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Geophysical-Engineering study in landfill site Al-Kifil District-Babylon Governorate Middle of Iraq

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Abstract

Four seismic refraction profiles for both compressional (P) and shear (S) waves had been surveyed within AlKifil District/Babylon Governorate, Middle of Iraq, by the use of three impacts; normal, center and reverse shootings. In addition, cross-hole, down-hole and up-hole seismic refraction using couple boreholes were also conducted in the investigated site. These two techniques were done in order to delineate depths and thicknesses of the layers (soils), their dynamic elastic modulus and groundwater level underlying such establishment building may use for future landfill purposes.

The calculations demonstrate that there are two shallow subsurface layers were found. The average of velocities and thicknesses of the first layer (consists of grayish silty sandy clay soil) are equal to 259.33, 147.83 m/sec and 6.58 m, and for the second one (consists of brownish and greenish silty clay soil with sand) are 517, 273.25 m/sec for each P and S-waves respectively. On the other hand, mean water table seems between 1.40 and 1.20 meters during Sep. 2012 and Sep. 2015 respectively. Moreover, the mean dynamic elastic constants were ranged between {κ= (69.51-605.16) Mpa, μ= (24.64-212.37) Mpa, E= (60.40-510.93) Mpa, λ= (41.85-392.22) Mpa, and, σ= (0.18-0.37)}.

Site engineering information including physical and geotechnical properties were also measured and analyzed to enhance the main targets of this study. Standard penetration test and bearing capacity values were performed and calculated for the studied soils. The average of the N-values in situ is equal to (11) impacts having bearing capacity (6.10) ton/m2 at (1.5) m depth interval. It noticed that the N-value is low near the ground surface because of the

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saturated clay existence (medium consistency). At depth intervals between (13-15)m, the N-value was reached (43) impacts and more; this indicates that the soil is cohesion and contains high percent of sand and low clays; therefore, all depth intervals or layers in the drilling wells are considered hard media and they have bearing capacity equals to (16) ton/m2. This means that the layers corresponding to these intervals were characterized by its hardness.

Key words: Seismic refraction survey, Cross-hole, Down-hole, Up-hole and Geotechnical.

دراسة جيوفيزيائية هندسية لموقع مكب النفايات في قضاء الكفل-محافظة بابل

الخلاصة

هناك أربعة مسارات زلزالية انكسارية للموجات الزلزالية الطولية والقصية على حدٍ سواء تم تنفيذها ضمن قضاء الكفل-محافظة الحلة, وسط العراق, بواسطة استخدام ثلاث حالات من النشر هي (الاعتيادي, المركزي, المعكوس). بالإضافة إلى ذلك. استخدم المسح الزلزلي عبر الأبار مثل (Cross-hole, Down-hole and Up-hole) التي نفذت في موقع التحري. هذه الطرقتين من المسح نفذت لغرض الحصول على أعماق وسمك طبقات التربة, أيضاً معاملات المرونة ومستوى المياه الجوفية تم حسابها لغرض معرفة طبيعة التربية لبناء المنشأ الهندسي والتي قد تستخدم مستقبلاً لغرض مشروع مكب النفايات.

الحسابات برهنت على وجود طبقتين تحت سطحية ضحلة لمنطقة الدراسة. معدل السرع والسماكات للطبقة الأولى هي ٢٥٩,٣٣, ١٤٧,٨٣ م/ثانية و ٦,٥٨ م والتي تتكون من تربة طين رملي غريني رمادي وتربة رمل غريني أخضر, أما الطبقة الثانية تتكون من تربة طين غريني أخضر-بني مع الرمل, كانت السرع الموجية الزلزالية والسماكات فيها تساوي ٥١٧, ٢٧٣,٢٥ م/ثانية للموجات الطولية والموجات القصية على التوالي. من ناحية أخرى, مستوى عمق المياه الجوفية في منطقة الدراسة كانت تتراوح ما بين (١,٤-١,٢) متر خلال Sep. ٢٠١٢ و Sep.٢٠١٦ على التوالي. علاوة على ذلك, متوسط معاملات المرونة كانت تتراوح مابين { κ= (69.51-605.16) Mpa, µ= (24.64-212.37) Mpa, E= (60.40-510.93) Mpa, λ= (41.85-392.22) Mpa, and, σ= (٠,١٨-٠,٣٧)}.

المعلومات الهندسية تتضمن الخصائص الفيزيائية والجيوتكنيكية التي تم قياسها وتحليلها للحصول على الأهداف الرئيسية للدراسة. فحص الأختراق القياسي وقيم سعة التحميل للتربة تم حسابها لغرض دراسة التربة. معدل قيم N في الموقع كانت تساوي (١١) ضربة وسعة التحميل (٦,١٠) طن\م٢ في العمق (١,٥) م. لوحظ أن قيمة N تكون قليلة عند الأعماق القريبة من السطح بسبب وجود الطين المشبع المتوسط التماسك. في الأعماق التي تتراوح مابين (١٥-١٣) م, قيمة N كانت تصل إلى (٤٣) ضربة وأكثر, هذا يشير إلى أن التربة تكون متماسكة وتحتوي على كمية عالية من الرمل مع قليل من الأطيان, لذلك جميع الأعماق أو الطبقات في الأبار المحفورة أعتبرت وسط صلب وتحتوي على سعة تحميل تصل إلى (١٦) طن\م٢. هذا يعني تلك الطبقات تعتبر لهذه الأعماق تمتاز بالصلابة أو Hardness.

الكلمات المفتاحية: المسح الزلزالي الانكساري, الكرووس هول, الداوون هول, الآب هول و الجيوتكنك.

