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Determination of geotechnical parameters using refraction seismic method

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ABSTRACT

Recognition and investigation of the quality of soil by the seismic methods are among the most essential tasks before performing any building/construction purposes. In this research, the Dynamic Elastic parameters of soil in Sangar site, located in the southeast of Rasht in Iran were delineated using refraction seismic and geotechnical borehole information. Seven shallow seismic profiles for P and S wave have been acquired. After applying conventional pre-processing methods, travel time curves have been obtained and processed using generalized reciprocal method. Also, using of the velocities of P and S waves and geotechnical parameters from 7 boreholes, the Dynamic Elastic parameters of soil such as Vp/Vs ratio, poisons ratio and Shear stress have been computed. Soil quality information was interpreted using seismic velocity values and strength parameters. The investigation site was then divided into different parts based on the obtained results. The aim of the research was to integrate the geophysical studies with the dynamic parameters to help in site characterization for seismic hazard estimation.

Keywords: Seismic refraction, Geotechnics, Dynamic Elastic parameters, Sangar, Iran.

INTRODUCTION

The use of Seismic refraction method in civil engineering projects has been extensively studied. This technique is routinely used in many applications such as engineering, environmental, groundwater, hydrocarbon, and industrial-mineral exploration (Bridle, 2006). Using seismic velocity which is depends on the elasticity and density of the subsurface material, measuring of material strengths and assessing rippability and rock quality could be provided. In most dynamic soils problems, the shear wave velocity and shear moduli are the most important properties of the soils. As such, direct measurement of the shear wave velocities, by using a rich source of shearing energy that is able to propagate over long distances, is in advantage for geotechnical earthquake engineering problems (Woods, 1978). The ultimate goal of the present study is to provide information about the Geomechanical properties of the subsurface, using P and S wave velocities from refraction studies and geotechnical information for the development of new construction, based on measured and calculated Dynamic Elastic parameters of the near surface. For each profile location, careful geological and lithological studies were carried out and all available wells were analyzed, assuring a good control on the litho-stratigraphic column.

GEOLOGY AND DATA GATHERING

The investigated site is located at southeast of Rasht in Iran having latitudes of 4110500 and 4110900 and longitudes of 384700 and 384950 meter. The geological information of the study area has been obtained via geological evaluations and 5 boreholes drilled in the area. The main geological feature of the study area, as shown in Figure 1, is undivided deltaic deposits, grey or grey-brown mudstone, siltstone and sandstone layers. Refraction seismic profiles and 7 drilled boreholes are shown in Figure 2. In order to map the layers in the site, a near surface refraction seismic survey has been conducted in the investigated site along 7 survey lines for both P and S waves. The field survey has been carried out using seismograph model ABEM RAS-24. The acoustic waves have been generated using a sledge hammer of 15 kg weight as a seismic source. The geophones have been placed in the ground along the straight lines through the shot points to acquire the direct and refracted waves. Every seismic line for P wave has been 10 geophones and the geophone interval of 4 m. we have selected seven shot points distributed all over the every profile as shown in Figure 3(a). Shear wave generation was conducted along the same seven profiles of P waves with geophone interval of 4 m. Figure 3(b) shows the Layout of S-wave profiles. The first arrival time data in each geophone have then been plotted in the graphical view of relationship between the geophone number versus the first arrival time of P and S waves for each shooting point. It should be a plot having two straight line sections, the first from the direct wave and the second from the refracted wave. From the graph, the curve of time arrival of each geophone is then picked in order to generate the intercept time graph. Then, the velocity and the thickness of each layer in the site are calculated.

