Determine Shear wave velocities and Elasto-Dynamic properties for Nassiriya Refinery project in Thi qar Governorate- Nassiriya District- South of Iraq

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Abstract
Four seismic refraction profiles for both compressional (P) and shear (S) waves had been surveyed within Nassiriya District/Thi Qar Governorate, South of Iraq, by the use of two impacts; normal and reverse shootings. This technique was done in order to delineate depths and thicknesses of the layers (soils) also elastic modulus were calculated for Knowledge a nature of the area soil to build engineering facilities. The calculations demonstrate that there are three shallow subsurface layers were found. The average of velocities and thicknesses of the first layer are equal to 645.95, 271.6 m/sec and 4.75 m, and for the second one 1130.55, 506 m/sec and 4.5m. and for the third one are 1666.6, 714 m/sec and 12.for each P and S-waves respectively. Moreover, Site engineering information including geotechnical properties were also measured and analyzed to enhance the main targets of this study, where the mean dynamic elastic constants were ranged between \( \kappa = (597.92-4376.06) \text{ Mpa} \), \( \mu = (138.31-1063.43) \text{ Mpa} \), \( E = (385.23-2951.24) \text{ Mpa} \) and, \( \sigma = (0.39-0.38) \).

Keywords: Seismic refraction survey, Shear velocity, Elastic moduli and Nassiriya Refinery.

1. Introduction
Today, the seismic refraction method is developing more and more, and it is one of the important geophysical methods, which played an important role in solving the geotechnical problems of civil engineering (soil studies and foundations studies). In addition, the refraction seismic method yields data with very high accuracy for shallow layers, especially if done correctly and by a specialized geophysicist. Often, the validity of the refraction seismic data is confirmed by comparing them with the results of geotechnical investigations of the soil, which are assumed to be nearly identical, such as the velocity of the seismic shear wave and the shear modulus of the geotechnical tests. It compared to the geotechnical tests, has a lower cost and less time to complete the work (a quarter of the time compared to the time required for the geotechnical tests) (Tezcan et al., 2009, Stephenson et al 2002, Dutta 1984, Steeples and Miller 1990). Therefore, researchers can obtain type and depth of each layer, young modulus and Poisson’s ratio, water table and the ultimate bearing capacity of the underlying layers dependent on the penetrating depth of both Primary and Share wave velocities. Usually, it is preferable to perform refraction surveying in addition to borehole surveying such as cross hole, down hole and up hole in order to detect a high-speed layer or hidden layer, a weak bed and / or cavities may exist under the examined soil.

The principles of refraction seismic method depend on generation seismic waves at shot points on the surface. The wave path that reaches a subsurface boundary is refracted at critical point and reaches the surface where it could be recorded.

The propagation of seismic waves is controlled by the parameters of rock elasticity and density. By measurements of the time intervals between the generation of pulse and its reception at geophones at
various distances give the velocity of propagation of the pulse in the ground, i.e. the P-wave and S-wave velocities can be measured for the subsurface soil layers. The thickness and any lateral changes within these layers can be identified too. By knowing the density (from the boreholes tests data) then the elasto–dynamic modulus and constants for the subsurface soil layers can be determined.

2. Location of the study area
The site of the study area (Nassiriya refinery project) is located at Nassiriya District-Thiqar Province, (Fig 1). The distance between it and the capital of Iraq (Baghdad) in the south is 370 Km. Longitude and latitude of the study area are (30°59'33.31'' N 46°13'38.17''E) (30°59'20.81'' N 46°12'59.02''E) (30°59'44.11'' N 46°12'48.20''E) (30°59'54.28'' N 46°13'22.77''E).

Fig (1): A geographical map showing the study area.

Geological setting of the study area
It is located in the southern part of the lower Mesopotamian basin, and it rises by (4-9) meters from Sea level (Buday and Jassim 1987). The quaternary period sediments cover the surface of the city and
are part of the sediments of the alluvial plain which are represented by Fluvial deposits, Flood plain deposits, Aeolian deposits, marshes deposits and Tidal flat deposits. (Jassam and Goff, 2006)

Aims of the study
1. Determine the primary and shear wave velocities for the surveyed layers within the study area, and from which the elastic modulus are calculated for each layer.
2. Knowledge of the physical properties of the soil layers of Refinery based on shear wave velocities and elastic moduli.