Introduction

At present days, seismic refraction method has become one of the important geophysical methods, and it plays a major role in civil engineering (soil investigation and foundation studies). However, it gives a lot of information with high resolution, valuable and more detailed to subsurface shallow layers. So, inferred data of seismic methods are almost identical to extract data from laboratory tests, such as shear wave velocity and shear modulus. This method is faster with less cost (the cost of P and S wave measurements at a particular site will not exceed a quarter of the total cost of the conventional bore-hole and laboratory testing (Tezcan *et al*., 2009). Therefore, researchers can obtain young modulus and Poisson's ratio, depth and type of each layer, water table and the ultimate bearing capacity of the underlying layers dependent on the penetrating depth of both P and S wave velocities.

Therefore, seismic refraction field work must include land survey, cross hole, down hole and up-hole techniques in order to detect a high velocity layer or the hidden layer, weak zone and/or cavities may exist underlying the investigated soil.

Location of the study area

The site understudy is located at the intersection among the street link between (Hilla-Najaf) Provinces and (Al-Kifl-Al-Qassim) Districts, (Fig 1). It is positioned on 130 Km south of Baghdad, the capital of Iraq. According to the information mentioned by some people who dwell study area, it was considered as a big hill and then it removed by humans (perhaps used as a quarry dust). Thus, the surface of the study area is irregular from one place to another, and this effects on the results obtained from boreholes (laboratory test), as well as seismic refraction survey.

Geological setting of the study area

All deposits in the study area are belonged to the Quaternary period (Jassim and Goff, 2006), they are a fluvial sediments of the Tigris and Euphrates rivers. Their branches represent the modern sediments that contained secondary amorphous and an amorphous grains Gypsum as follows:

1- Primary gypsum melting then deposited.

2- The transportation by wind of desert areas consisting of Gypsum fragments and then deposited in the other soils.

3- Deposition of water irrigation-containing Gypsum.

4- The chemical reaction with the soil itself when the presence sulfur unreacted with calcium carbonate with the presence of microorganisms (Namik, 1985).

Also, there are a depression fill deposits and these deposits accumulate as a result the floods, which generally consist of thin layers of fine sand, clay and silt clay (Parsons, 1957). The marsh soils are salt flats that occupy multiple areas of the lower part of the alluvial plain, and that the study area (the city of Hilla) part of it (Al-Abdullah, 1997)

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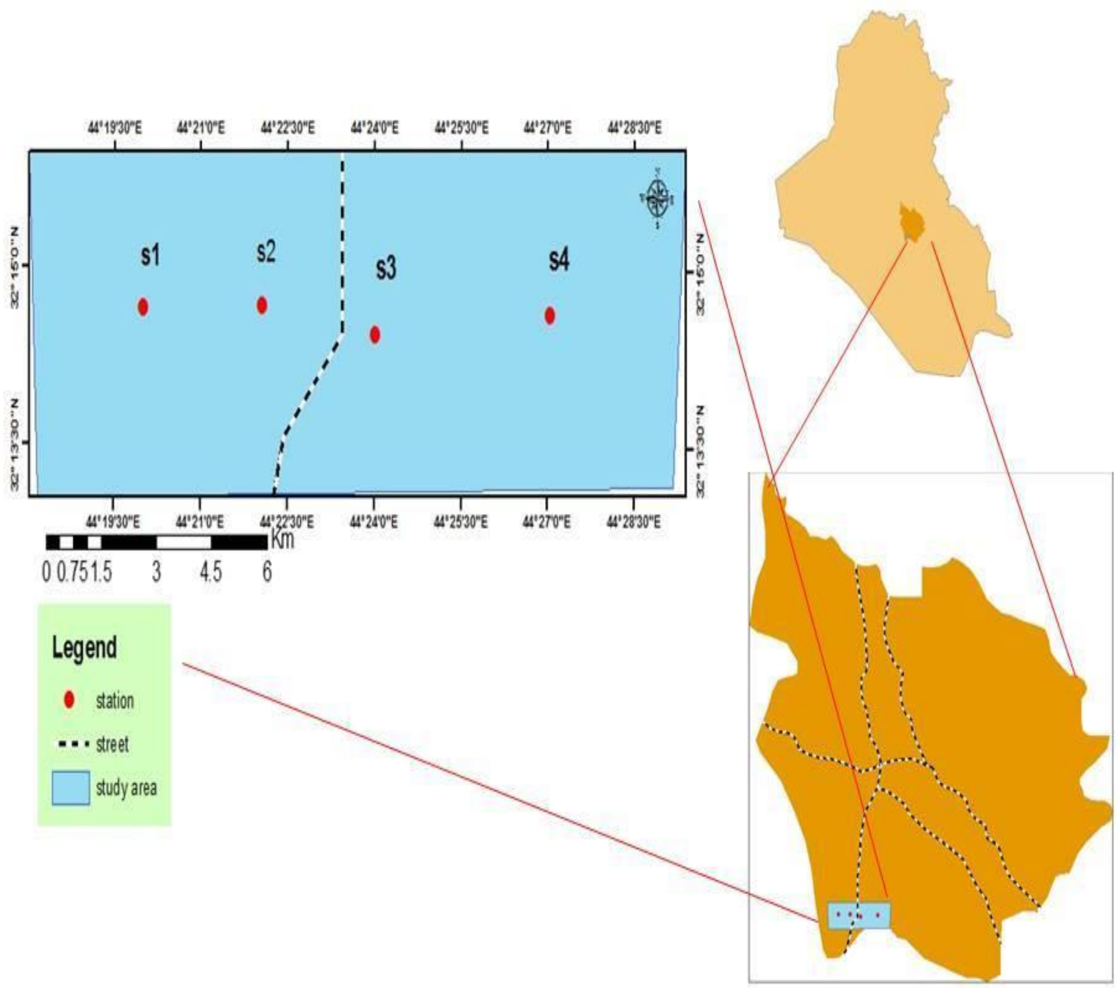

Fig (1): Map represents to location of the study area.