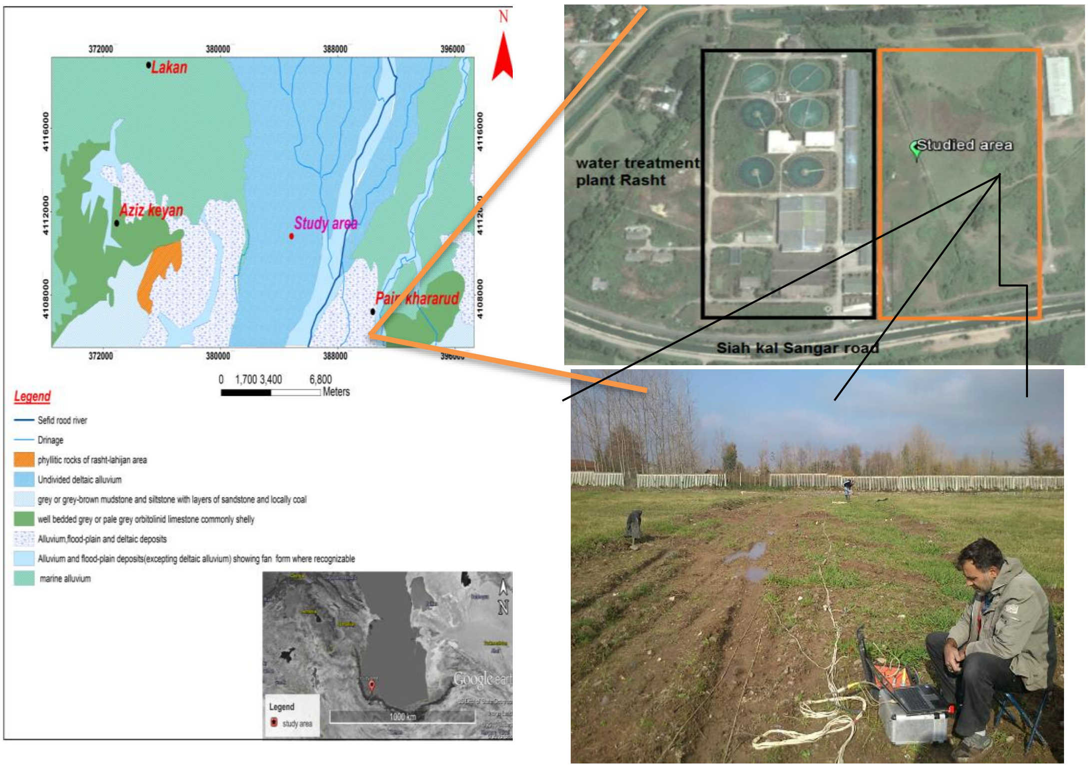


Figure 1. Geological map and data collection of the study area.

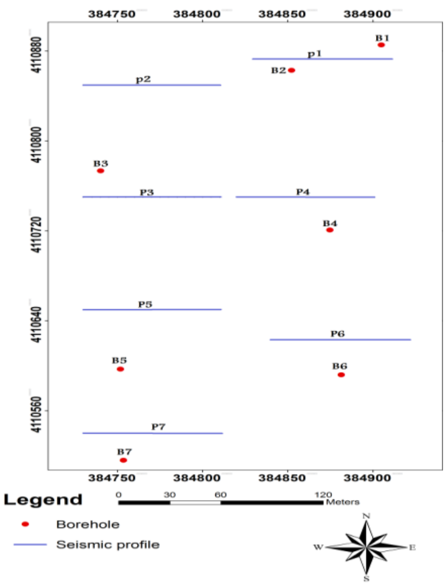


Figure 2. Seismic profile location of boreholes in the study area.

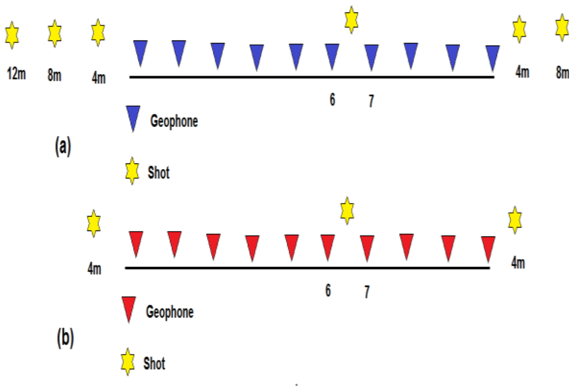


Figure3. (a) layout of P-wave profiles, (b) layout of S-wave profiles.

