Geotechnical Assessment of Dar Al Salam Complex in Hilla City, Babylon Using the Seismic Refraction

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Abstract

In this study, the horizontal seismic refraction survey method was used to calculate the elasticity coefficients of the soil of the Dar Al-Salaam complex site in the city of Hilla, Babil Governorate. A seismic survey was conducted along four lines to find the shear and longitudinal velocities. Two lines of length (115) meters in the direction north-south and others in the direction east-west, with a front, medium and reverse shock in each direction. The data were processed and interpreted by using the Reflex 2D Quick software. The results for the first layer were for the longitudinal velocity (Vp) (189-259 m/sec and for the second layer (342-411) m/sec and the thickness of the layer was (3.7) m. While the shear velocity of the first layer (VS) was (119-109) and the second layer (197-233.5) m/sec. The dynamic elasticity coefficients were calculated from these velocities, such as Poisson's ratio(δ) and Young's modulus (E), Bulk modulus (K), shear modulus (μ), The amount of the Poisson's ratio for the first layer ranged between (0.32-0.44) and its average in the first layer is 0.37 while the Poisson's ratio in the second layer ranged between (0.35-0.276) and its average in the second layer is 0.305, while the highest value of the Shear Modulus(u) was recorded in the second layer at 103.7 MPa and the average of Young's Modulus of the first layer was recorded at 25.5 MPa, which indicated the second layer was characterized by its high hardness, strength, while the highest value of the Bulk modulus (K) was recorded in the second layer at 288.7 MPa and the average of Bulk modulus (K) of the first layer was recorded at 74.8 MPa ,while the highest value of the Young's Modulus was recorded in the second layer at 209 MPa and the average of Young's Modulus of the first layer was recorded at 57 MPa, which showed the improvement of engineering soil properties in the second layer in all stations of the study area.

Keywords: Dar Al Salam Complex; Waves; Geotechnical assessment; Reflex 2D

1. Introduction

The seismic-refraction method is considered one of the most applied geophysical techniques in exploratory work because of its high accuracy and great penetrability. The availability of high-accuracy and suitable analytical methods in order to improve seismic data that aim to determine properties of elastic modulus (Washima et al., 2020). The basic principles in the seismic refractive survey process are the use of initial arrival times captured from recorded refracted seismic and drawing the time-distance curves of the surveyed point, where each time of the initial arrival times is attributed to a specific fracture surface. Depths, velocities and extensions of the fracture layers, can be estimated through the slope of

the velocity line of that surface in the time-distance curve. One of the most important problems facing the interpreter is the process and interpretation of the refracted data and determining the extension of the fractured surface on the (time - distance) curve, so perhaps the reverse order of the interpreted publication may help, but it is not a solution to this difficulty, hence the importance of the geological knowledge of the survey area when performing the interpretation (Al-Jeraisy, 1992). The most appropriate methods are chosen in the process of interpretation of seismic data, depending on the nature of the subsurface and the type of data obtained (Dobrin, 1976). It also has the ability to explain the vertical and horizontal changes that contribute to the interpretation of some engineering properties of the soil, in addition to the fact that the process of drilling wells is expensive or sometimes it is not possible to dig it in some places (Ehlers, 2008) for (Al-Hiti, 2014).

The aim of this study is to determinate the thicknesses and velocities of the subsurface layers and to understand the characteristics feature of these layers., for example Poisson's ratio (δ), Young's modulus (E), Bulk modulus (K), and shear modulus (μ). The geotechnical properties of the soil and its ability to bear the engineering structure on it forms the engineering point of view, it includes studying the physical and mechanical properties of the soil through special tests for that, and calculating some elasticity factors, including calculating the bearing capacity of the soil using the seismic refraction survey as a geophysical method by measuring the velocity of the two waves (P and S), from which the number of layers and the depth of each layer can be determined

