Determination of Elastic Moduli and Geotechnical Parameters of the Upper Soil Layer Using Ultrasonic Waves in Al- Jadiriyah Area - University of Baghdad-Iraq

Salman Zainal -Abdin Khorshid

Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.
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Abstract

Analysis and determination of some of the elastic moduli and other geotechnical parameters in the campus of the University of Baghdad performed by using New Sonic Viewer in the field to measure (Vp) and (Vs) velocities as well as the density of the upper soil inside the campus. Seventeen profiles were selected each of (10) m. length distributed randomly inside the university campus to evaluate the top soil properties in addition to the soil profile.

The ultrasonic waves showed two layers of the soil with different velocities of (Vp) and (Vs). The velocities of p-wave of the first layer ranged from (288-642) m/sec. On other hand the velocities of shear wave (Vs) in the same layer ranged from (88-193) m/sec. In the second layer the velocities of p-wave ranged from (681-972) m/sec., and the velocities of shear wave ranged from (327-463) m/sec.Depending upon the value of (Vs) and according to Caltrans soil types, these two layers were considered as soft and stiff soils of types (E and D) respectively. The mean depth of the first layer in the area is (1.91) m. The densities of the first layer ranged from (1743-1999) Kg/m^3.

The values of Poisson's ratio, Young's modulus, Shear modulus, Lame's constant, Bulk modulus and Compressibility are also determined as well as some of geotechnical properties as earth lateral pressure at rest (K_O), Concentration index, Ultimate bearing capacity, Material index, and the empirical relation was used to calculate (N) values of the standard penetration test (SPT) from shear wave velocities and its value ranged for the first layer from (2-35) b/30 cm. and for second layer the (N) values ranged from (25-45) b/cm., as well as the relationship between the most important geotechnical and elastic modulus with their equations on each graph.

Keywords: Al-Jadiriyah Soil Type, Field Ultrasonic Investigation.

قياس وتحليل معاملات المرونة والمعاملات الجيوتكنيكة لطبقة التربة العليا باستخدام الموجات فوق الصوتية في منطقة الجادرية– جامعة بغداد– العراق

سلمان زين العابدين خورشيد

قسم علم الارض ، كلية العلوم ، جامعة بغداد، بغداد ، العراق

الخلاصة

تم إيجاد بعض معاملات المرونة وقسم من المعاملات الجيوتكنيكية في ساحات الحرم الجامعي لجامعة بغداد باستخدام جهاز الموجات فوق الصوتية في الحقل لقياس سرع الموجات الطولية والمستعرضة للمسارات

Email: dr.salman Khorshid@yahoo.com

المختارة عشوائيا، فضلا عن أخذ نماذج للتربة وذلك لقياس الكثافة في كل موقع قياس والتي بلغ عددها

(17) موقعا مختارا للقياس، واجري تحليل لهذه القياسات لتقييم خواص الآجزاء العليا للتربة بالاضافة الى

الشكل الجانبي للتربة، علما بان طول كل مسار كان (10) أمتار وعدد القياسات في كل مسار كانت (10)

قياسات.

أظهرت سرع الموجات فوق الصوتية وجود طبقتين للتربة ذات سرع مختلفة للموجتين الطولية

والمستعرضة، وكانت سرع الموجة الطولية للطبقة الاولى بين (288–642) م/ثا. وان سرع الموجة

المستعرضة لنفس الطبقة كانت بين (88–193) م/ثا. أما السرع في الطبقة الثانية فكانت سرعة الموجة

الطولية بين (681– 972) م/ثا. وسرعة الموجة المستعرضة بين (327–463) م/ثا. واعتمادًا على قيم

السرعة المستعرضة واستنادا الى تقسيم (كالترانس) فان نوع التربة للطبقتين كان عبارة عن طبقات هشة

ومتوترة للطبقة الاولى ومن نوع (E) و (D) على التوالي. أما الطبقة الثانية فكان نوع التربة من نوع (D)

فقط وعلى نفس التقسيم. وكان معدل عمق الطبقة الاولى في منطقة القياسات (1.91) م. أما الكثافات

المحسوبة للتربة فكانت للطبقة الاولى فقط بين (1743–1999) كغم/م3 .

ولقد تم ايضا إيجاد كلا من نسبة بوزان ومعامل يونك ومعامل القص ومعامل الصلابة ومعامل

الانضغاطية ، فضلا عن بعض الخواص الجيوتكنيكية مثل ضغط الارض الجانبي في حالة السكون ومعامل

التركيز وقابلية التحمل القصوى ومعامل المادة وقيم (عدد الدقات) من (S.P.T) وذلك من سرع الموجات

المستعرضة وكانت قيمها تتراوح بين (2–25) ضربة/30 سم. للطبقة الاولى وبين (25–45) ضربة/30سم.

للطبقة الثانية. وكذلك تم رسم العلاقات بين معظم معاملات الجيوتكنيكية والمرونة المهمة مع معادلة كل شكل

على المنحنيات.