Aims of the study

1. Calculate the velocity values (P and S wave) of the underlying layers and then determining the elastic modulus and engineering properties of each layer at the studied site, as well as calculate bearing capacity of subsurface soil with the assistance of the standard penetration test results.
2. Identify the weak zones, cavities and shallow faults that may exist in the investigated soil of the proposed project.

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3. Determine the groundwater table boot to its flow direction.

So, there are five wells drilled in the study site ranged between (10-15) meters, and these wells showed a sequence of four major layers as follow: (Al- Mawal Report, 2015). Details correlation between boreholes of soil layer in study as illustrated in soil profile "boreholes" at (Fig 2).

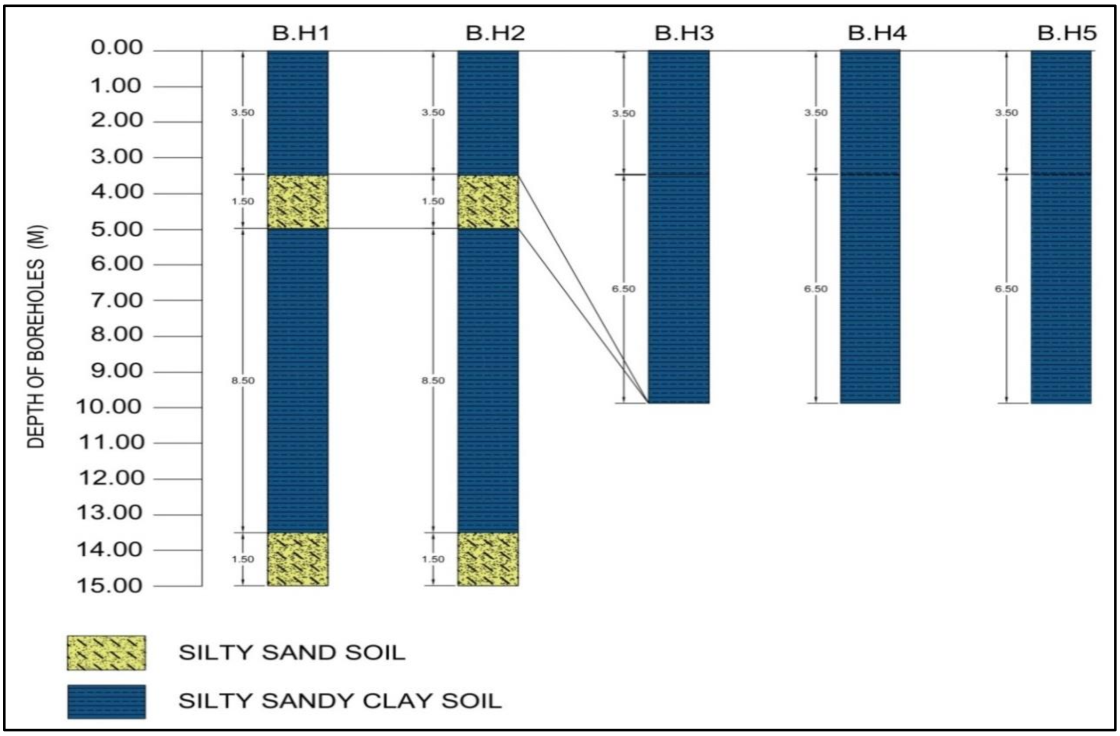

Fig (2): Correlation between boreholes (1, 2, 3, 4 and 5) that digged in the study area.

Instruments and Field work

A modern Sweden (2011) device known as (ABEM Terraloc Pro) was used for the purpose of this study, seismic refraction survey traces and seismic refraction by boreholes (Cross hole, Down hole and Up hole). It belongs to Al-Mawal Company. Furthermore, this new version is used in Iraq for the first time. The multi-channel digital seismograph is useful for cost-effective refraction and high-resolution reflection surveys, tomography, vibration measurements, and more, anywhere in the world in all weather conditions. (ABEM Instrument AB: instruction manual, 2011). So, seismic waves (either compressional or shear) can be generate using a sledge hammer with a weight of 25 kg by lifting it to top and then falling to iron plate (Reynolds, 1997).

1-Seismic refraction survey

During 10/11/2015, four seismic refraction profiles (1, 2, 3 and 4) were carried out for both P and S waves inside the study area (Fig 3). 24 vertical geophones for P-wave and 24 horizontal one for S-wave also deployed with 2m spacing along 48m for both profiles (1 and 3). However, profiles (2 and 4) having geophones spacing 3 and 5 along 72m and 120m length respectively. The total seismic surveys are equal to 178m length. Three impacts (normal, centered, reverse) were applied using 25 kg hammer as mentioned above in order to measure the first arrival of the generating P-wave. Also, the same impacts wave due polarizing source.

2-Seismic refraction by boreholes

Cross-hole method

It includes one seismic profile between boreholes (BH1 and BH2), where one borehole is the source and the other borehole is as receiver. The offset between boreholes is (10) m. So, the survey was started from (6.5) m depth going towards ground surface, the interval between traces is (0.5) m.