## 2. Tectonic and Geological Setting of the Study Area

The study area is located within the stable shelf and it forms part of the sedimentary plain of Mesopotamia belonging to the Euphrates secondary zone according to the longitudinal tectonic divisions of Iraq (Buday and Jassim, 1987). The study area is characterized by the presence of shallow base rocks, whose depth ranges between 8-9 km. (Jassim and Goff, 2006). The study area more stable during the Paleozoic Era, but then became more mobile during the Mesozoic Era and the Triassic (Fig. 1). The thickness of the sedimentary cover of the Mesozoic Era and the Tertiary Era in this region is within the limits of 3.5-4 km in the direction of the west and more than 5.5-6 km in the east, while the thickness of the sediments of the Paleozoic era is very little, most of the sediments of this era are missing, especially the pre-Cambrian sediments (Buday and Jassim, 1987).

For the geological setting we notice that the Tertiary Age deposits are revealed in large parts of the station represented by the flood plain deposits, which usually consist of a succession of well-permeable silt and clay layers of varying thickness and change suddenly in the vertical and lateral directions and within very short ranges (Parsons,1957) as well as deposits Streams and Depression fill deposits These sediments collect as a result of floods and generally consist of thin layers of fine sand, silt, clay and silt.

3. Materials and Methods

In this study, the seismic refraction equipment consists of source, detector and recorder. The source of seismic survey is 7 kg of sledge hammer that strike on an impact plate. For detectors, use a 24 unit of 10 Hz vertical geophone to detect high frequency wave from the sledgehammer seismic source for shallow depth investigation. While ABEM Terraloc MK-6.2 seismograph was used for the recorder for seismic raw data. For data acquisition, there are two reels of geophone cable and each reel consists of 12 geophones connector point. During setup the geophone cable, the cable was in linear or straight line to have optimum result during recording. The geophone spacing for this study is 5 meter and the geophones should be placed on clear area and approximately level with the ground. Offset distance for peat soil and clay soil are depend on the critical distance that viewed from the seismograph. The seismograph, it placed at the center of geophone array line. (Fig. 2) the seismic refraction equipment
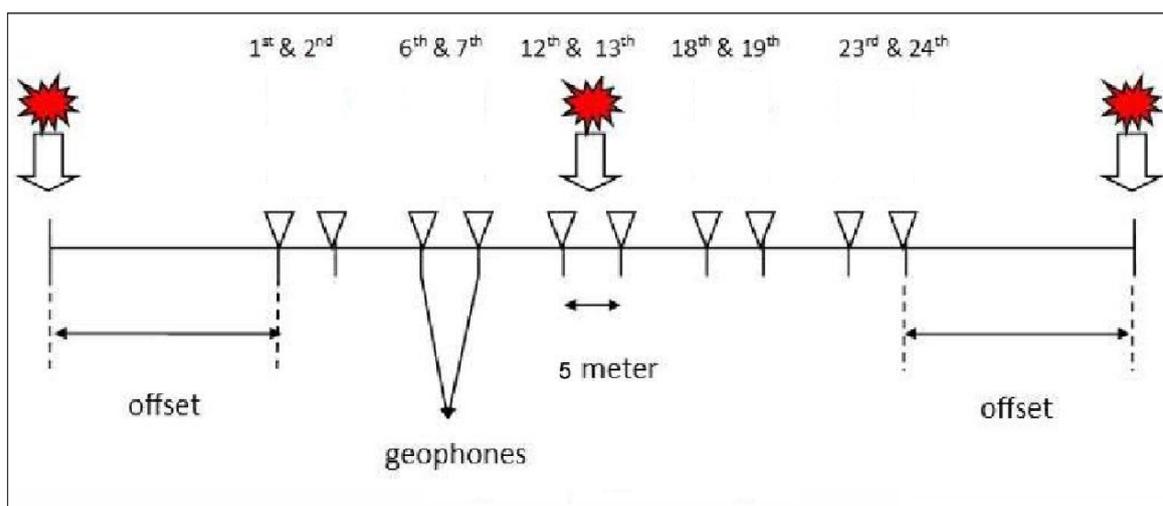
shows arrangement geophone array lines. There are three shot point with a front, medium and reverse shock in each direction as shown in Fig.3.
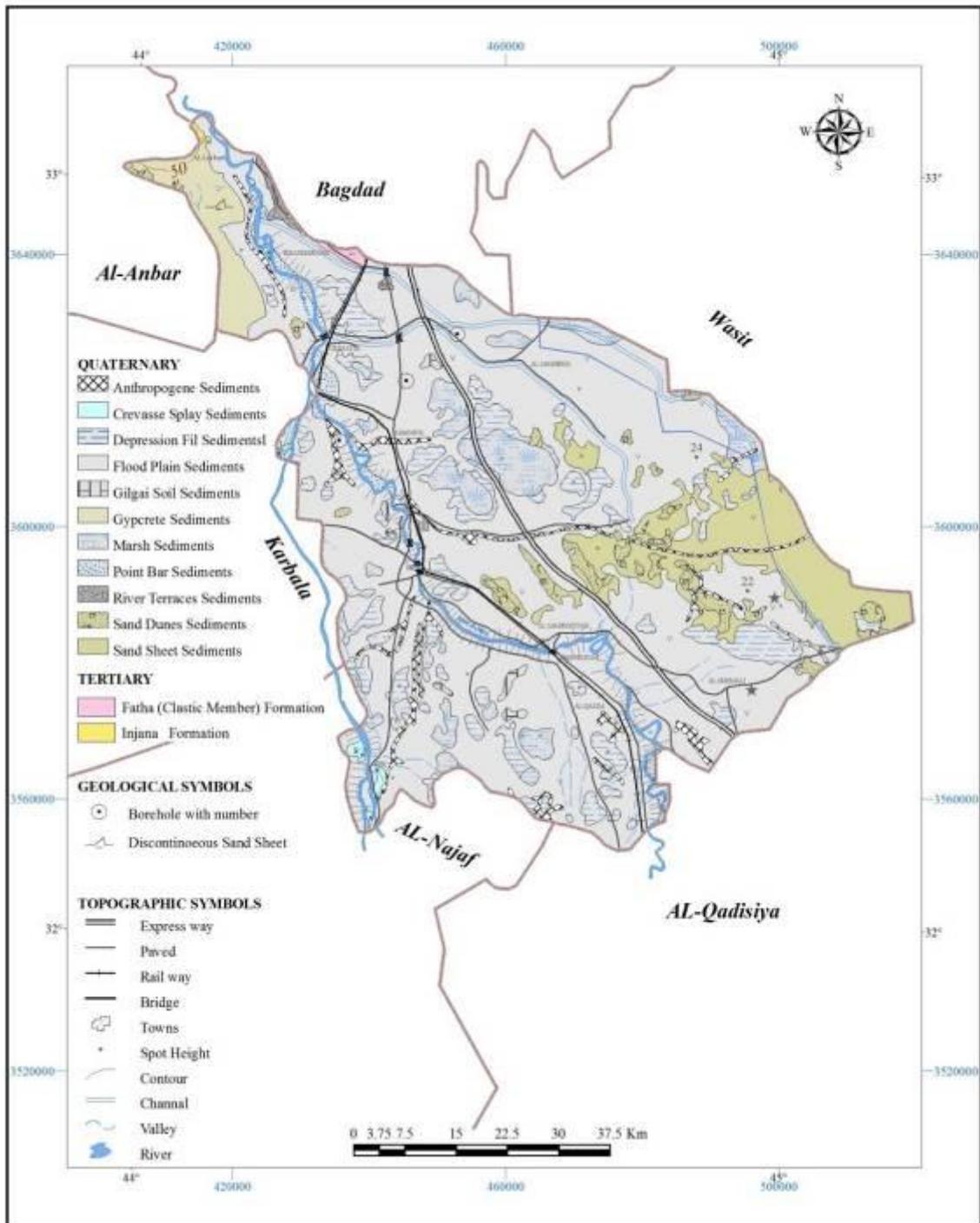
Fig.1. Geological map of the study area (Al-Nafa'ay, 2021)
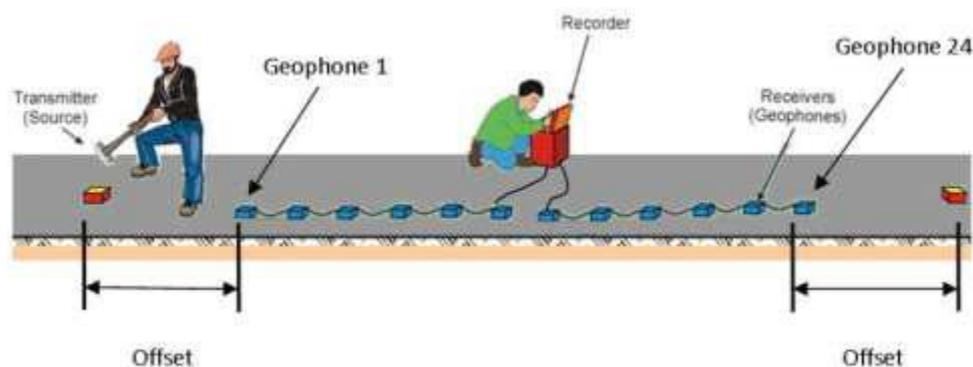
Fig.2. Seismic refraction equipment arrangement with geophone array lines

