P AND S-WAVES EVALUATION FOR ENGINEERING SITE INVESTIGATION AT A HOSTEL COMPLEX INSIDE BASRAH UNIVERSITY, SOUTHERN IRAQ

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ABSTRACT

The area understudy was surveyed using seismic refraction techniques as an available tool for engineering purposes. Eight seismic profiles for either P and S-waves had been chosen and carried out by the use of five impacts (center, normal, reverse, between geophones 6-7 and 18-19), in order to delineate layers thicknesses and depth of water table underlying such a hostel complex site inside Basrah University, southern Iraq. Dynamic elastic modulii were also calculated depending upon the velocities of P and S-waves of these layers and its densities.Accordingly, three shallow subsurface soil layers were found. Their mean thicknesses are ranged between (2.15-2.45) m, (17.65-18.4) m below ground surface for the top and first layers respectively. On the other hand, mean water table seems to be at (2.3) m depth and the mean dynamic elastic constants are ranged between {κ= ($0.194-7.352\times10^3$) Mpa, μ= ($0.145-2.994\times10^3$) Mpa, E= ($0.364-7.385\times10^3$) Mpa, λ= ($0.092-5.764\times10^3$) Mpa, and, σ= (0.19-0.35)}.

تقييم الموجات (P) و (S) لتحريات موقع هندسي لمجمع أقسام داخلية داخل
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تم مسح منطقة الدراسة بإستخدام تقنية الطريقة الزلزالية الانكسارية كأداة ملائمة للاغراض الهندسية. وقد أُختيرت ثمان مسارات زلزالية لكل من الموجات الطولية (P) والمستعرضة (S) ، حيث تم تنفيذ خمس ضربات على هذه المسارات (في المركز ، إعتيادي ، معـــــكوس ، بين اللاقطات 6 - 7 و 18 - 19) بهدف تقدير سماكات الطبقات وعمق المياه الجوفية المتواجدة في موقع بناء أقسام داخلية داخل جامعة البصرة ، جنوبي العراق .كما حسبت معاملات المرونة الحركية إعتمادا على سرع الموجات (P) و (S) وكثافات هذه الطبقات .

حددت ثلاث طبقات صخرية تحت سطح الأرض ، تراوح معدل سماكاتها بين (2.15 – 2.45) م ، (17.65 – 18.4) م تحت مستوى سطح الأرض لكل من الطبقة السطحية والطبقة الأولى على التوالي . ومن جهةٍ أُخرى ، يبدو بأنه معدل مستوى المياه الجوفية عند عمق (2.3) مترا وتراوحت قيـــــــــم ثوابت المرونة الحركية بين :

K = (0.194-7.352×103) Mpa, μ = (0.145-2.994×103) Mpa,
E = (0.3647.385×103) Mpa, λ = (0.092-5.764×103) Mpa, σ = (0.19-0.35).

INTRODUCTION

The application of seismic refraction method in geophysical prospecting for delineating layers thicknesses, depth of water table, and determining the dynamic elastic modulii such as (Bulk modulus-κ, Shear modulus-μ, Young's modulus-E, Poisson's ratio-σ, and lame's constant-λ) is entirely dependent on the difference between the elastic properties of the layers. These properties are the velocities of the compressional (P) and shear (S) waves, as well as the densities of these layers. If the velocities of both P and S-waves through any media be known, then the medium may be defined in terms of the usual elastic constants, (Griffin, 1995). Velocities and elastic constants for representative three layers of clay and sand soils which indicated on time-distance curves were obtained by the observations of the vertical and horizontal geophones at a suggested hostel complex site inside Basrah University, southern Iraq (Basrah subzone), in which it reaches (62500) m^2, (Fig.1). Lithologically, it composed of alluvial and flood plain deposits represent Dibdiba Formation (Quaternary deposits), (Buday, 1980).