Down-hole method

It includes one seismic profile in BH2 that considered as a receiver and the source put on ground surface with offset between borehole and source equals to (1) m. So, the survey started from (6.5) m depth going to ground surface, the interval between traces is (0.5) m.

Up-hole method

It includes one seismic profile in BH1 which considered as a source and the receiver place on ground surface far about (0.5) m as offset between borehole and receiver. Therefore, the survey was started from (7.5) m depth to (0.5) m, the interval between traces is (0.5) m.

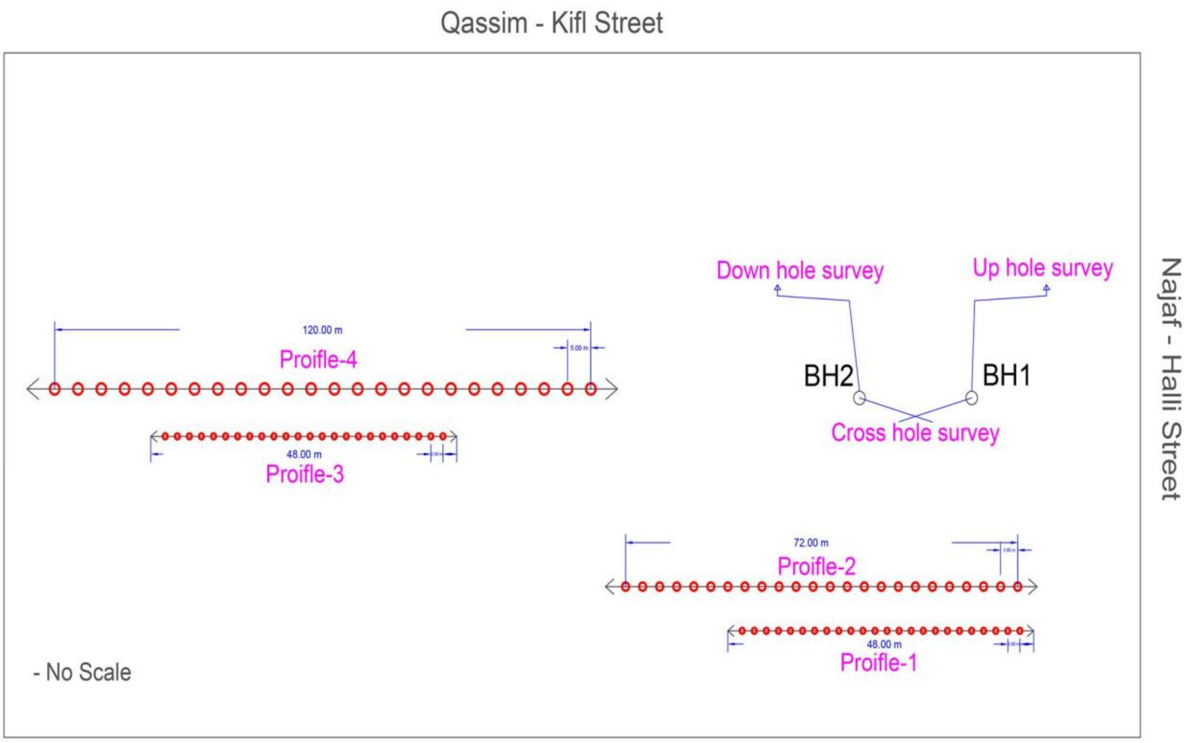

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Fig (3): Base map of the study area including boreholes and seismic profiles.

Results and Interpretation

1-Seismic Refraction data

In this stage, time-distance curves that plotted for the selected seismic profiles 1 and 2 of P and S-waves below to the study area were interpreted using seisTW software. Several applications such as T-plus-minus, Mean-mines-T and Least Square Fitting were used as meaning tools for this interpretation these calculations clear that there is an undistinctive difference between the subsurface layers velocities and thickness related to them. Therefore, the average has been considered in this study of P and S-waves as shown in (Table 1).

Table (1): Shows the values of both P and S-wave velocities and average thicknesses related to the ground surface level.

Profile No.	Spacing between geophones (m)	Layer	Shooting						Mean thickness (m)
			Primary wave velocity (m/sec)			Shear wave velocity (m/sec)			
			Normal	Central	Reverse	Normal	Central	Reverse	
1	2	First	206	190	197	120	114	119	6.55
		Second	454	--	476	211	--	208	--
2	3	First	281	280	288	174	167	172	6.91
		Second	569	--	569	323	--	330	--
3	2	First	308	327	328	--	185	171	6.28
		Second	528	526	534	--	324	333	--
4	5	First	280	271	287	--	170	--	_
		Second	543	555	558	--	337	--	--

From this table, the first layer having average velocities and thicknesses for P-waves ranging between (197.66-321) m/sec and (6.55-6.91) m, respectively in all profiles. While in case of the S-waves, the results are (117.66-178) m/sec for layer velocity. This layer may represents the (grayish silty sandy clay-greenish silty sand soil).

Also, the second layer for all profiles is characterized by its highly velocity and thickness values (Vp = 2Vs). The values are ranging between (465-569) m/sec and (209.5-337) m/s for P and S-waves respectively. This layer may consists of (brownish, greenish silty clay soil with sand, medium to stiff consistency).