Fig. 3. Shot point locations

The quality of raw seismic data was increased by stacking the data during data acquisition using a seismograph. This allows improving the signal to noise ratio (S/N) that's very important in seismic refraction method to observe the wave first arrival in the seismograph. Typically, five times of stacking data are sufficient for seismic refraction on hard soil, but it's a different case for soft soil. For peat soils, it was required 15 successful blows of sledgehammer, while for soft clay, it was required 10 successful blows for each shot point's location. The amount of data stacking may increase because it depends on the seismic wave first arrival observed in the seismograph (Mohd et al., 2015)

4. Results and Discussion

4.1. Interpretation of the Seismic Refraction Survey

Interpretation of time-distance curves plotted for all seismic tracks using the time-plus-minus method for subsurface layers and their thicknesses Time–distance curves for longitudinal as well as transverse seismic waves of perpendicular seismic lines were plotted in the study area based on the first arrivals times and locations of surface pickups for seismic paths by normal shooting, central shooting and reverse shooting using seismic interpretation software (REFLEXW,2DQuick version 3.5). Where the processing of the seismic waves obtained is carried out, including the selection of appropriate filters for the purpose of eliminating or reducing noise as much as possible as well as the work of the Trace coordinate to ensure the correctness of the distance set between the geophones, and after the completion of the processing process, the data becomes ready for interpretation where the initial arrival time of the