3. Instruments and Field work
The device used for this study is (ABEM Terraloc Pro), which was manufactured in 2011. It belongs to Al-Mawal Company. Furthermore, Seismograph has the multi-channel digital is useful for cost-effective refraction and high-resolution reflection surveys, vibration measurements, tomography. it used anywhere from our country or in the world and in all weather conditions. (ABEM Instrument AB: instruction manual, 2011). So, primary and secondary seismic waves can be generate using a sledge hammer with a weight of 10 kg or up weight depending on the target depth by lifting it to top and then falling to iron plate (Reynolds, 1997, Sjogren 2000 and Telford, 1976).

The seismic refraction survey was carried out at Nassiriya Refinery project site using the 12 channels seismic refraction system (ABEM Terraloc MK6 System, ABEM AB, Sweden) (Fig. 2).

Fig (2): Shows the seismic refraction instrument (Terraloc MK6) and the working team at Nassiriya site.

The field seismic work was conducted along one profile of 65 meters length (Fig. 2), where the daily temperature may reach 16°C. The site is covered by a thin layer of the soil. This top of layer could cause some problems for the seismic refraction energy generation that usually comes from Hammer impacts. We have drilled few centimeters to make the hammer impact on cohesive soil. In the field survey we usually apply two techniques; one is for P-wave velocity measurements, while the other is for the shear wave velocity. Four successive shot points are applied per each profile, which results in two seismic records for P-wave and two seismic records for S-wave. The records are obtained using an array of 12 geophones. For S-wave measurements, however, S-wave geophones are used. The impacts
for P-wave measurements are generated by using 10.0 kilos hammer hits. While for S-wave measurements the impacts are generated by applying special horizontal hits of 10.0 kilos hammer in small pits (fig.3). For S-wave measurements the energy source was the hammer impacts on the side wall of a bit.

Fig (3): Shows the top soil nature at refinery site.

Fig (4): Shows the hammer impacts for the generation of S-wave

4. Seismic refraction survey
Two traces (1, 2) (Fig 5) of seismic refraction were carried out inside the study area. The configuration of geophone, for Primary wave 12 vertical geophones and for Shear wave 12 horizontal geophones, in addition, offset between the first geophone and the source is 5 meters and the total distance 65m for both profiles. (1 and 2). To ensure the interface between the layers, is it inclined or horizontal? two methods (normal, reverse) were performed to measure the first arrival of the generated primary and secondary wave velocity. Also, the same impacts wave due polarizing source.

Fig (5): Base map showing the distribution of the seismic profiles in the study area.

5. Results and Interpretation

The picking of the first arrival times was done for the 4 seismic records (2 records for P-wave measurements and 2 records for S-wave measurements). The velocity and intercept time of each refractor was calculated. The thicknesses of the seismic layers were calculated beneath each shot point using the general thickness layer equation:

\[ Z_{n-1} = \frac{V_n V_{n-1}}{2(V_n^2 - V_{n-1}^2)^{1/2}} \left[ \frac{1 - Z_0 (V_n^2 - V_{n-1}^2)^{1/2}}{V_n V_{n-1}} - \frac{2Z_0 (V_n^2 - V_{n-1}^2)^{1/2}}{V_n V_{n-1}} \right] \]

It seems that the top seismic layer has P-wave velocities that are ranging from 625.3 m/sec to 666.6 m/sec and S-wave velocities that are ranging from 270.0 m/sec to 273.3 m/sec (Table 1). Its thickness is ranging from 4.5 m. to 4.9 m. The second seismic layer reflects more compact and sound stiff layer. It has a thickness range from 4.6 meters to 4.2 meters. It shows P-wave velocities that are ranging from 1111.1 m/sec to 1150.0 m/sec. While, for S-wave velocities the values are ranging from 500.0 to 512 m/sec. The third layer is a stiff soil layer with P-wave velocity of 1666.6 m/sec. The S-wave velocity of this layer is 715.0 m/sec. This layer starts at a depth around 9.5 meters and down to 22.0 meters.

Elasto-Dynamic Properties

The elasto-dynamic modeled and constants of the three subsurface soil layers (seismic layers) were calculated using the recorded P-wave and S-wave velocities and the densities (obtained from the core samples of boreholes data). The related familiar equations (listed below) were used. The results are tabulated in the table No.2. The average elasto dynamic parameters with the seismic layers thickness are shown in Table 2 too.

Dynamic young modulus (E) = \(2V_p^2 \frac{\nu + \nu}{(1 + \nu)(1 - 2\nu)} \)
Dynamic shear modulus (\(\mu\)) = \(\frac{\nu V_p^2}{2(1 - \nu)} \)
Poisson ratio \( (\nu) = \frac{(V_p/V_s)^2 - 2}{2(V_p/V_s)^2 - 2} \) \ldots \ldots 1-3

Dynamic bulk modulus \( (k) = \rho \frac{V_p^2}{3(1-\nu)} \mu \) \ldots \ldots 1-4

Where: \( \rho \): Density and it is measured by gm/cm\(^3\) and \( g \): The acceleration of gravity.