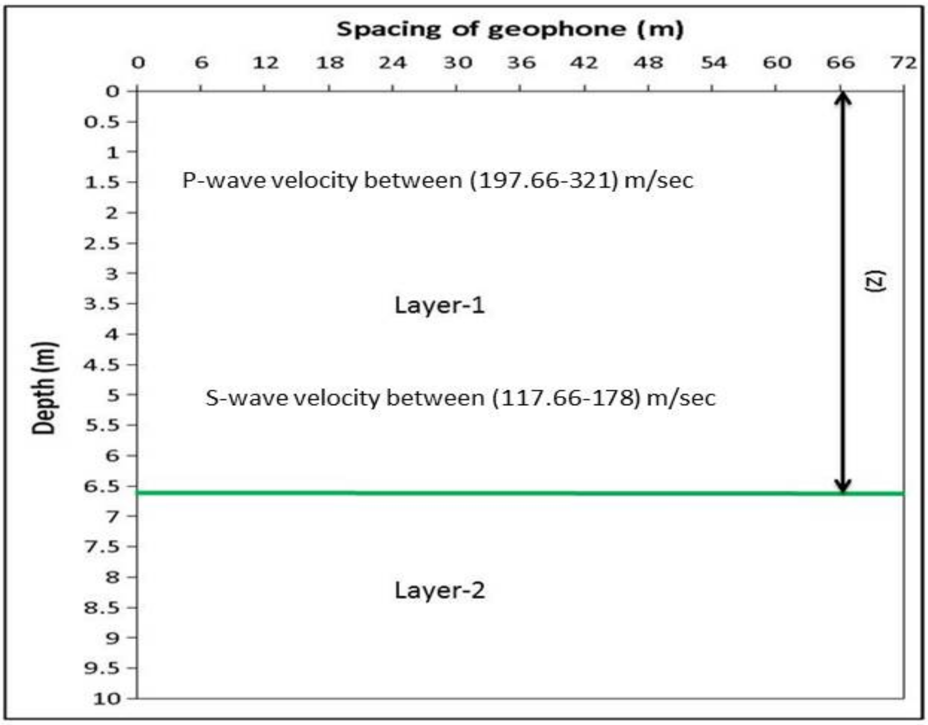

Fig (4): Represents to depth section of seismic refraction profiles for two subsurface layers.

The depth average to the first layer was (6.58) m from all profile of seismic refraction survey in the study area (Fig 4). Additionally, the depth section to subsurface layer draws by using Excel program.

2-Seismic survey by borehole

Seismic survey by borehole such as cross hole, down hole and up hole are usually used in civil engineering investigations and petroleum exploration, which can prove its accuracy and possibilities. It is to be a successful alternative to a lot of soil testing operations especially in confined areas containing cavities or find out the extended cables position or wires and other. Seismic survey by borehole used in civil engineering problems that fall within the following projects are foundation pads, embankments, dikes, dams and road construction. Seismic methods applications by boreholes are being very few in Iraq.

Seismic Cross-hole data

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The cross-hole (Tomographic) survey is one of the best methods used for determining the variation with depth of low strain shear wave velocity (Luna, and Jadi, 2000). The method can be used in relatively deep holes and can provide much finer resolution than the surface source (Boore, 2006).

The main target of cross hole method is to obtain a detailed in situ seismic wave velocity profile (P and S-wave) for depths sequentially from ground surface to bottom (the desired depth). Through seismic wave velocity we get lateral change to layers in situ (may be the presences of cavities or foreign body can be determined). And thus give very accurate information to the layers of elastic properties and geotechnical characteristics of the soil.

Seismic Down-hole data

The objective of the down-hole survey is to measure the travel times of P and S-wave from propagation wave during layers of soil between source and receiver boreholes.

Seismic Up-hole data

Up hole seismic survey is similar to down hole survey. There is one difference is the seismic source (Probe) inside borehole while receiver (triaxial component geophones) put on the ground surface adjacent to the borehole, required only one shallow borehole or more (Massarsch, 2007). Up hole survey provides a direct measurement of the seismic wave travel time in the low velocity layers.

Relationship between elastic moduli, geotechnical properties and velocity with depth

The relationship between elastic moduli, geotechnical properties and velocity with depth for seismic survey by borehole (cross-hole, down-hole and up-hole) as shown in (Fig 5, 6 and 7) below. Any change in velocity with depth means there are a change elastic properties or type of layer. Distinct anomalies can be observed overall these plot which indicate the existing of weak zones or either thin layers and cavities.