Introduction
   Ultrasonic techniques are widely used for determining most dynamic elastic modulus after measurement of the velocities of compressional (Vp) and shear waves (Vs) as well as the density of rocks and soils. The dynamic elastic constants are of interest for solving different geological problems. There are different ultrasonic techniques in which pulses
transmit in core samples or rectangular cross sections of rocks[1,2] or soils in the laboratory, as well as the same techniques are used in the field by using sledge hammer for source and the receiver channel for receiving the transmission time from source to receiver [3]. In the field any one can generate pulses at distance up to (15)m. as mentioned in the catalogue of the instrument [4].
   The ultrasonic profiles at Al-Jadiriyah area involves study of (Vp) and (Vs) that response to an input pulse excitation at individual points up to (10)m. distance, the method therefore necessitates the use of high intensity sources by sledge hammer of (10) Kg. weight with aluminum plate on the ground, so these characterize by strong absorption. The receivers must be at a good coupling on the surface to receive the pulses from different distances ranging from (0.5-10) m.
Methodology and fifld work
   The survey at Al-Jadiriyah area performed by using New Sonic Viewer Model 5217A, this instrument has capability to simultaneously recording either in laboratory using the transmitter and receiver or at the field using sledge hammer and receiver only, for measuring both (Vp) and (Vs). The sonic viewer has the signal enhancement capability which collects signals from several shots added together to increase the signal to noise ratio for obtain the times of (P) and (S) waves precisely from the records to determine the velocities of (Vp) and (Vs), the frequency of p-wave receiver is (63000) Hz. and for S-wave receiver is (33000) Hz. for measuring the transit times on less compact soils. The instrument used in this survey has two channels (A) and (B), the channel (A) used for signals of P-waves and the channel (B) for signals of S-wave for comparison of the times of each signal [4].
   At the beginning of field work seventeen profiles were chosen at Al-Jadiriyah area for measuring (Vp) and (Vs) velocities using ultrasonic instrument (New Sonic Viewer 5217A) plate (1) shows the instrument in the field of the courtyards and football yards of Al Jadiyah area which have longitudes between (44° 22' 42.78" - 44° 22' 52.54") E and latitudes between (33° 16' 24.28" - 33° 16' 28.33") N, the length of each profile was (10)m., the source points at each profile was kept using sledge hammer

of (10) Kg. weight, and the distance of receiver interval were ranged between (0.5-1) m., also at each profile station the samples of soil were taken for density determination by tacking the samples inside a cylindrical shape like tube with known shape and volume with more or less the same moisture content and compaction, after measuring the weight the density determined Table -1.

Plate 1- Field work at Al Jadiriyah area for measuring (Vp) and (Vs) velocities.

Interpretation of soil type from (Vs) values

All data were collected by researcher from the field using new sonic viewer, the velocities of (Vp) and (Vs) were calculated for each station . The data gave two layer at each profile, the depths of first layer ranged from (1.55-2.30) m. These depths were supported by electrical surveying at study area that was done by the researcher, also depending upon the values of (Vs) and according to Caltrans soil classification [5], the first layer considered as stiff soil type (D) at locations (3,4,5,6,7,8,10 and 12), and for other locations are soft soil type (E) which have (N) values less than (15) b/30 cm., as well as all the second layer is considered as stiff soil type (D) which has (N) values between (15- 45) b/30cm. Table-1. The soil layer in Al Jadiriyah area silty clay brownish color and clayey silt, this is seen and clear at the top layer. It is expected from the higher velocities of the second layer is fine silty sand.

Calculation Of Dynamic Elastic Modulus:

Determination of elastic dynamic modulus to any material, could be known depending on longitudinal (Vp) and shear (Vs) wave velocities as well as the density of the substance and using the related equations such as Young Modulus (E) , Rigidity Modulus (µ) , Bulk Modulus (K), Poisson's ratio (σ) ….etc., [6,7]. Most of the modulus are sensitive to moisture content, mixture of sand, silt and clay, packing of grains and compaction [8].

Young‚s Modulus(E):

Equation (1) was used for determination of Young's Modulus (E), this is the most important parameter for engineering purpose which is useful to know the bearing capacity of the material. The range of this parameter in the study area was between (3.95E+07 – 2.16E+08) Pascal (Pa). Table -1.

$$E=2\mu(1+\sigma)\ldots\ldots\ldots\qquad\ldots\ldots\ldots\ldots(1)$$

Rigidity Modulus(μ)

Equation (2) was used for determination of rigidity modulus in the study area, This value was ranged from (1.35E+07 − 7.45 E+07) Pa. The value of this parameter varies because it depends on changes in shear velocities that are very sensitive to changes in porosity of soil and rock, especially in shallow depths as in Al-Jadiriyah area , and increasing in the value of this modulus indicates to the rock hardness, also it is very important from an engineering standpoint, where its value is zero in fluids [9] Table-1.

$$\mu = Vs^2\rho \dots\dots\dots\dots \dots\dots\dots\dots..(2)$$

Poisson's ratio (σ)

Equation (3) was used for calculation of this ratio , the values of this ratio were ranged between (0.41-0.47) for first layer and (0.34-0.36) for the second layer. After calculation of this ratio, some areas show high values, and this reflects the ratio of the voids in that area saturated with water. In soil mechanics the Poisson's ratio often ranges between (0.2-0.4) [10],t the first layer falls within this range Table -1.

$$\sigma = (1 - 2\left(\frac{vs}{vp}\right)^2)/(2 - 2\left(\frac{vs}{vp}\right)^2)\dots\dots\dots \dots\dots\dots\dots.. ..(3)$$

Bulk Modulus (K)

Equation (4) used for calculation of (K) , the value of (K) ranges between (9.86E+07 − 6.26E+08) Pa,. we noticed that the value of (K) increases in some areas that means low porosity of that area increases and vice versa [11], Table -1.

$$k = \frac{3\lambda+2\mu}{3} \dots\dots\dots\dots\dots\dots\dots \dots\dots\dots\dots...(4)$$

Lame's Constant (λ)

Equation (5) used for calculation of this constant, and it is the same as rigidity that is valid for isotropic media [12,13]. Its value was ranged between(1.09E+08 − 6.75E+08) Pa., Table -1.   .
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$$\lambda = Vp^2\rho - 2\mu \dots\dots\dots\dots\dots.\dots \dots\dots\dots\dots… (5)$$

Dynamic Geotechnical Properties :

The following parameters are calculated by indirect relationship to calculate them from seismic velocities by geophysical method, they are useful for civil engineering purposes, that they are depends on the following parameters.