Table (1): Shows the P-wave and S-wave velocities for the seismic profiles at Nassiriya

| Profile No. | Soil Layer | Primary wave velocity (m/sec) | Shear wave velocity (m/sec) |
|-------------|------------|------------------------------|-----------------------------|
| 1           | First      | 625.3                        | 270.4                       |
|             | Second     | 1111.1                       | 512.0                       |
|             | Third      | 1666.6                       | 713.0                       |
| 2           | First      | 666.6                        | 273.3                       |
|             | Second     | 1150.0                       | 500.0                       |
|             | Third      | 1666.6                       | 715.0                       |

Table (2): Average seismic refraction velocities and the average elasto-dynamic parameters for the three layers

| Soil Layer | Thickness (m) | Density (KN/m3) | Primary wave velocity (m/sec) | Shear wave velocity (m/sec) | Poisson Ratio | Young Modulus E (MPas) | Bulk Modulus K (MPas) | Shear Modulus G (MPas) |
|------------|---------------|-----------------|------------------------------|----------------------------|---------------|----------------------|----------------------|------------------------|
| First      | 4.75          | 18.75           | 645.95                       | 271.6                     | 0.39          | 385.23               | 597.92               | 138.31                 |
| Second     | 4.5           | 20.38           | 1130.55                      | 506.0                     | 0.37          | 1434.69              | 1909.12              | 521.80                 |
| Third      | 12.0          | 20.86           | 1666.6                       | 714.0                     | 0.38          | 2951.24              | 4376.06              | 1063.43                |

6. Seismic Refraction data
In this stage, the data obtained from the field work were plotted and interpreted by seisTW software as a time-distance curve for the seismic profiles in the study area. Several applications such as Mean-mines-T, T-plus-minus 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 seismic velocity waves was taken as an average for all seismic profiles as shown in (Table 1).

From table (1&2), the average velocities and thicknesses for Primary waves in the first layer ranging between (625.3-666.6) m/sec and (4.5-4.9) m, respectively in two profiles. While the results of shear waves are (270.4-273.3) m/sec for layer velocity.

Also, two profiles of the second layer are characterized by its highly velocity and thickness values (Vp = 2Vs). The results are ranging between (1111.1-1150) m/sec and (500-512) m/s for Primary and Shear waves respectively.

So, the average velocities and thicknesses for Primary waves in the third layer is (1666.6) m/sec and (12) m, respectively in two profiles. While the results of shear waves, the results are (713-715) m/sec for layer velocity.

Fig (6): showing seismic refraction velocities with depth for two subsurface layers.

The first layer has depth average is (4.75) m to seismic refraction survey for two profiles in the study area (Fig 6). in addition, the form of (seismic refraction velocities with depth) drawing by using Excel program.

7. Relationship between velocity and elastic moduli with depth

The relationship between velocity wave and elastic moduli with depth for seismic survey as shown in (Fig 7) below. Any change in velocity wave with depth means there is a change in type of layer or elastic properties. From below curves, observed it can be seen that the soil has gradually increasing in all elastic moduli and wave velocities with depth.
Fig (5): Represents the relationship between elastic moduli, geotechnical properties, and velocity with depth for cross-hole survey.

Fig (7): Represents the relationship between seismic wave velocity and elastic moduli with depth for surface seismic survey.
8. Conclusions

1- The results of seismic refraction was observed that there are three layers in the study area, the first layer extends from ground surface to (4.75) m, while the second layer extends between (4.75-9.25) m and the third layer extends between (9.25-21.25) m.

2- Observed there are increases in primary and shear seismic wave velocity naturally, thus, obtaining the physical properties of elastic moduli are better than above depth with increasing depth gradually, to carry heavy weights and use them to build engineering facilities.

3- Seismic refraction survey (P-wave and S-wave velocities) show that there is gradual change in and it was noted from surface m to below. Therefore, elastic modulus behavior tends to make the soil properties in the study area become more compact.

4- Depending on seismic wave velocities the study area does not contain weak zones or cavities.

9. Recommendations

1- Emphasize on the use of other method such as cross-hole, electric and GPR due to of their ability to get valuable results and detection to thin layer or weak layers.

2- Conducting geotechnical study ways of engineering and geophysical surrounding areas around the study area to get more details about the soil properties behavior.

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