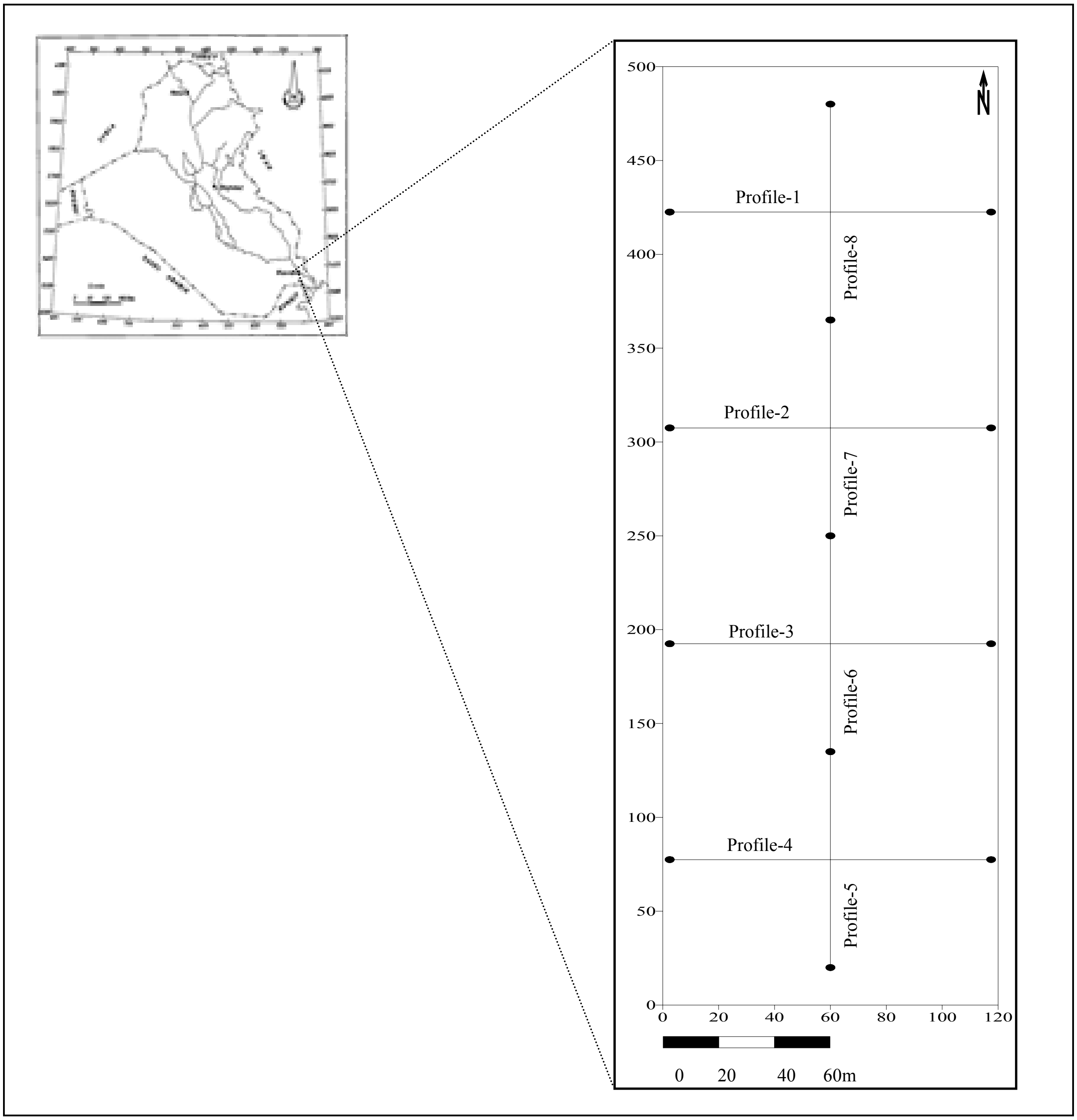
Al-din *et, al.,* (2004a, and b), carried out two projects dealing with seismic refraction and elastic modulii for engineering purposes, southern Iraq (Basrah). Also, (Michael's, 2001) used the similar aspects to investigate a site for a bridge foundations with the assistance of geotechnical boreholes.

This paper attempts to: (1) Delineate layers thicknesses, (2) Depth of water table; and (3) Determining the above mentioned elastic modulii (κ, μ, E, σ and λ). These tasks are performed to evaluate some of the geotechnical parameters of the investigated site.

Eight seismic refraction profiles were chosen as a suitable array to completely cover the area understudy for both P and S-waves. (24) Vertical and horizontal geophones for either P or S-waves were also deployed with (5) m spacing along (115) m for each profile. Each geophone was individually recorded using (ABEM Terraloc Mark-Π) equipment, and then in processing, arrays were formed to cancel traffic noise comes from the roadway.