Material Index (Im)

It is very important geotechnical parameter which represents the degree of material efficiency that depends on the ratio of (Vs/Vp) as well as to some of elastic moduli like the ratio of (μ/K) and (λ/K) (11). Equation (6) were used to calculate this index, and all the calculated numbersis between [(-0.64) − (-0.9)] for first layer and between [(-0.36) − (-0.44)] for the second layer [11] Table -1.

Im= (3(Vs/Vp)^2-1)/(1-(Vs/Vp)^2) …………   …………(6)

Concentration Index (Ic)

This parameter is useful for qualification of foundation and other civil engineering purposes. This index deals with soil of lateral extends which are subjected to different pressures [14-15], and this depends on Poisson's ratio which is determined from (Vp) and (Vs) as well as the pressure distributions at depths. Equation (7) was used for determination of this index, its range is between (3.1-3.4) for first layer and while for second layer the range is between (3.8-3.9) Table -1.

Ic = (1+σ) / σ ………   ……… …..(7)

This value equals (3) for loose or saturated materials, and ranges between (3-6) for medium compacted soil at shallow depths. In more compacted and stiff soils its value is greater than (6). In Al-Jadiriyah area this index is between (3-6) for both layer which is medium compacted, because the soil of this area is soft at upper part and stiff in the second layer, Table -1.

Coefficient of Lateral Earth Pressure At Rest (Ko)

This coefficient is very important and commonly used in civil engineering [16] , and in terms of effective stresses it expresses the stress conditions in the ground [17]. (Ko) under natural conditions, without any effect to the construction or loading changes represents the scale of lateral pressure of soil, and it refers to the material strength at depth which is subjected to the constant geostatic pressure resulted from the weight of sediments [10]. Equation (8) were used to calculate this coefficient which is related by direct relationship with (σ) as follows, the values of (Ko) for the first layer ranged between (0.70 – 0.90) and for the second layer ranged between (0.51 -0.56) , Table-1.

$$Ko = σ / (1- σ)…………… ……………(8)$$

Ultimate bearing capacity (Qu)

Ultimate bearing capacity is defined as the maximum load required to cause failure [18]. It is one of the most important geotechnical properties in site investigation. Its importance appears in sites which are subjected to both static loading and cyclic dynamic loading [14]. For calculation (Qu) by using (VP), equation (9) was used as follows.

$$Qu = ((Vp/240)^{2.38})/3 ………… …………...(9)$$

The range of (Qu1) for first layer is between (0.5 - 3.5) Kg/cm2, and the range of (Qu2) for second layer is between (4 - 9) Kg/cm^2. Table -1.

Standard Penetration Test-SPT (N-value)

There are many empirical relations between the number of standard penetration test (N-value) and shear wave velocity for clay, sand, silt, silty clay and other types of soil. In Al-Jadiriyah area two layer are shown, first layer is silty soil and second layer is fine sand, for this reason two types of equation are used as follows [19].

$$Vs = 68.3 (N)^{0.292} ………… …………… (10)$$

Equation (10) was used for determination of (N-value) for silty soil of the first layer [20, 21], this value is to the depth of 1.91m.

$$Vs = 157.13 + 4.74 N …… …………..(11)$$

Equation (11) was used for determination of (N-value) for sands of the second layer to the depth greater than 1.91m. by using the correlation factor of (0.69) .

The range of (N-values) is between (2-35)b/30cm. for first layer and between (25-45)b/30cm. for second layer, Table-1. For geophysicist there is no difficulty for determination of (Vs), so from this values any one can calculate (N-values) empirically as shown in the following equations for average values of (Vs1) and (Vs2). These two equations were modified by researcher.

$$N=10^{Log(Vs/68.3)/0.292}…………$$

This equation can be used for calculation of (N-values) for the first layer.

$$N=((Vs-157.13)xo.69)/4.74$$

This equation can be used for calculation of (N-value) for the second Layer.

Plasticity Index (P.I)

This index is defined as the soil moisture content in percent at which the soil remains at plastic state (P.I) or it is defined as the difference between the liquid limit and the plastic limit of the soil. Equations (12) and (13) were used for determination of this index. These equations show that there is a relationship between the coefficient of lateral earth pressure at rest (Ko) and (P.I) for soil and as follows [10]:

Ko = 0.4 + 0.007(P.I)   0 < P.I < 40……   …………….(12)
Ko = 0.64 + 0.001 (P.I)   40 < P.I < 80……   …………….(13)

All calculations of (P.I) are shown in Table-1. This table shows that (P.I) for the first layer ranges between (42-72) so it is classified as very high plastic soil for the first layer according to [22]. The Plasticity index of the second layer ranged between (16-23) so it is classified as high plastic soil.

Table 1- Shows Elastic Modulus and Geotechnical parameters for first layer.

