Central Shooting

R: Reverse Shooting


A Zone
B Zone
A Zone
0
100
200m
50 100 150 200 250 300 350 400 450 500 550 600m
N
0.36
0.34
0.32
0.3
0.28
B Zone
A Zone
B Zone
A Zone
B Zone
0
100
200m
50 100 150 200 250 300 350 400 450 500 550 600m
N
0.44
0.42
0.40
0.38
0.36
B Zone
B Zone
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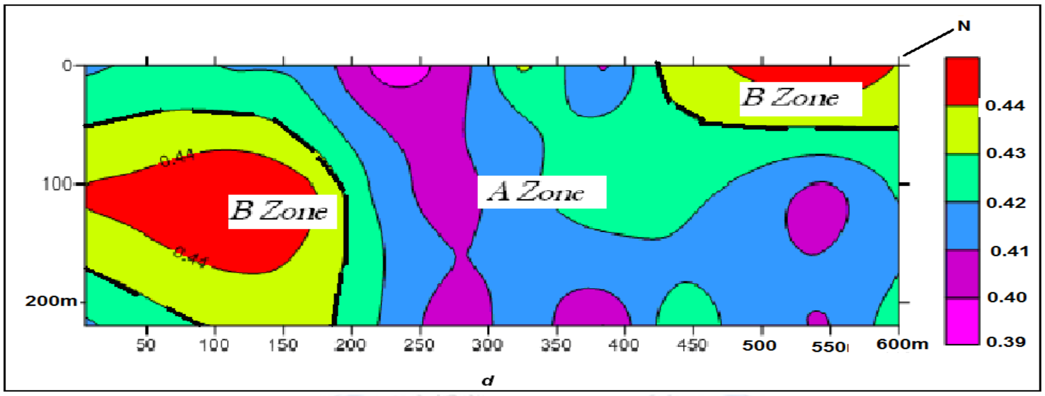


Figure (2) Contour maps for values of Poisson's ratio(σ) for a- First layer ,b- Second layer c-Third layer, d- Fourth layer.

The range and mathematical means of the second layer are larger than for the first layer, indicate incompetent to slightly competent sediments ,because of the water and clay content in this layer which directly proportioning with the poisson's ratio. The contour maps, figure(2b) , illustrate concentration of the sediments of Zone A, by comparing with Zone B, which represents weak zone or loose sediments.

The Poisson's ratio for the third layer is characterized by low values, because of the lithological changes resulted from appearance of the gravels sediments as a third layer, as inferred from drilled wells information at the study area . The contour maps, figure(2c) , and table -4- illustrate that the sediments at the third layer lies between fairly to moderate competent sediments. The area characterized by Zone A is more consolidated by comparing with Zone B.

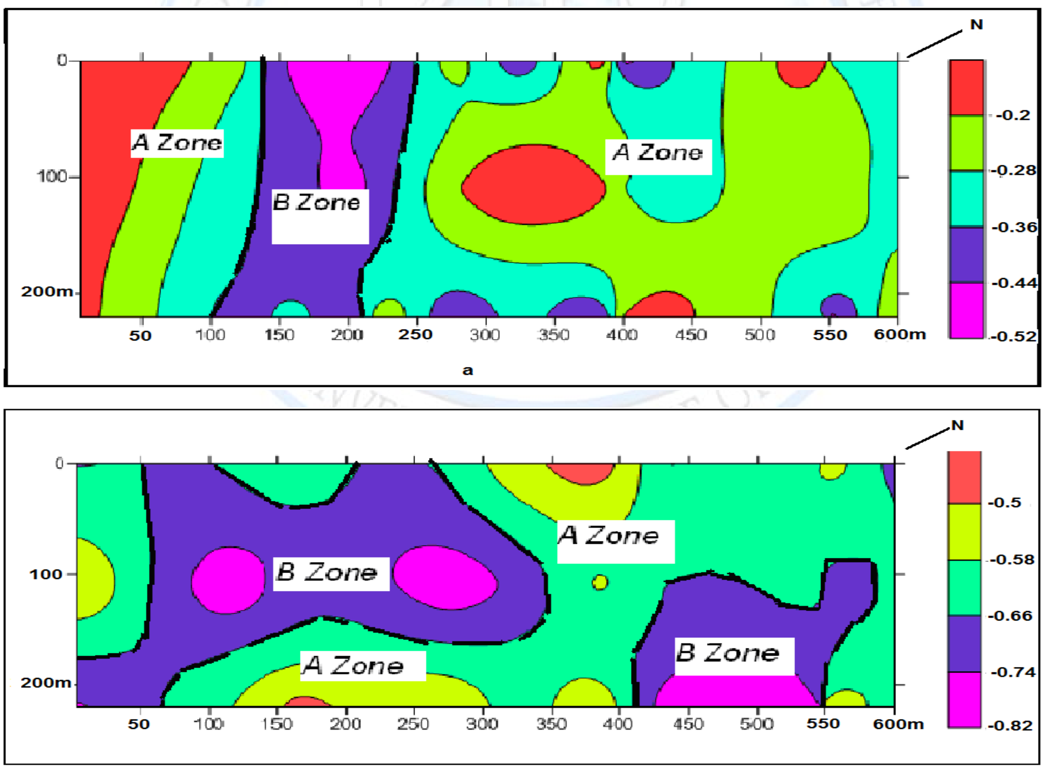
The fourth layer is characterized by high values of poisson's ratio , as shown in figure (2d) . The increasing of the values of poisson's ratio for this layer is due to saturation of the sediments with the ground water. Since the existence of ground water affects the poisson's ratio values ,this ratio can be used to delineate the ground water level and saturated layers ,specially at the sudden increasing for this ratio with depth.