waves is determined, and the velocities of the longitudinal and transverse waves are calculated for each sub-surface layer in the study site by measuring the slope of the straight lines in the curves time distance, Figs.4 & 5, depending on the times of the first arrivals and in addition to the locations of the antennas on the surface of the earth described in the refraction seismic sections performed by normal shooting, central shooting.
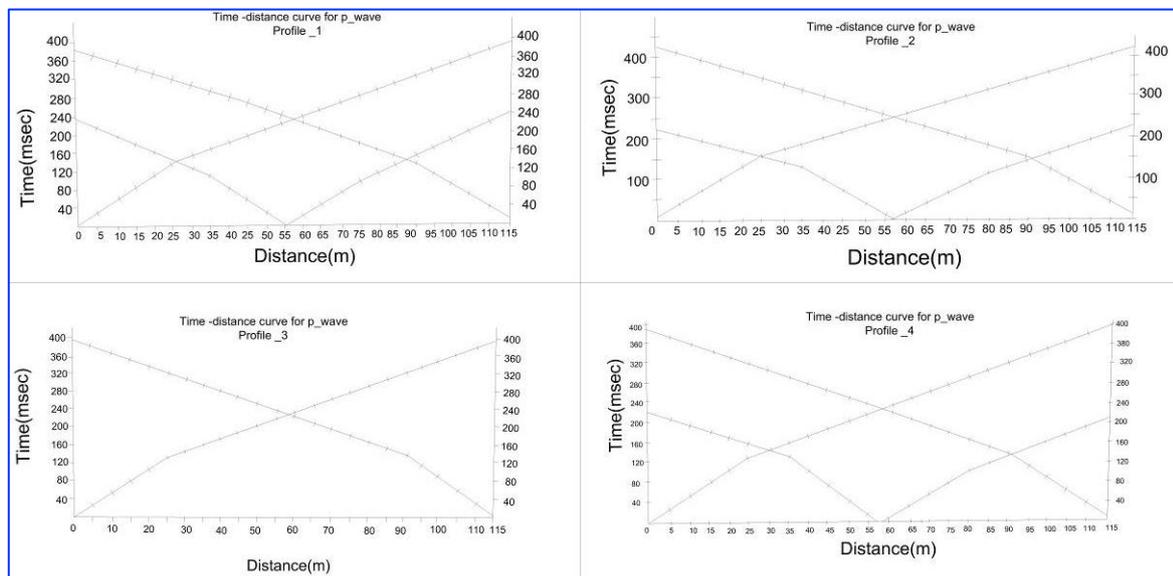

Fig. 4. Represents the time-distance curves of the longitudinal waves of the study site stations.
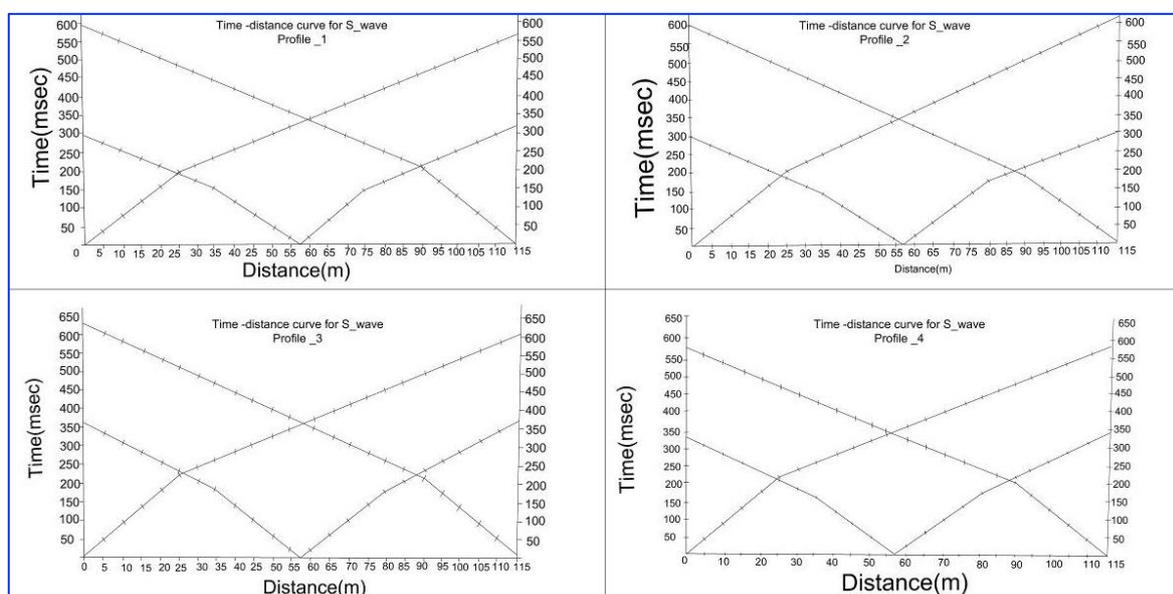

Fig. 5. The time-distance curves of the wave's transverse to the stations of the study site

4.2. Calculation of the Elastic Modulus

The elasticity coefficients were calculated for the study site, which were calculated depending on the velocities of the longitudinal and transverse seismic waves and the ratio between them (Vp/Vs), as well as the density values measured in the laboratory and for different depths of the rock models taken from the wells drilled in the study area, through the application of mathematical equations, as shown in Table1. The velocities of longitudinal and transverse seismic waves and elasticity coefficients are calculation for all paths of the study area shown in Table 2.