Vp1	Vs1	ρ	σ	μ	Lamda(λ)	Bulk M.	Comp.(B)	Ko1	Ic1	P.I1	Qu1-Kg/cm2	Im1	Young's M.	SPT
m/s	m/s	Kg/m3	Ratio	Pascal	Pascal	Pascal	Pascal						Pascal	N1
467	134	1886	0.46	3.39E+07	3.44E+08	3.21E+08	3.12E-09	0.84	3.2	62	1.6	-0.82	9.86E+07	10
522	143	1894	0.46	3.87E+07	4.39E+08	4.13E+08	2.42E-09	0.85	3.2	64	2.1	-0.84	1.13E+08	13
605	176	1998	0.45	6.19E+07	6.08E+08	5.66E+08	1.77E-09	0.83	3.2	62	3	-0.82	1.80E+08	26
557	168	1985	0.45	5.60E+07	5.04E+08	4.66E+08	2.14E-09	0.82	3.2	60	2.5	-0.8	1.62E+08	22
633	181	1998	0.46	6.55E+07	6.70E+08	6.26E+08	1.60E-09	0.84	3.2	62	3.4	-0.82	1.91E+08	28
642	193	1999	0.45	7.45E+07	6.75E+08	6.25E+08	1.60E-09	0.82	3.2	60	3.5	-0.8	2.16E+08	35
567	158	1894	0.46	4.73E+07	5.14E+08	4.83E+08	2.07E-09	0.84	3.2	64	2.6	-0.83	1.38E+08	18
534	151	1892	0.46	4.31E+07	4.53E+08	4.24E+08	2.36E-09	0.84	3.2	63	2.2	-0.83	1.26E+08	15
386	126	1785	0.44	2.83E+07	2.09E+08	1.90E+08	5.25E-09	0.79	3.3	55	1	-0.76	8.16E+07	8
481	163	1888	0.44	5.02E+07	3.36E+08	3.03E+08	3.30E-09	0.77	3.3	53	1.7	-0.74	1.44E+08	20
354	138	1756	0.41	3.34E+07	1.53E+08	1.31E+08	7.64E-09	0.7	3.4	42	0.8	-0.64	9.43E+07	11
587	172	1903	0.45	5.63E+07	5.43E+08	5.06E+08	1.98E-09	0.83	3.2	61	2.8	-0.81	1.64E+08	24
368	123	1768	0.44	2.67E+07	1.86E+08	1.68E+08	5.95E-09	0.78	3.3	54	0.9	-0.75	7.69E+07	8
288	96	1690	0.44	1.56E+07	1.09E+08	9.86E+07	1.01E-08	0.78	3.3	54	0.5	-0.75	4.48E+07	3
572	128	1893	0.47	3.10E+07	5.57E+08	5.37E+08	1.86E-09	0.9	3.1	71	2.6	-0.89	9.14E+07	9
556	122	1886	0.47	2.81E+07	5.27E+08	5.08E+08	1.97E-09	0.9	3.1	72	2.5	-0.9	8.28E+07	7
335	88	1743	0.46	1.35E+07	1.69E+08	1.60E+08	6.27E-09	0.86	3.2	66	0.7	-0.85	3.95E+07	2

Table 1-Continued for second layer.

Vp2	Vs2	σ	Ko2	Ic2	P.I2	Qu2	Im2	SPT
m/sec	m/sec	Ratio				Kg/cm2		(N2)
721	338	0.36	0.56	3.8	23	5	-0.44	26
854	421	0.34	0.51	3.9	16	7	-0.36	38
713	342	0.35	0.54	3.9	20	4	-0.4	27
681	327	0.35	0.54	3.9	20	4	-0.4	25
972	463	0.35	0.55	3.8	21	9	-0.41	45
864	422	0.34	0.52	3.9	18	7	-0.37	39
755	365	0.35	0.53	3.9	19	5	-0.39	30
830	398	0.35	0.54	3.9	20	6	-0.4	35
727	356	0.34	0.52	3.9	17	5	-0.37	29
822	403	0.34	0.52	3.9	17	6	-0.37	36
905	442	0.34	0.52	3.9	18	8	-0.37	42
689	333	0.35	0.53	3.9	19	4	-0.39	26
903	445	0.34	0.51	3.9	16	8	-0.36	42
763	368	0.35	0.53	3.9	19	5	-0.39	31
831	406	0.34	0.52	3.9	18	6	-0.37	36
843	413	0.34	0.52	3.9	17	7	-0.37	37
774	369	0.35	0.55	3.8	21	5	-0.41	31

**Relationships between seismic velocities and some of the elastic Modulus:**

There are many relationships between seismic velocities and elastic modulis most of them are linear, but some of them are directly proportional, other are inversely. The following figures show some of these relationships.

The Relationship Between Density of First Layer and (Vp1,Vs1)