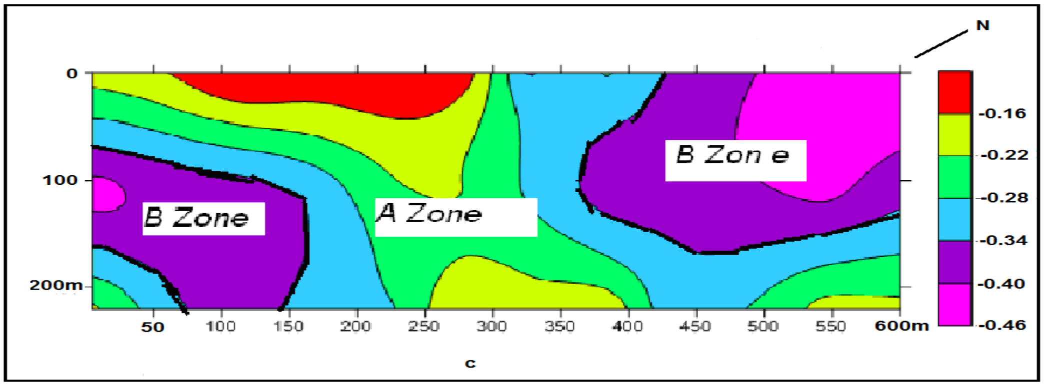
Material Index(Im)

The values of material index are calculated according to the following equation:-

$$I_m = \frac{3\left(V_s/V_p\right)^2 - 1}{1 - \left(V_s/V_p\right)^2} \quad \text{------------------------(8)}$$

The ranges and mathematical means of the material index for different layers along all profiles at the study area are illustrated in table-4-. The contour maps for different layers are drawn to show the distribution of the material index values , as illustrated in figure (3) . The first layer is characterized by wide range of values of material index, reflects heterogeneity of this layer because of the lithological changes and the variations in degree of consolidation.





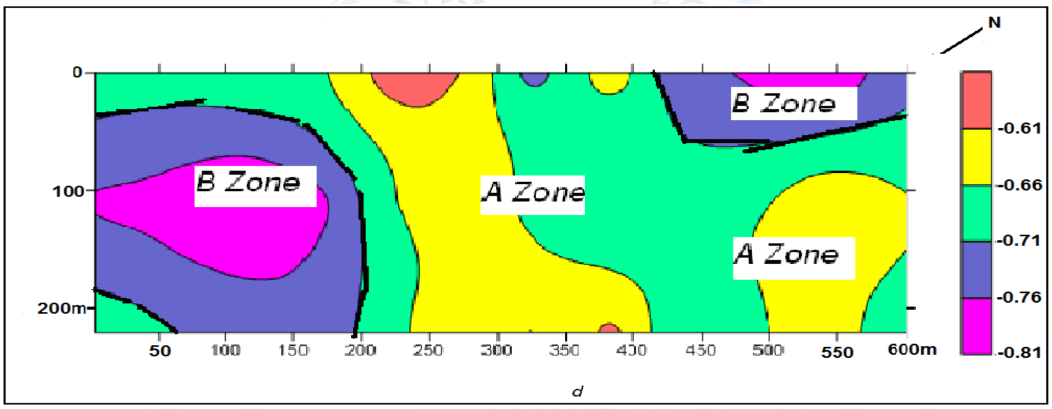


Figure (3) Contour maps for values of material index (I_m),for a-First layer ,b- Second layer, c-Third layer d- Fourth layer.

The contour maps, figure(3a) , and table -4- illustrate that the sediments at the first layer lie between fairly to moderate competent sediments. The area characterized by Zone B represents weak zone or loose sediments. The range and mathematical means of the second layer are lower than for the first layer, indicate incompetent to slightly competent sediments ,because of the water and clay content in this layer. The contour maps, figure(3b) , illustrate concentration of the sediments of Zone A, by comparing with Zone B, which represents weak zone or loose sediments . The values of the material index increase at the third layer because of appearance of the gravely sediments as a third layer at the study area. This layer may lie between fairly to moderate competent sediments. The area characterized by Zone A is more consolidated by comparing with Zone B which represents loose sediments or weak zone,figure(3c).