Figure 4 shows the final depth-velocity model for seismic profiles 1. The first Layer is predominantly made up of top soil consisting of Med to stiff Fat brownish clay soil with depth < 4.5m which forms the overburden (P-wave velocity ranges between 600 m/s and 800 m/s and S-wave velocity ranges between 250 m/s and 570m/s). Velocity is slightly increases when encounter different medium which indicated by black reddish clayey gravel with velocity 1320 to 1440 m/s for P wave and 410 to 430 m/s for S wave with depth extend from 3m to 7m. Layer 3 is suggested to be consisting of very dense clayey Gravel with velocity 1850 to 2030 m/s for P wave and 680 to 835 m/s for S wave. A good agreement in some profiles was found between P-wave and S-wave models but in others the depths of the interfaces of P and S models differ greatly. The observed discrepancy could be justified with shallow water table of 1m. For other profiles, the interface depth discrepancy can be attributed to the different properties that compressional and shear waves respond to. A good conformity was between the seismic refraction results and the corresponding available adjacent boreholes.

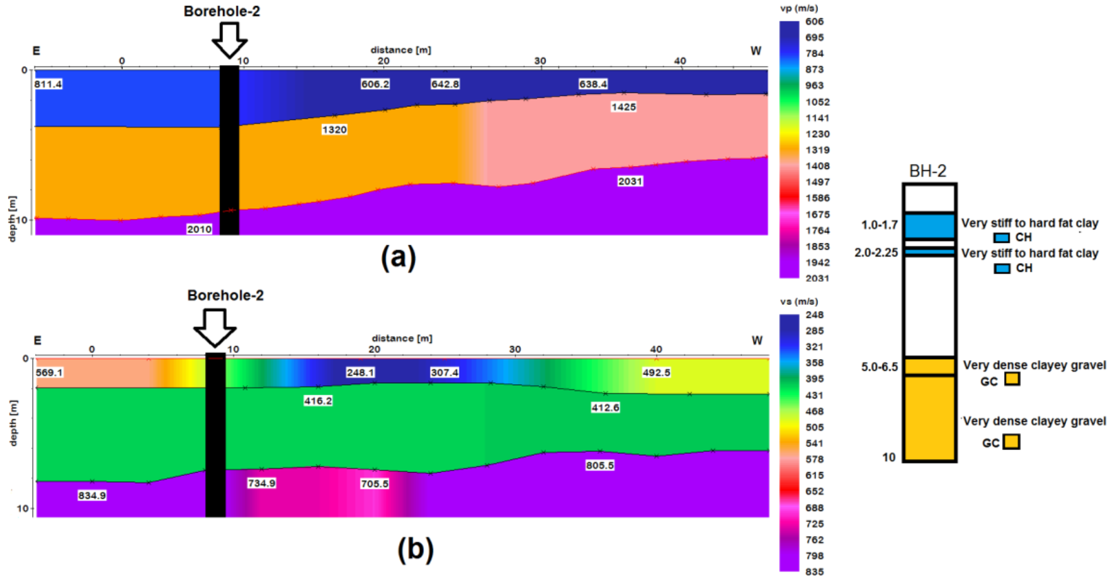


Figure 4. Final velocity depth model of profile 1 for (a) p wave and (b) S wave.