The relationships between the density of first layer and (Vp1 ,Vs1) were drawn to (17) locations are shown in Figures-1 and 2, which are linear with their equations of positive slope that mean direct proportions between them.
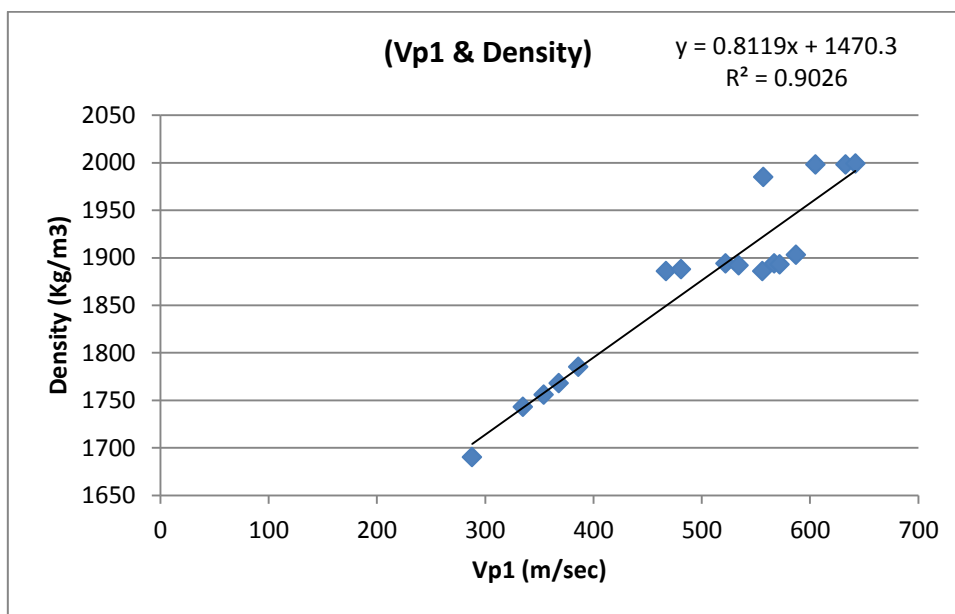
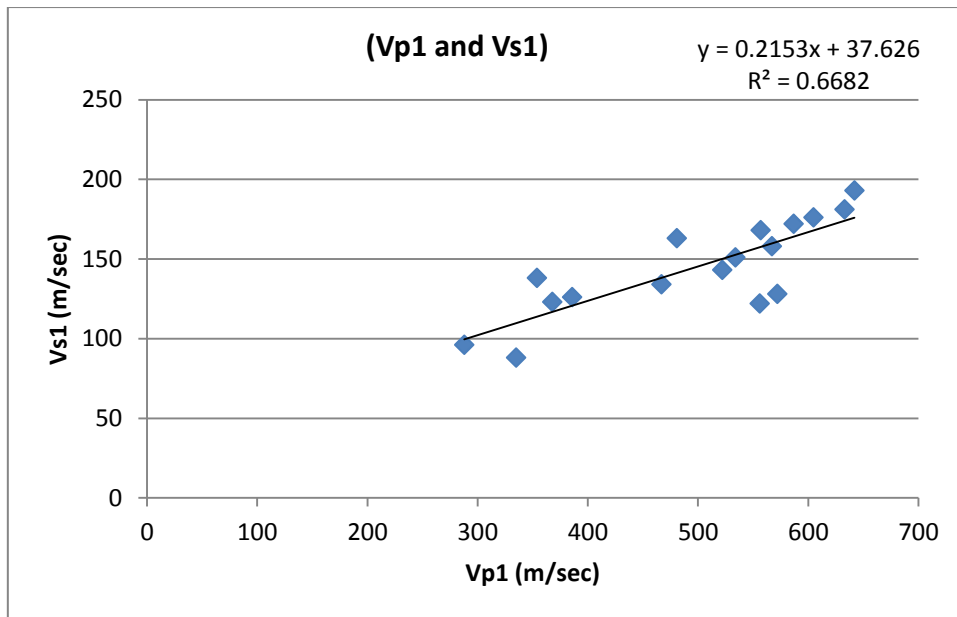**Figure** 1- Shows the relationship between (Vp1) and density of the first Layer.
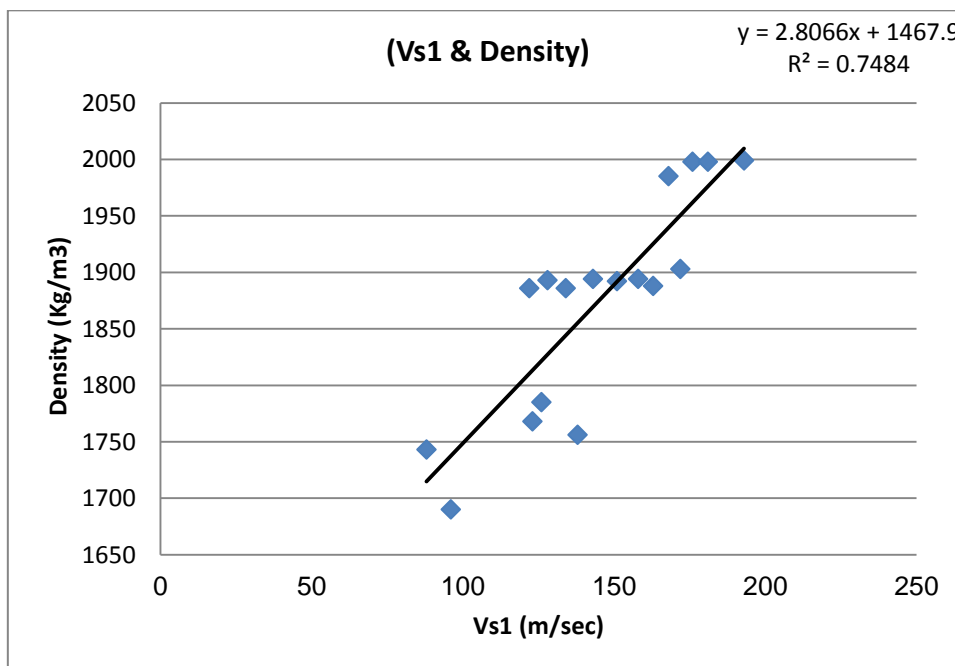
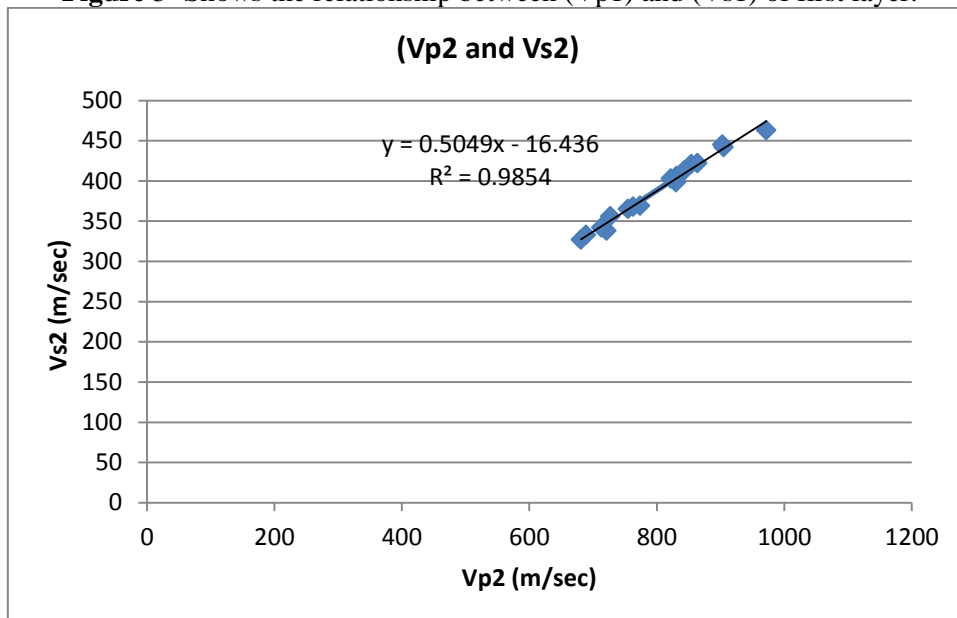**Figure 2**- Shows the relationship between (Vs1) and density of the first layer.