Five impacts (center, normal, reverse, between the geophones 6-7 and 18-19) were applied by using (20) lbs hammer, in order to measure the first arrivals of the generating

P-waves. The same impacts were also done for generating S-waves by the use of special horizontally polarizing source.



(Fig.1) Location and base map of the considerable area

FIELD WORK

PROCESSING OF FIELD DATA

As is often the case, P and S-waves were masked by other larger amplitude data, included lower frequency surface waves, and roadway noise. Traffic noise was attenuated by band pass filters from (35-120) Hz (Khorshid, 1986 and 1994) and gain control of all channels. The time distance curves were interpreted by least square fitting, ABC, ABEM, plus-minus and T-minus mean methods (SjØgren, 1984). These methods showed no significant difference between the velocities of layers and thicknesses.

The first arrival times for each seismic trace were picked for (80) full seismic records of (24) channels (traces), 40 records for either P or S-waves measurements. The time-distance curves of the above records were plotted for all profiles as shown in the example below, (Fig.2). The velocity and the intercept time of each refractor were calculated, while the following equation was used to determine the thicknesses and depths of the seismic layers beneath each shot point, (Dobrin and Savit, 1988).

$$Z_0 = T_{i_1} \frac{V_1 V_0}{2\sqrt{V_1^2 - V_0^2}} \quad \text{..........} (1)$$

$$Z_1 = \frac{1}{2}\left[T_{i_2} - \frac{2Z_0\sqrt{V_2^2 - V_0^2}}{V_2 V_0}\right]\frac{V_2 V_1}{\sqrt{V_2^2 - V_1^2}} \quad \text{..........} (2)$$

Where:

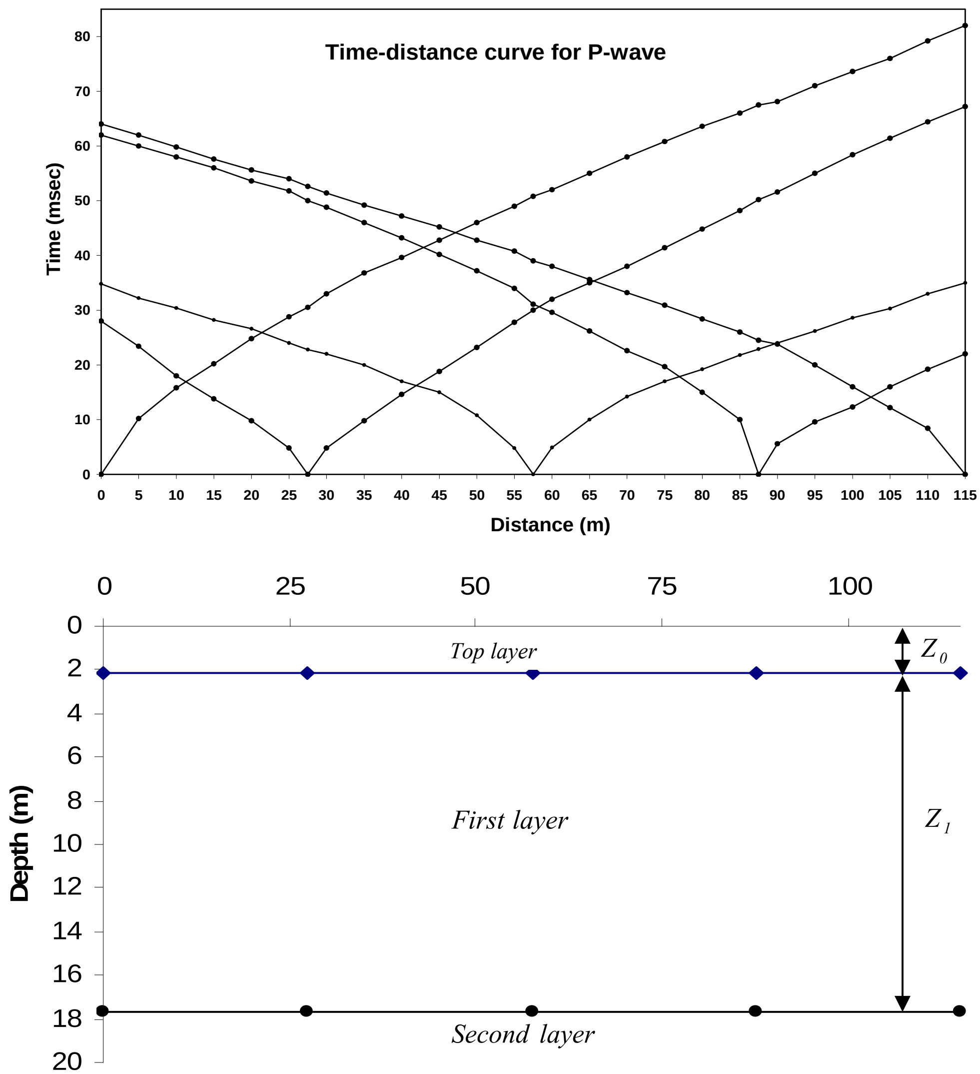
Z_0: Thickness of the top layer.

