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Engineering Application of Refraction Seismology

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Abstract: Compressional (P) and shear(S) wave sources and detectors were jointly used in refraction surveys carried out at Abakaliki (Long. 8°5'- 8° 10'E; lat. 6°15'- 6°20'N) to investigate the strength of materials of the subsurface with respect to engineering construction works such as high rise buildings. A seismograph and its accessories were utilized. The elastic constants evaluated were the Young's modulus, E, the bulk modulus k, the shear modulus μ and the Poisson's ratio, ν. The result obtained show that the first and second layers of Abakaliki have E–values of $0.5x10^8 N/m^2$ and $1.4 \times 10^8 N/m^2$; of K-values $1.7x10^9 N/m^2$ and $2.3x10^9 N/m^2$; of μ-values $1.6x10^8 N/m^2$ and $5.4x10^8 N/m^2$ respectively. These yielded values of Poisson's ratio as 0.14 and 0.17 for the first and second layers respectively. The result indicates that Abakaliki rocks are of desirable quality for engineering constructions.

Key words: Refraction · Seismograph · Seismology · Geophone and Refractor

INTRODUCTION

Refraction seismology is a method that maps geologic structures using the travel times of head waves. Head waves are elastic waves that enter a high-velocity medium (Refractor) near the critical angle and travel in the high velocity medium nearly parallel to the refractor surface before returning to the surface of the earth [1]. The objective in refraction surveys is to measure the arrival times of head waves as a function of source-receiver distance so that the depth to the refractors in which they traveled can be used to study subsurface velocity and layer interface structure by analyzing the first arrival times of compressional or P-waves at the surface of the earth.

Refraction seismology is applied to a wide range of scientific and technical problems from engineering site investigations to experimental designs to study the structure of the entire crust or lithosphere. It is also used to locate buried archeological objects, assess subsurface geological hazards, define aquifer geometry and explore for fossil fuel and other natural resources [2]. In this study, refraction paths of compressional waves were used to investigate the elastic parameters of rocks in Abakaliki (Long. 8°5'- 8° 10'E; lat. 6°15'- 6°20'N), so as to assess the strength of the materials for engineering construction purposes. The geophysical method employed was the seismic refraction method. Some geophysical investigations have been carried out in Abakaliki and environs. Agha and Anyigor [3] carried out a seismic refraction survey within the premises of Ebonyi State University (EBSU) main campus, Abakaliki. Their aim was to determine the lithostratigraphy of the area. The result of their research showed that the average P- wave velocity in EBSU for the first three layers from the surface are 998m/s, 1922m/s and 3008m/s. The layers were interpreted to be made of shale, clay and carboniferous sediments respectively.

MATERIALS AND METHODS

Instrumentation: The instruments used for the seismic refraction survey of the area under study include a surveyor's tape, cables, clinometers, metal plate, P- and S-save sources and geophones, a seismograph and a sledge hammer.

Method: During the field work, the area was first surveyed to ensure safety and tolerable environment. Considerations were also made in the aspect of accessibility, topography, possible damage to crops and convenience of the field crew. The field configuration

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consists of seismic sources (P-S) with sets of geophones. Single line profiling was adopted. The intergeophone spacings were made with the aid of the surveyors tape. The clinometers were used to measure the orientation and location of transverse of refraction profiles. The metal plate and sledge hammer both served as seismic sources which were used to generate p and s waves. The times, T (ms) of arrival of the waves to the various geophones were measured and recorded alongside the offsets, X(m).

RESULTS AND DISCUSSION

Results: The seismic velocities obtained from a plot of arrival times, T versus offsets, X for both P- and S- wave propagations are shown in Tables 1 and 2 respectively.

The ratio of primary wave velocity, V_p to shear wave velocity, V_s was used to estimate the elastic parameters of the rock layers. The parameters evaluated were the Young's modulus, E, shear modulus, μ, bulk modulus K and Poisson's ratio, ν. (Table 3).

Discussion: From the P-wave analysis (Table 1), three layers of the study area were revealed. The velocities of the layers are 743m/s, 1709m/s and 2500m/s. These were interpreted to be probably laterite, clay and mudstone. The thicknesses of the first and second layers from the surface are 4.8m and 8.2m respectively. From the S-wave analysis (Table 2), two layers were delineated and their velocities are 200m/s for first layer and 625m/s for second layer. The thicknesses of the layers are 3.6m and 8.4m respectively.

Table 3 shows the values of the elastic constants of the rock layers. From the table, the first and second layers of the study area are of E- values 0.5×10^8N/m^2 and 1.4×10^8N/m^2; of K-values 1.7×10^9N/m^2 and 2.3×10^9 N/m^2; of μ-values 1.6×10^8N/m^2 and 5.4×10^8N/m^2 respectively. These gave values of Poisson's ratio, ν as 0.14 and 0.17 for the first and second layers respectively.

Table 1: P- Wave Velocities, Depth And Thickness Of Layers In The Study Area

Layer	Velocity (m/s)	Depth (m)	Thickness (m)
1	743	4.8	4.8
2	1709	13.0	8.2
3	2500	-	-

Table 2: S-Wave Velocities, Depth To Refractors And Thickness Of Layers In The Study Area

Layer	Velocity (m/s)	Depth (m)	Thickness (m)
1	200	3.6	3.6
2	625	-	-

Table 3: Elastic Constants Of Layers Delineated By The Waves In The Study Area

Layer	E(N/m^2)	K(N/m^2)	μ(N/m^2)	N
1	0.5×10^8	1.7×10^9	1.6×10^8	0.14
2	1.4×10^8	2.3×10^9	5.4×10^8	0.17

According to Dobrin [4] the Poisson's ratio (ν) ranges from 0.05 for very hard rigid rocks to 0.45 for soft poorly consolidated materials. Okwueze [5] suggested that for areas/zones where ν = 0.33, the rocks are more likely to be very good foundation materials than when ν> 0.33 due to the high value of μ obtainable in the former case.

CONCLUSION

Since the rock layers of Abakaliki have Poisson's ratio values of 0.14 and 0.17 for the first and second layers respectively which are each less than 0.33, we conclude that Abakaliki rocks are of desirable strength for engineering constructions such as high ways, high rise buildings and dams.

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