The relationships between (Vp) and (Vs) for the two layers

It is considered as one of the most important relationship, so for the difficulties of generating of shear waves then one can use this relationship after knowing the longitudinal velocity. These relations are shown in Figures- 3 and 4, for first and second layers.

Figure 3- Shows the relationship between (Vp1) and (Vs1) of first layer.

Figure 4- Shows the relationship between (Vp2) and (Vs2) of second layer.

The relationship between (Vp1) and Young Modulus (E1)

The modulus (E) is considered as a function to (Vp), and there is direct proportion between them Figure -5, so this was considered as an indicator of the quality factor of the soil (the number of cracks or fisher on the ground per meter) ranging from (1.5-2.0) for low velocities , while up to (1.0) in high velocities [13].
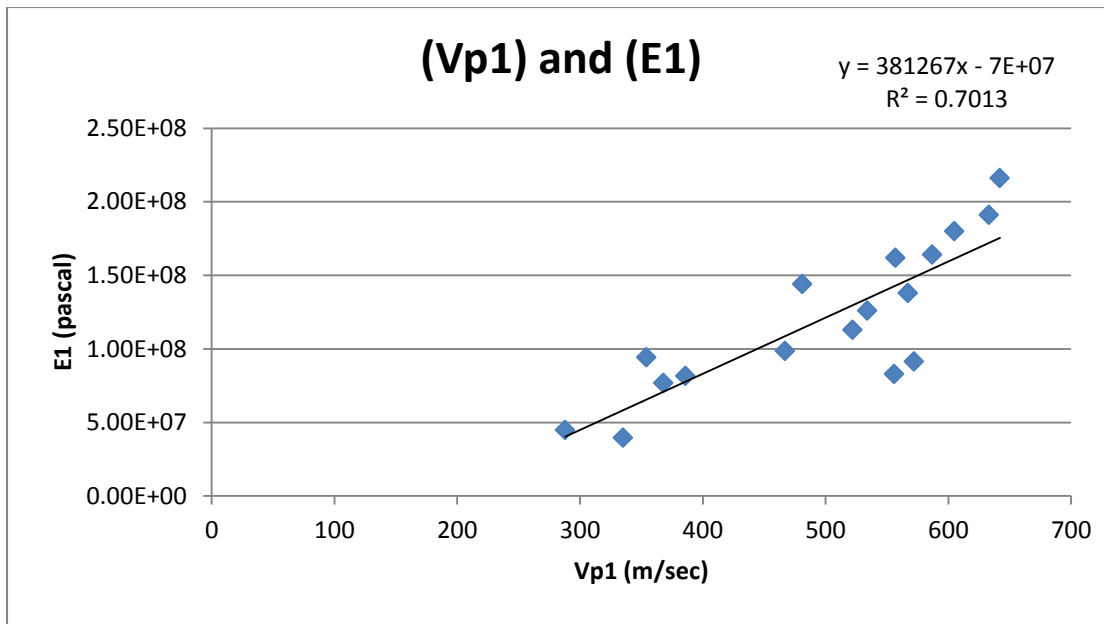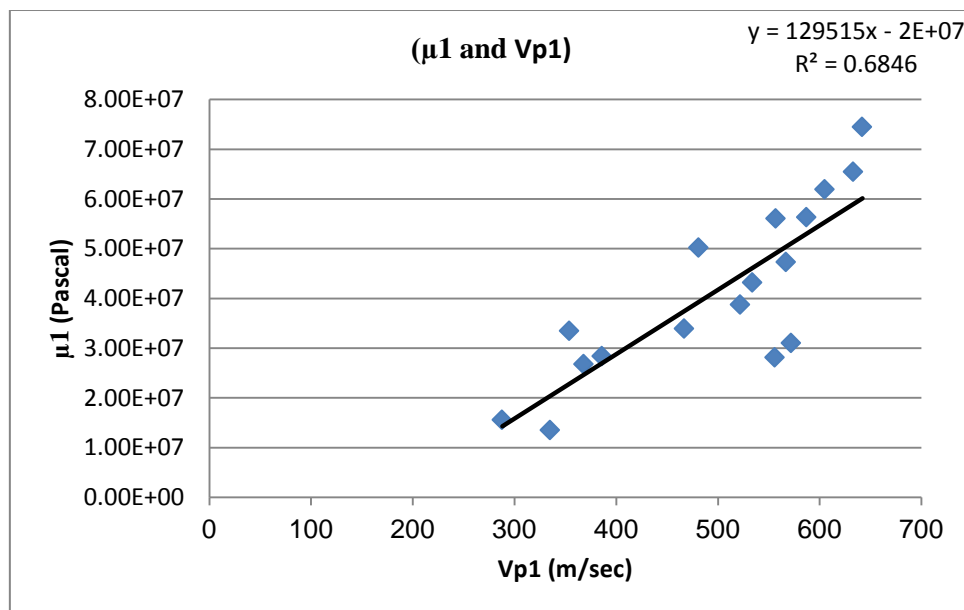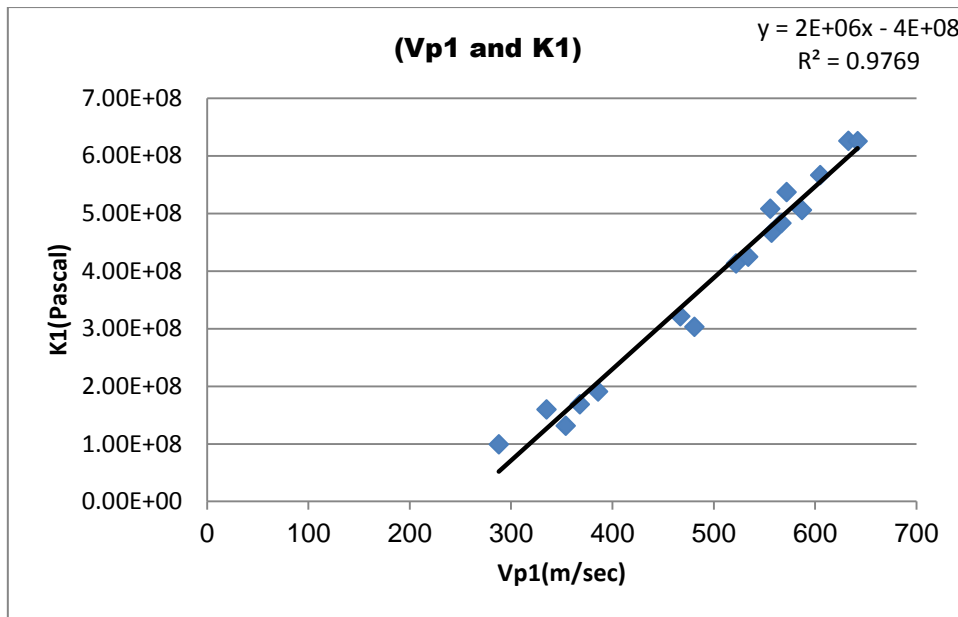
Figure 5- Shows the relationship between (Vp1) and Young Modulus(E1).