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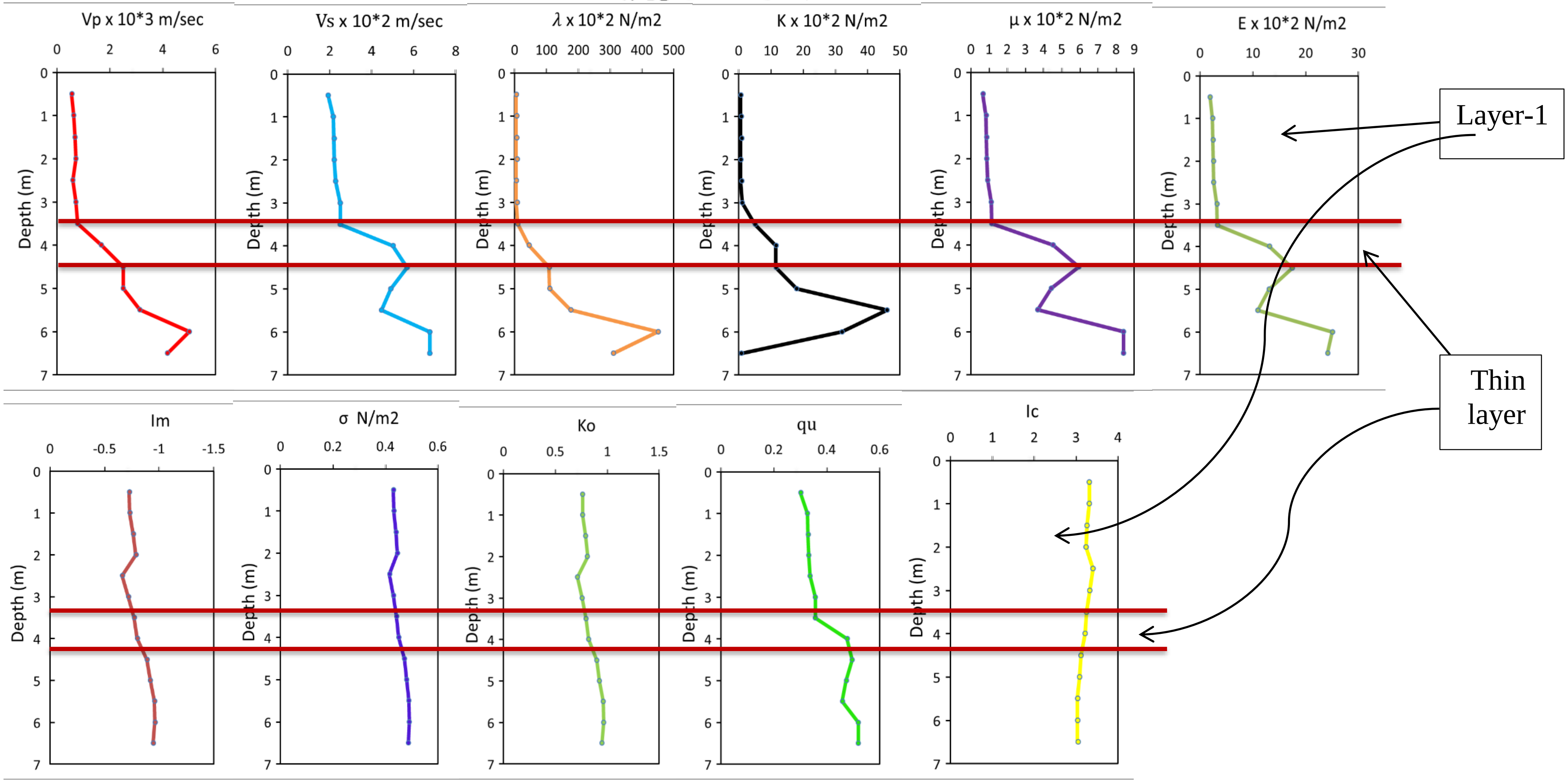

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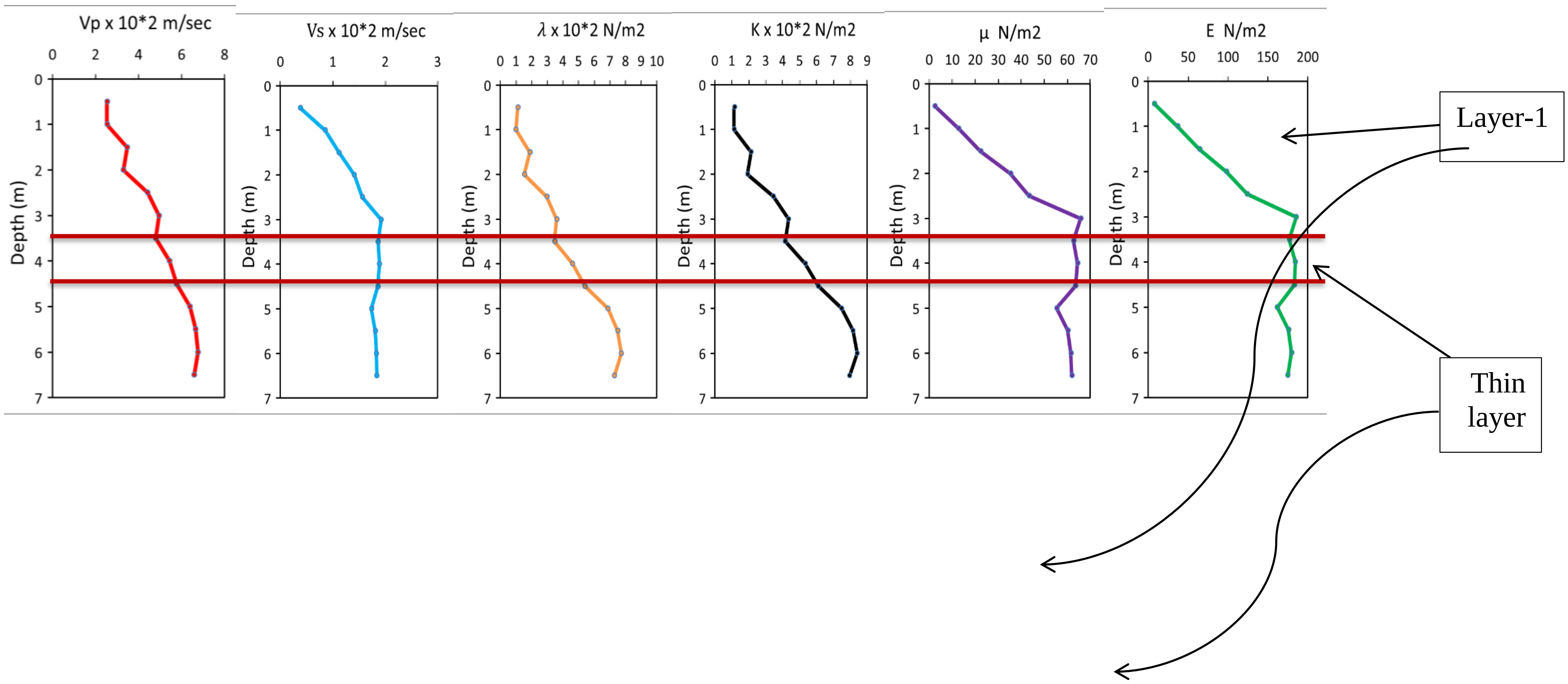
Fig (5): Represents to relationship between elastic moduli, geotechnical properties and velocity with depth for cross-hole survey.