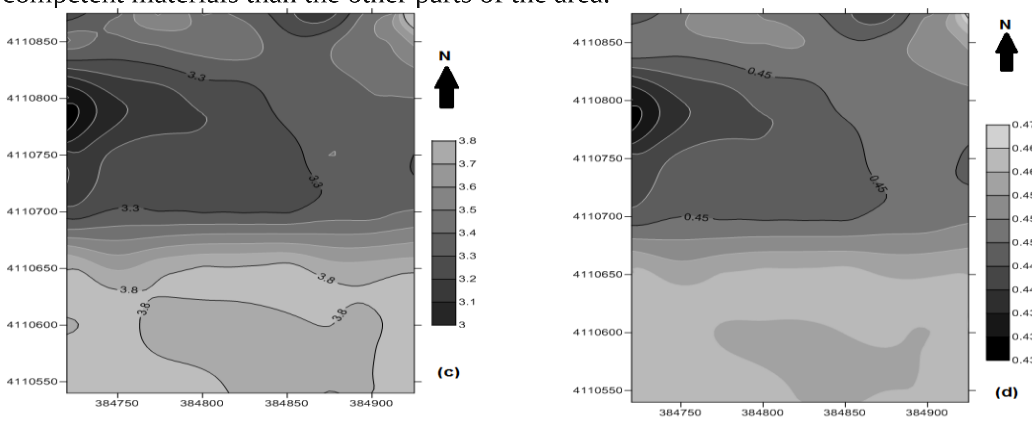
ELASTIC PARAMETERS

In order to evaluate the competence of material for construction, the Dynamic Elastic parameters were calculated. The Velocity contour maps were generated for the second layer since the first surficial layer will be removed prior to any construction activity in the study area. Three parameters are calculated; Vp/Vs ratio, Poisson's Ratio (σ) and the Shear Modulus (μ). Both P and S-wave velocities were obtained from the acquired seismic refraction profiles. The density values were obtained from laboratorial analysis of soil samples collected from the available boreholes, and the elastic moduli values were calculated from the equations listed in (Salem, 2000).

Vp/vs ratio: The second layer consists of Very Dense black reddish clayey gravel to Very Dense Clayey sand (GC, and SC), medium to hard consistency and starts from the depth of 4.5m. The range of P-wave Velocity in the second layer was 1320 to 1580 m/s and the range of S-wave Velocity was 410 to 480 m/s. The Vp/Vs ratios are more than $\sqrt{2}$ that is attributed to the nature of the lithology which clay is the dominant material in the second layer. Values of VP/VS ratios up to 9 however, have been several times reported in water-saturated, unconsolidated or clayish sediments (Salem, 2000). Figure 5.a shows that the smallest values of Vp/Vs occupy the central parts of the area, while the largest values are prevailing at the rest parts of the area, which means the central parts of the area probably includes less clayish materials than the rest parts of the area.

Poisson's ratio: According to Telford et al. (1997), the smallest values of Poisson's ratio are addressing more competent (hard) material and vice versa. A Poisson's ratio of $\sigma = 0.35$ is generally considered adequate for clayey layers in drained conditions. Negative Poisson's ratio is also recorded for very hard indurate anisotropic rocks. Poisson's ratio of this study, was found to range from 0.43 to 0.47, which is consistent with that of clayey surface soils and sediment elsewhere (Telford et al., 1997). Figure 5.b shows that the smallest values occupy the central parts of the area, while the largest values are prevailing at the rest parts of the area, which means this zone, includes less competent materials than the central parts of the area.

Shear Modulus (rigidity): This parameter is used in defining the stiffness matrices for finite element analysis of earth structures and foundation soils. The calculated shear modulus varies from 0.21 to 0.47 Gpa for the second layer. The Shear modulus seems to be uniform except in the central parts where a higher values is observed in the Figure 5.c, which means this zone includes more competent materials than the other parts of the area.



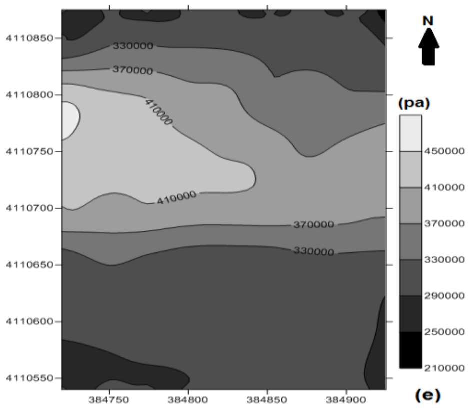


Figure 5: (a) contour map showing the P-wave velocity of the second layer, (b) contour map showing the S-wave velocity of the second layer, (c) contour map showing the Vp/Vs ratios of the second layer, (d) contour map showing the Poisson’s ratio of the second layer d (e) contour map showing the shear modulus of the second layer.

Conclusion:

The objective of this work was to provide information about the Dynamic Elastic properties for the second layer of the subsurface, using P and S wave velocities from refraction studies and geotechnical Information. By using refraction seismic surveys, we were able to build first structural subsurface models of the Sangar site. The obtained velocity models clearly outline the major relevant subsurface structures which are believed to be critical in order to understand the detailed knowledge of subsurface geometry and identifying acoustic impedance boundaries within the overburden and at the bedrock contact. Also, in order to access the degree of soil stability based on the elastic constants, Vp/Vs ratio, Poisson's ratio and Shear modulus were mapped to cover the whole site. Integration between different strength parameters indicated a high competent of materials in the central part of the site. The results will help to estimate seismic hazard and to design land-use maps that avoid critical and dangerous zones at the unseen second layer.

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