The relationship between (Vp1) and Rigidity Modulus (µ)

Rigidity Modulus (µ) Considered as a function to the (Vp1), and it is a directly proportional with (µ) and this is considered as an indicator of the quality factor of the soil (the number of cracks or fisher on the ground per meter) ranging from (1.5-2.0) for low velocities , while up to (1.0) in high velocities [13]. Figure-6 shows this relationship.

Figure 6- Shows the relationship between(Vp1) and Rigidity Modulus (µ1).

**The relationship between (Vp1) and Bulk Modulus (K1)**

It is considered as a function to (Vp1) , and it also directly proportional with (K1) where increasing values of this parameter increase with increasing of (Vp1) Figure-7 shows the relationship between them with their equation.

Figure 7- Shows the relationship between (Vp1) and Bulk Modulus (K1).

The relationship between Poisson's ratios (σ1, σ2) and the ratios (Vs1/ Vp1) and (Vs2/Vp2)

   These relationships between Poisson's ratios (σ1 , σ2) and the ratios of (Vs1/Vp1) and (Vs2/Vp2) are   pointed as   inverse relationships, this   means that   increasing of Poisson's ratios reduce the ratios of (Vs / Vp) and this will reduce the brittleness and rigidity of materials. These relations are   shown in   Figures – 8 and 9 respectively. Figure-9   seems to be   three points, but here   all (17)   points are concentrated at three locations.
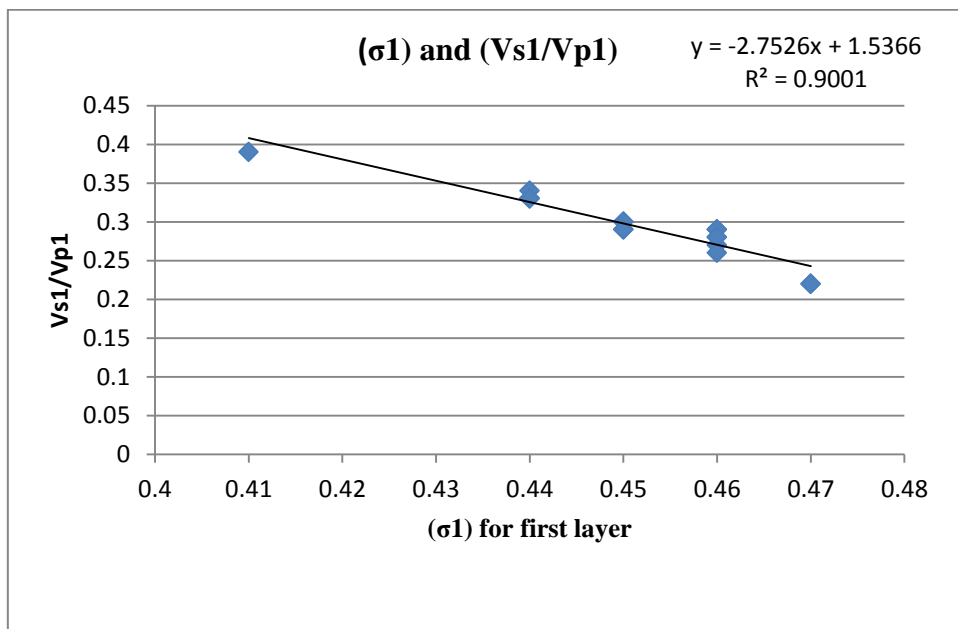
Figure 8- Shows the relationship between (σ1) and (Vs1/Vp1) for first layer.