Z_1: Thickness of the first layer.

T_{i_1} : The intercept time of the top layer

T_{i_2} : The intercept time of the first layer.

Three different velocities (V_0, V_1, and V_2) had been obtained in this research depending upon the constructed time-distance curves as mentioned above. They represent three subsurface layers at the studied area. Table -1 reveal the results of the above calculations.



(Fig.2) An example for profile 1 represents time – distance curve for P-wave and depths calculated for the three subsurface layers

GEOTECHNICAL INVESTIGATIONS

According to the information derived from the geotechnical boreholes drilled in the adjacent area inside Basrah University (Mahmood, and Al-badran, 2002) (Table-2), and the seismic refraction results, three layers were found. Their thicknesses along all the studied profiles were ranged between (2.15-2.45) m below ground surface for the top layer, their mean is (2.33) m. Also, thicknesses of the first layer were ranged between (17.65-18.4) m and their mean is (18.02) m. Mean water table seems to be at (2.3) m according to the calculated P-wave velocities of these layers, (Fig.3).

(Table-1) Velocities of P and S waves and mean thicknesses of the three layers for the selected profiles

Profile No.	Layer	Shooting										Mean thickness (m)
		Normal		Center		Reverse		Between geophones				
								(6-7)		(18-19)		
		V_p (m/s)	V_s (m/s)	V_p (m/s)	V_s (m/s)	V_p (m/s)	V_s (m/s)	V_p (m/s)	V_s (m/s)	V_p (m/s)	V_s (m/s)	
1	Top	510	312	675	320	620	295	565	292	590	310	2.15
	First	1525	895	1442	872	1540	868	1503	855	1490	786	17.7
	Second	1951	1110	-	-	1875	993	-	-	-	-	-
2	Top	608	364	625	410	620	387	625	342	625	326	2.45
	First	1392	753	1376	814	1410	840	1355	725	1405	710	18.14
	Second	1915	1032	2158	1211	2096	1184	1992	-	2084	-	-
3	Top	410	344	511	282	454	253	465	-	525	-	2.23
	First	1476	785	1614	791	1515	889	1508	-	1483	-	18.2
	Second	2418	1151	2234	1098	2347	1115	2256	-	2451	-	-
4	Top	472	263	465	295	515	284	484	305	526	276	2.4
	First	1524	827	1497	792	1538	781	1480	765	1465	792	17.9
	Second	2265	1175	1942	1256	1986	1190	2013	1211	2154	1280	-
5	Top	505	258	463	288	511	301	492	266	478	292	2.45
	First	1472	788	1508	836	1502	795	1487	786	1521	798	17.8
	Second	2144	1226	1986	1161	2218	1197	2058	1218	1996	1176	-
6	Top	458	315	490	294	506	266	428	278	473	305	2.31
	First	1584	776	1520	798	1471	843	1497	811	1473	832	18.4
	Second	2360	1142	2408	1108	2246	1126	2271	1153	2287	1125	-
7	Top	625	408	628	395	625	367	612	325	625	361	2.35
	First	1366	741	1408	768	1375	815	1398	792	1450	722	18.3
	Second	1955	1190	2130	1125	2151	1172	2053	-	1982	-	-
8	Top	625	315	553	286	586	322	650	298	628	302	2.21
	First	1511	882	1468	858	1533	796	1487	881	526	832	17.65
	Second	1942	1096	2022	988	1855	1052	1870	1055	1915	1038	-