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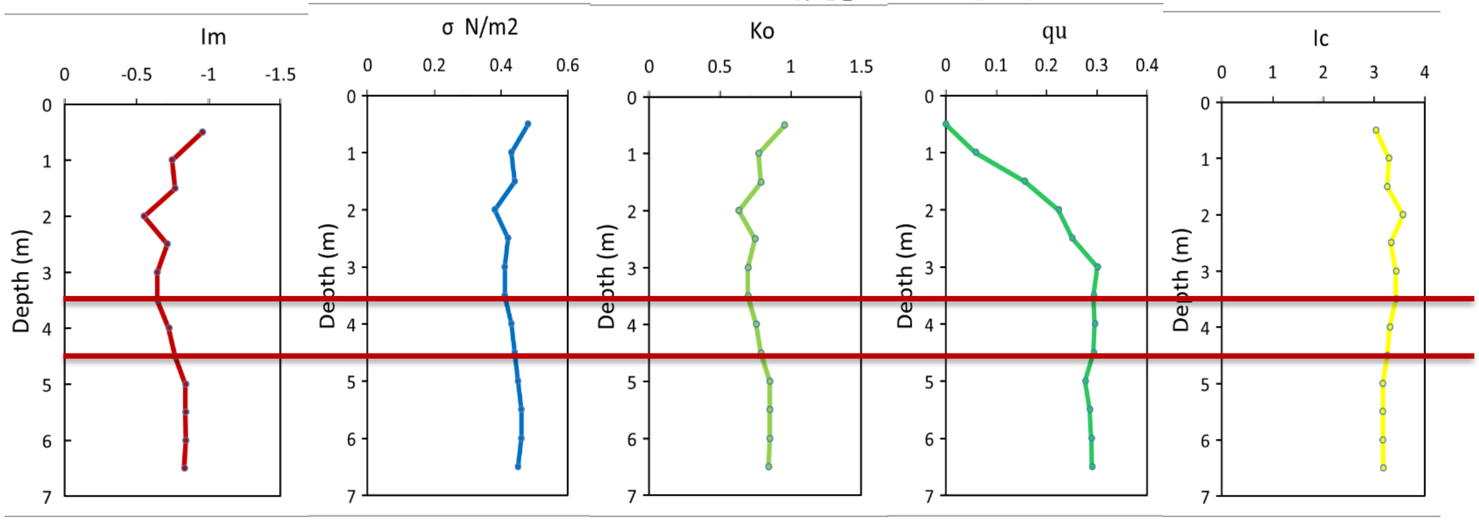

Fig (6): Represents to relationship between elastic moduli, geotechnical properties and velocity with depth for down-hole.

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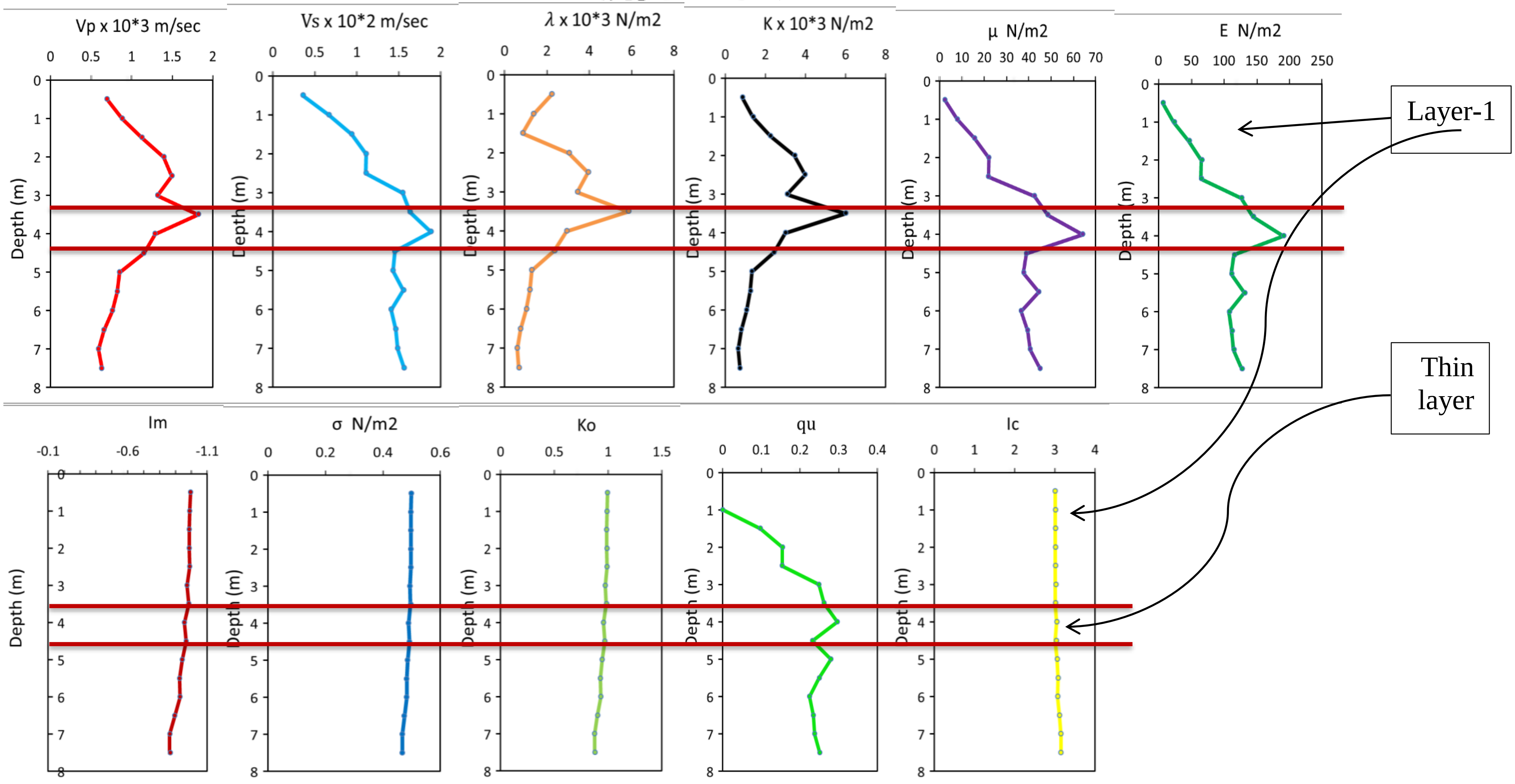