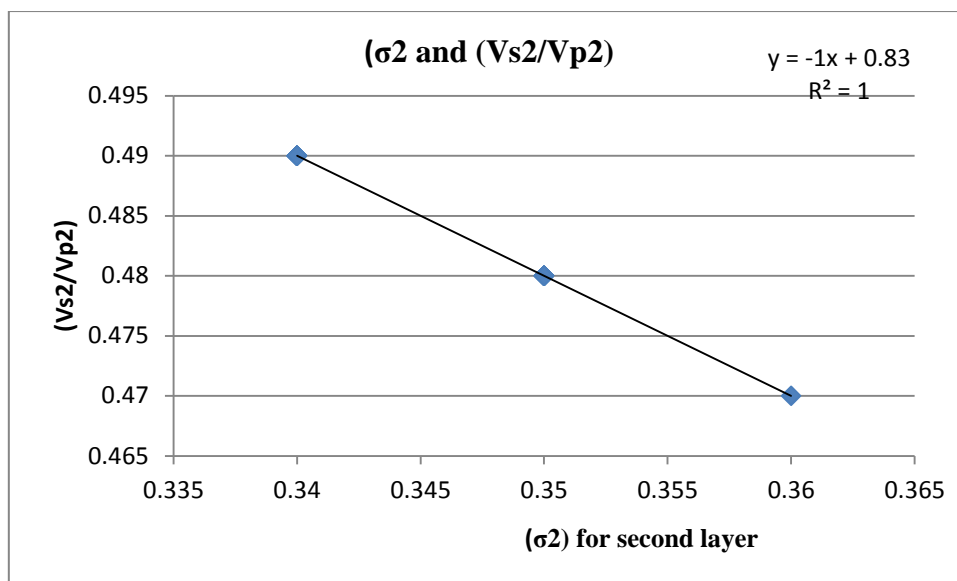**Figure** 9- Shows the relationship between (σ2) and (Vs2/Vp2) for second layer

The relationship between the ratio (K / μ) and the ratio of Vs1/Vp1

This relationship is a very important one from an engineering point of view where it can be used to separate the weak zone areas from the strong zones [23], the relationship between these percentages gave an inverse relationship as shown in Figure -10.
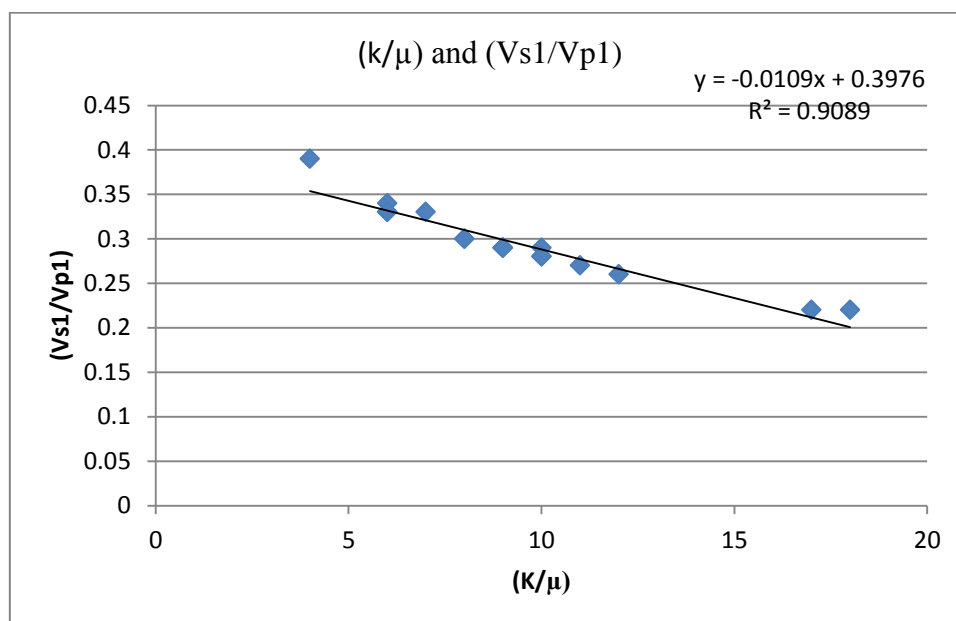

Figure 10- Shows the relationship between the ratio of (K/μ) and the ratio of (Vs1/Vp1).

Conclusions

From the analysis of data and determination of velocities, densities, elastic modulus and geotechnical parameters, the following conclusions were done:

1- The ranges of (Vp) values were between (288-642) m/sec for the first layer, and (681-972) m/sec for the second layer.
2- The ranges of (Vs) values were between (88-193) m/sec for the first layer, and (327-463) m/sec for the second layer.
3- The range of surface soil densities ranged between (1743-1999) Kg/m^3.

The first layer values of the most important elastic modulus and geotechnical parameters were determined and the range of results are as follows:

1- Poisson's ratio were (0.41-0.47).
2- Shear modulus were (1.35-7.45) x 10^7 Pascal.
3- Young's modulus were (3.95-21.6) x 10^7 Pascal.
4- Lame's constant were (1.09-6.75) x10^8 Pascal.
5- Bulk modulus were (0.986-6.25) x 10^7 Pascal.
6- Compressibility were (1.6-10.1) x 10^{-9} m$^{2/}$N or (1/Pascal).
7- The Earth lateral pressure at rest (Ko) were (0.70- 0.90).
8- Concentration index were (3.1-3.4).
9- Material index were (-0.64) - (-.90).
10- Plasticity index were (42-72), used for Ko greater than 0.4.
11- Ultimate bearing capacity ranges from (0.5- 3.5) Kg/cm2.
12- N-value of Standard Penetration Test (SPT) ranged between (2-35) b/30 cm.
13- $N = 10^{Log\{Vs/68.3)/0.292.}}$

The second layer values of the most important elastic modulus and geotechnical parameters were determined and the range of results are as follows:

1- Poisson's ratio were (0.34-0.36).
2- The Earth lateral pressure at rest (Ko) were (0.51- 0.56).
3- Concentration index were (3.8-3.9).
4- Material index were (-0.36) - (-.44).
5- Plasticity index were (16-23), used for Ko greater than 0.4 .
6- Ultimate bearing capacity ranges from (4-9) Kg/cm2.
7- N-value of Standard Penetration Test (SPT) ranged between (25-45) b/30 cm.
8- N=((Vs-157.13)xo.69)/4.74.

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