(Table-2) Geotechnical properties of the borehole drilled inside Basrah University (After Mahmood and Al-badran, 2002)

Depth (m)	Moister content (%)	Liquid limit (%)	Plasticity Index	Soil contents (%)			SPT	Description
				Clay	Silt	Sand		
0-1	30	47	20	49	42	9	-	Medium to stiff yellowish brown, silty clay with organic spots
1-2		42	17	51	46	3	7	
2-3		40	15	45	53	2	4	
3-4	29	35	11	40	59	1	2	Successive bands of soft to medium yellowish, grey and green highly silty clay and sands
4-5		35	14	42	56	2	2	
5-6		35	13	44	55	1	3	
6-7		36	13	45	54	1	4	
7-8		38	15	43	55	2	3	
8-9		41	16	42	56	2	2	
9-10		41	16	47	51	2	2	
10-11		39	15	52	46	2	3	
11-12		38	15	46	53	1	3	
12-13		36	15	42	57	1	3	
13-14		36	14	40	59	1	3	
14-15		37	15	56	43	1	5	
15-16		37	15	59	37	4	5	
16-17		37	15	47		53	5	
17-18		36	14	41		59	8	
18-19		35	14	63		37	10	
19-20	29	32	13	83		17	30	Medium to dense grayish brown silty sand

DYNAMIC ELASTIC CONSTANTS

Seismic waves have always been an available as part of any civil engineering site investigation; the velocity data derived when used in any diagnostic manner nearly always refer to the P-waves propagation. For a complete assessment of the dynamic elastic constants, there is a need to measure shear wave phenomena. The relevant interrelationships between P-wave, S-wave and various elastic modulii are: (Davis and Schultheiss, 1980), (Al-sinawi *et. al,* 1990).

$$Dynamic\ Bulk\ Modulus\ (\kappa) = \frac{\ell}{g} V_S^2 \left[\left(\frac{V_p}{V_S} \right)^2 - \frac{4}{3} \right] \ldots\ldots(3)$$

$$Dynamic\ Shear\ Modulus\ (\mu) = V_S^2 \frac{\ell}{g} \ldots\ldots(4)$$

$$Dynamic\ Young\ Modulus\ (E) = \frac{V_S^2\ \ell}{g} \left[\frac{3 (V_p / V_s)^2 - 4}{(V_p / V_s)^2 - 1} \right] \ldots\ldots(5)$$

$$Poisson\ \mathrm{Ratio}\ (\sigma) = \frac{(V_P / V_S)^2 - 2}{2 (V_P / V_S)^2 - 2} \ldots\ldots(6)$$

$$Lame\ Constant\ (\lambda) = \frac{\ell}{g} V_S^2 \left[(V_p / V_s)^2 - \frac{4}{3} \right] - \frac{2 V_S^2\ \ell}{3\ g} \ldots\ldots(7)$$

Where:

V_P, V_S: The velocities of P and S-waves.

ℓ: Unit weight.

g : Acceleration of gravity.

Dynamic elastic constants of the three subsurface soil layers (seismic layers) were calculated from the velocities of P and S-waves, and the densities measured from the drilling boreholes at different depths. The results are tabulated in (Tables -3).

INTERPRETATION OF GEOTECHNICAL RESULTS

1. As checked by the results of the borehole records mentioned in table-2, the ranges of mean velocity of the top layer of this survey (471-623) m/s indicate a uniformity unconsolidated alluvial surface sediments (silty clay). The first layer has mean velocity ranged between (1380-1519) m/s of this geophysical run indicating poorly consolidated silty clay to sandy clay. This change may be due to the seepage. The second layer indicates weakly consolidated fine grained soil (silty sand to sand). This is because of its own mean velocity values ranged from (1913-2349) m/s.
2. Due to the almost similarity and homogeneity of these soil layers, they show almost similar geotechnical properties such as moisture content (29 %), liquid limits (38 %) and plasticity index (15 %). So that, the seismic velocities show insignificant differences due to the variations in densities.

3. In fact, the surface ground elevation in this area is (2) meter above sea level. So, the mean thicknesses of the top and first layers were found to be (2.33 and 18.02) m, respectively, which almost coincide with the drilled borehole (Fig.3).