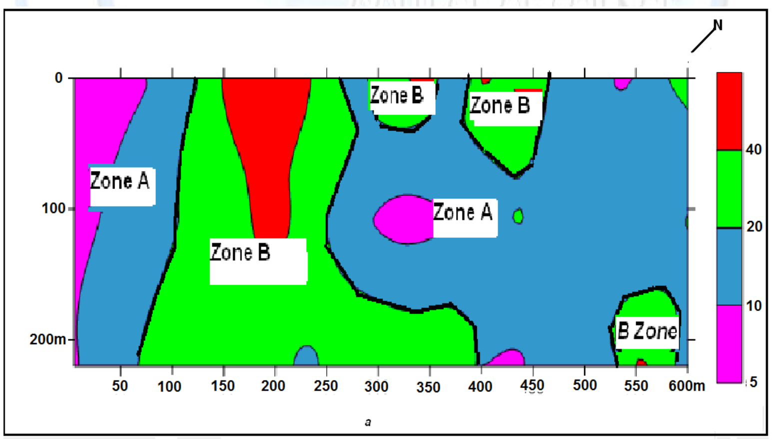
The ranges and mathematical means for the fourth layer are lower than that for the third layer (figure 3d), because of saturation of the gravels with the ground water, which influence the value of material index.

Plasticity index (P.I)

The following equation is used to calculate the values of plasticity index:-

$$\log(PI) = \frac{0.81 - 2(Vs/Vp)^2}{0.233} \qquad (9)$$

the This equation is applied only for unsaturated dry layers ,therefore the values of plasticity index (P.I) for second and fourth layers aren't calculated because of its water content. Table -4- illustrates the ranges and mathematical means of values of plasticity index (P.I) for first and third layers along all profiles at the study area . The contour maps are drawn to show distribution of (P.I) values, as illustrated in figure (4). The first layer is characterized by wide range of values of plasticity index reflects heterogeneity of this layer because of the lithological changes and the variations in degree of consolidation.



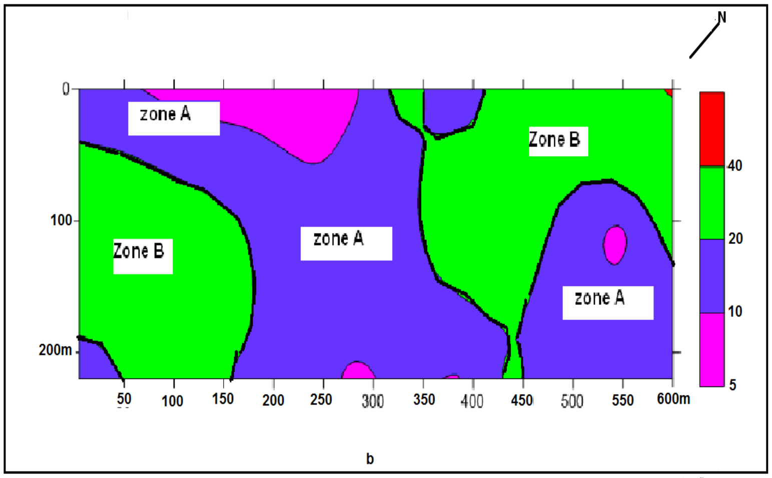


Figure (4) Contour maps for values of Plasticity index (P.I) ,a-First layer b- Third layer

According to the soil classification for plasticity index ,(8), the area referred as Zone A represents low to intermediate plastic soil by comparing with Zone B which represents high plastic soil, figure (4a). The range and mathematical means for the values of plasticity index (P.I) at the third layer is lower than that for the first layer. This layer represents low to intermediate plastic layer because of concentration of the low values of this index at the study area Zone A . There are some places north and south of the study area are characterized by high values of plasticity index represent high plastic layer (Zone B) ,(figure 4b).

Table -4- The ranges and mathematical means for the values of calculated geotechnical properties at the study area.

Layer no.		Geotechnical Properties		
		σ	**Im**	**P.I**
First layer	Range	0.28-0.37	-0.50-0.12	7.24-58.7
	Mean	**0.325**	**-0.303**	**22.75**
Second layer	Range	0.34-0.45	-0.81- 0.37	--------
	Mean	**0.405**	**-0.623**	--------

Third layer	Range	0.27-0.36	-0.44-0.10	5.9-41.2
	Mean	**0.316**	**-0.265**	**17.45**
Fourth layer	Range	0.395-0.45	-0.80-0.58	--------
	Mean	**0.42**	**-0.68**	--------

CONCLUSIONS

The results of interpretation show four main layers at the study area , the first layer represent top soil , second layer represent wetted sand silt clay mixture ,third layer consist of gravel to sandy gravel sediments ,while the fourth layer represents saturated gravel to sandy gravel sediments. Engineering competence of these layers can be evaluated from geotechnical properties . The results of evaluation show that the first and third layers are fairly competent to intermediate competent layers as foundation material by comparing with second and fourth layers which represent incompetent layers, and in general the sediments of the study area ranges between low plasticity to intermediate plasticity sediments.

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