Fig (7): Represents to relationship between elastic moduli, geotechnical properties and velocity with depth for up-hole.

From this curves, it can be seen that the soil have low Vs wave at depth interval between the ground surface until 6.5 m, whereas Vp from the same behavior till 3.5 m. After that, values of Vp wave will increase with depth due to the changing may occur to the soil at depth between (3.5 to 6) m.

Conclusions

1- Based on seismic refraction results it was observed that there are two layers in the study area, the first layer extends from ground surface to (6.58) m, while the second layer extends from (6.58) m to below.

2- From cross-hole, down-hole and up-hole results with help depths-velocities curve it may occur (Thin Layer) in the study area and it did not appear in seismic refraction survey, it ranged from (3-3.5) m to (4.5) m depth.

4- The source of water supplier is local from rain and leakage of a drainage water and sewage. Therefore, the groundwater levels in the study site are ranged between 1.40 and 1.20 meters during Sep. 2012 and Sep. 2015, respectively.

5- Increasing in primary wave velocity due to great groundwater level in the study area is more than shear wave velocity. The seismic wave velocities to:

- Cross-hole survey:

  Vp = (555.55-5000) m/sec
  Vs = (192.30-675.67) m/sec
- Down-hole survey:

  Vp = (252.53-675.85) m/sec
  Vs = (37.87-192.30) m/sec
- Up-hole survey:

  Vp = (589.16-1494.44) m/sec
  Vs = (35.71-163.55) m/sec

6- Seismic refraction survey, cross-hole survey, down-hole survey, up-hole survey and laboratory results show that there is gradual change in elastic behavior and it was noted from 3.5 m to 6 m and it tends to make the soil become more compact.

7- There is a difficulty to obtain seismic wave velocity (Vp and Vs-wave) when taken 5 a distance between geophones and it is may be due to a weak soil layers in the study area and it also gives inaccurate data.

8- Average bearing capacity of soil in the study area (BH1 and BH2) based on Standard Penetration Capacity (SPT) results were (6.10) T/m^2 and (11) N to (1.5) m depth while they were (16) T/m^2 and (29) N to (16) m depth. Therefore, the results show bearing capacity of soil gradually increase with depth according to the soil type and properties in the study area. So, it calculated as average to (cross-hole, down-hole and up-hole) dependent on primary and shear wave velocities were ranged between (0.157-0.519) kg/cm^2 to depths (1.5-7.5) m.

9- Elastic modulus and geotechnical properties of seismic surveys by boreholes, where Possion ratio were ranged between (0.415-0.49) N/m^2 and material index ranged between (-0.662) to (-0.962) in cross-hole survey, while in down-hole survey, Possion ratio were ranged between (0.38-0.46) N/m^2 and material index ranged between (-0.550) to (-0.954) to (0.5-6.5) m depths, respectively. And in up-hole survey, Possion ratio were ranged between (0.4661-0.4986) $N/m^2$and material index were ranged between (-0.864) to (-0.994) to (0.5-7.5) m depths, respectively, and depending on (Hunt, 1986) the soil type in the study area is clays and while according to (Abdul Rahman,1989) the degree of competent is (non-less competent). Thus, Young modulus in down-hole survey shows gradually increases with depth from (7.59) N/M^2 to (185.62) N/M^2 and concentration index (Ic) ranged between (3.04-3.57) to (0.5-6.5) m depth while in up-hole young modulus ranged from (6.80) N/M^2 to (190.99) N/M^2 and concentration index (Ic) ranged between (3.005-3.145) to (0.5-7.5) m depths. As well as, the results in the study area indicate to young modulus proportional with shear modulus and bulk modulus proportional with lame modulus.

10- The soil in study area do not contain weak zones or weak layer.

Recommendations

1- Making drained net to ground water about the proposed project in the study area that dig wells to get rid of the high water level which may affect on the proposed building foundations.

2- Emphasize on the use of cross-hole method due to of their ability to give valuable results and detection to weak layers or thin layer.

3- Conduct geotechnical study by engineering and geophysical methods to the surrounding areas about the study area to obtain more detail about the behavior of the soil to Al-Kifil district.

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