(Table-3) Mean V_p, V_s, density, and dynamic elastic constants of the three subsurface layers along the considerable profiles

Profile No.	Layer	Mean							
		V_p (m/s)	V_s (m/s)	Density (Kg/m3)	σ	μ×10 ³ (MPa)*	E×10 ³ (MPa)	λ×10 ³ (MPa)	κ×10 ³ (MPa)
1	Top	592	306	1752	0.32	0.164	0.433	0.285	0.395
	First	1500	855	1845	0.26	1.348	3.397	1.453	2.352
	Second	1913	1052	1938	0.28	2.145	5.504	2.802	4.232
2	Top	621	366	1861	0.23	0.249	0.615	0.219	0.385
	First	1388	768	1920	0.28	1.132	2.897	1.434	2.189
	Second	2049	1142	1972	0.27	2.572	6.536	3.135	4.250
3	Top	473	293	1782	0.19	0.153	0.364	0.092	0.194
	First	1519	822	1857	0.29	1.255	3.244	1.755	2.611
	Second	2341	1121	1943	0.35	2.442	6.593	5.764	7.352
4	Top	492	285	1846	0.25	0.150	0.375	0.147	0.246
	First	1501	791	1921	0.31	1.202	3.143	1.924	2.725
	Second	2072	1222	2005	0.23	2.994	7.385	2.619	4.615
5	Top	490	281	1841	0.25	0.145	0.364	0.151	0.248
	First	1498	789	1915	0.31	1.192	3.118	1.913	2.707
	Second	2080	1208	1998	0.25	2.916	7.232	2.812	4.756
6	Top	471	292	1791	0.19	0.153	0.364	0.092	0.194
	First	1509	812	1849	0.30	1.219	3.169	1.772	2.585
	Second	2314	1131	1962	0.34	2.509	6.724	5.486	7.159
7	Top	623	371	1858	0.23	0.256	0.629	0.209	0.380
	First	1400	768	1916	0.28	1.130	2.893	1.495	2.248
	Second	2054	1162	1975	0.25	2.667	6.721	2.998	4.776
8	Top	608	305	1781	0.33	0.166	0.441	0.327	0.437
	First	1505	850	1862	0.27	1.345	3.405	1.526	2.423
	Second	1921	1048	1944	0.29	2.135	5.508	2.903	4.327

* *MPa=Mega Pascal*

4. The calculated water table was (2.3) m below ground surface in (23/2/2005) using the seismic refraction technique. Because the water table alternates seasonally, it was measured again after two months in (23/4/2005) from the borehole and it was found to be (2.4) m.
5. The results of SPT test (number of blows) are very low (2-4), which are indicative of fine soil as silty clay.
6. The range of the dynamic Young's modulus in the top, first and second layers ($0.364-7.385\times10^3$) Mpa is greater than the $\text{Elasticity}_{state}$. This difference may occur due to the water presented within the pores of the soil and homogeneity or uniformity of these fine soils. Poisson's ratio lies in the same range as for many materials (0.15-0.35) and the average is (0.25), which almost coincides with (0.19-0.35) values obtained by this research. Dynamic modulus of expansion (bulk modulus) is indicative of naturally unconsolidated fine soil ($0.194-7.352\times10^3$) Mpa. Although the dynamic shear modulus is low ($0.145-2.994\times10^3$) Mpa. But it represents a shear modulus mostly fine grained which is greater than the state ones.

CONCLUSIONS

1. Due to the homogeneity of the subsurface layers, there is no significant difference appeared in seismic wave velocities.
2. Three subsurface soil layers were detected from P-wave in the investigated area, their thicknesses ranged between (2.15-2.45) m, (17.65-18.4) m below ground surface for the top and first layers respectively.
3. The P-wave gives the mean water table at (2.3) m below ground surface.
4. The values of mean dynamic elastic constants are ranging between {κ= ($0.194-7.352\times10^3$) Mpa, μ= ($0.145-2.994\times10^3$) Mpa, E= ($0.364-7.385\times10^3$) Mpa,
   λ= ($0.092-5.764\times10^3$) Mpa, and, σ= (0.19-0.35)}.
5. There are very good matching between the depths that are determined by seismic refraction technique and the drilled borehole which clearly shows the contacts between the three layers.
6. It is appeared that there is a proportional relationship between the dynamic elastic constants κ, λ, E and μ.

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