Table 1. Mathematical relationships used in calculating elasticity coefficients

Elastic coefficient	Formulas	References
Poisson's ratio (δ)	$\delta = 1\backslash 2 \left[1 - \dfrac{1}{(Vp\backslash Vs)^2} \right]$	(Adams,1951; Salem, 1990)
Young's Modulus	$E = P \left[\dfrac{3VP^2 - 4Vs^2}{(Vp\backslash Vs)^2} \right]$	(Adams ,1951)
Lame's Constants (λ)	$\lambda = \dfrac{\delta E}{(1 + \delta)(1 - 2\delta)}$	(King, 1966; Toksoz et al.,1976)
Shear Modulus (μ)	$M = \dfrac{E}{2(1 + \delta)}$	(King,1966; Toksoz et al.,1976)
Bulk modulus (K)	$K = \dfrac{E}{3(1 - 2\delta)}$	(Knödel et al., 2007)

Table 2. Table of results for elasticity values in the study area

Profile	Layer	Vp (m/s)	Vs (m/s)	Vp/vs	Density (kg/m)	E MPa	U MPa	K MPa	(δ)
1	First	197	114	1.72	1645	59.12516	23.13	63.8	0.338266
	Second	342	217	1.57	1710	209.0121	88.05	192.288	0.2763048
2	First	189	119	1.58	1645	61	25.206	58.727	0.321591
	Second	335.5	197	1.7	1710	199.2365	72.575	192.1521	0.286413
3	First	259	109	2.37	1645	51.28292	21.148	110.32	0.42232
	Second	411	194	2.11	1710	176.5891	70.37932	288.7163	0.356663
4	First	202	117.5	1.71	1645	59.26802	25.57513	67.08848	0.44307
	Second	372	233.5	1.59	1710	249.509	103.710	288.1158	0.2965595

5. Conclusions

Velocity values have been obtained after the process of the raw seismic data for two layers; the average velocity of the longitudinal wave was recorded in the first layer is (208) m/s and the average velocity of the transverse wave for the same layer was about (114.85) m/s. While the average velocity of the longitudinal wave of the second layer was (371) m/s, and the average velocity of the transverse wave of the second layer was (210) m/s, the velocity value of the second layer has increased slightly, which shows it has a stiff layer compared with the top layer. The amount of the Poisson's ratio for the first layer ranged between (0.32-0.44), and its average in the first layer is 0.37, while the Poisson's ratio in the second layer ranged between (0.35-0.276) and its average in the second layer is 0.305. The value of the first layer is somewhat high as it is hard Medium is less than the hardness of the second layer due to the weakness of the first layer as a result of its direct exposure to various erosion factors, while the highest value of the Shear Modulus(u) was recorded in the second layer at 103.7 MPa and the average of Young's Modulus of the first layer was recorded at 25.5 MPa, which indicated the second layer was characterized by its high hardness, strength, while the highest value of the Bulk modulus (K) was recorded in the second layer at 288.7 MPa and the average of Bulk modulus (K) of the first layer was recorded at 74.8 MPa which indicated the second layer was characterized by its high hardness ,while the highest value of the Young's Modulus was recorded in the second layer at 209 MPa and the average of Young's Modulus of the first layer was recorded at 57 MPa, which indicated the second layer was characterized by its high hardness, strength and cohesion as a result of high the values of Young's Modulus, volumetric modulus, and hardness modulus, in general, these coefficients indicate an improvement in the engineering properties, especially in the second layer in all stations of the study area, that is, the Yonk modulus increases with the increase in the velocity of seismic waves and the hardness of the rocks.

Acknowledgements

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