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Applying the Seismic Refraction Tomography for Site Characterization

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Abstract

Seismic refraction method is a geophysical method that has been developed for shallow subsurface investigation. It provides 2-dimensional profiles including depth and distance that simplified the characterization of relatively large volumes of the subsurface. Interpretation of seismic refraction data using seismic tomography involves continuous velocity gradient across a subsurface which is more effective for site characterization compared to conventional seismic refraction. Three parallel seismic refraction survey lines were conducted at Kaki Bukit, Perlis with the aim of characterizing the subsurface of the area. 2m geophone spacing was used with total length of 46m. The separation between lines is 20m. Weight drop of 20kg and steel plate were used as seismic source. A total of 20 shotpoints were performed for survey line L1, 23 shotpoints for survey line L2 and 22 shotpoints for survey line L3. The high quality seismic data obtained were then processed using SeisOptPicker and SeisOpt2D software to produce a seismic tomography section for each survey line. Results indicate that the study area is said to have 4 main layers with velocity increase fairly with depth. The first layer with velocity 300-500 m/s predominantly consists of top soil and form overburden. Second layer with velocity 500-800 m/s is suggested to be a highly weathered limestone. The third layer represents by highly fractured limestone with velocity 800-1500m/s. Limestone bedrock represent by the fourth layer with velocity > 2000m/s. Competent limestone bedrock is identified at survey line L3 with velocity > 3000m/s.

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Keywords: Seismic refraction; tomography; site characterization; velocity gradient

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1. Introduction

Seismic refraction was the first major geophysical method to be applied in the search for oil bearing structures but its application in oil exploration is reduce over years due to variety of the modern reflection surveys. However, the method has found increasing use on a smaller scale mapping of near surface particularly in site investigations for civil and geotechnical engineering. It is a powerful investigative tool for shallow survey when used in conjunction with exploratory drill [1]. Conventional interpretation of seismic refraction data visualized the subsurface as a layered media where each of the layers has discrete seismic velocity where the measured travel time of seismic wave that return to the surface are converted into depth values [2]. Nowadays, the interpretation method is being developed, making the possibility to interpret velocity changes as gradient as well as discrete layer. This velocity gradient is also known as refraction tomography which use the ray tracing algorithm including the gradational, gradual velocity changes and an explicit interpretation of travel paths for the first arrival seismic energy passing through the subsurface [3]. In this study, the velocity gradient interpretation represented by non-linear optimization is applied. Seismic refraction survey was performed at Kaki Bukit, Perlis to map and characterize the subsurface of the area. There are total of three parallel seismic refraction survey lines were conducted with total length of 46m with 2 m geophone spacing.

2. Seismic Refraction Tomography

Seismic refraction tomography also known as velocity gradient or diving-wave tomography uses first arrival traveltime of seismic wave as input [4; 5]. It generalized the subsurface medium into continuous medium where the first arrival traveltime recorded is not necessary related with a medium or refractor with high velocity contrast. It shows the velocity gradient with respect to depth of the subsurface of the area. It uses the generalized simulated annealing where the algorithm performed repeated forward modeling, and new models are conditionally accepted or rejected based on probability criterion. This criterion allows the algorithm to escape from non-unique, local, travel-time minima to achieve a unique, globally optimized model of subsurface velocity structure. The algorithm makes no assumptions on the orientation of the subsurface velocity gradient, and can therefore reveal vertical structures and strong lateral gradients, if present. The method is therefore ideal in areas characterized by strong lateral velocity gradients, and in areas with extreme topography or complex near-surface structure where the user has little or no prior knowledge of subsurface structure [6].

3. Geological Setting of Study Area

Study area takes place at Jalan Sahabat, Kaki Bukit, Perlis. It is located at the Northern part of Perlis state. There are seven rock formations in Perlis which are Machinchang Formation (Cambrian), Setul Formation (Ordovician to Early Devonian), Kubang Pasu Formation (Late Devonian to Early Permian), Chuping Limestone (Early Permian to Late Triassic), Bukit Arang Tertiary beds and Quaternary alluvium. Granite body is located at the Northern tip of Perlis [7]. The study area is said to be underlain by Kubang Pasu Formation which forms syncline in the middle of Perlis and the outcrops of the formation are widely exposed [8]. The Kubang Pasu Formation is the result of further deep basin sedimentation. The sandstones form typical North - South strike ridges as a result of folding. Above the Kubang Pasu Formation, lie the eroded residues of the Chuping Limestone, which occupies two narrow parallel synclines [9]. Setul Formation is located at Western part of the state which also extends to Kaki Bukit. The limestone outcrop is observed at study area (Fig 1).

Fig. 1. Limestone outcrop that can be observed at study area.

4. Methodology

The study involves seismic refraction data acquisition followed by data processing and tomography interpretation. The acquisition was performed using 24 channel ABEM Terraloc MK8 seismograph and 28Hz geophones. Total of three parallel seismic refraction survey lines were conducted with 20m line spacing. Geophones are coupled firmly into the ground with spacing of 2m hence the total length of survey line is 46m. 20kg weight drop was used to produce seismic wave.

4.1. Data acquisition

In order to perform seismic refraction tomography during interpretation, sufficient shotpoints are executed to obtained high quality of seismic data. Total of 20 shotpoints were executed for survey line L1, while 23 shotpoints for survey line L2 and 22 shotpoints for survey line L3. The location of shotpoints for each of survey lines are show in Fig.2.

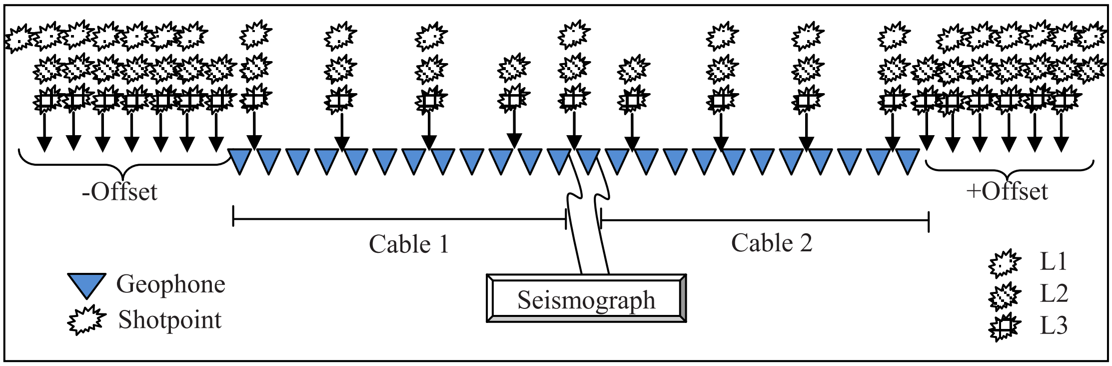

Fig. 2. Location of shotpoints for every survey lines.

5. Results and discussion

Generally, seismic tomography sections (Fig 3-5) show that the study area is characterized into 4 main layers. Layer 1 with velocity 300-500m/s is predominantly made up of top soil with depth < 1m which forms the overburden. Velocity is slightly increases when encounter different medium which indicated by highly weathered limestone with velocity 500-800 m/s with depth extend from 1m to 4 m. Layer 3 is suggested to be consist of highly fractured limestone rock with velocity of 800-1500m/s. This layer is identified at depth 4-10m. Limestone bedrock represent by the fourth layer with velocity > 2000m/s. Competent limestone bedrock is identified at survey line L3 with velocity > 3000m/s.

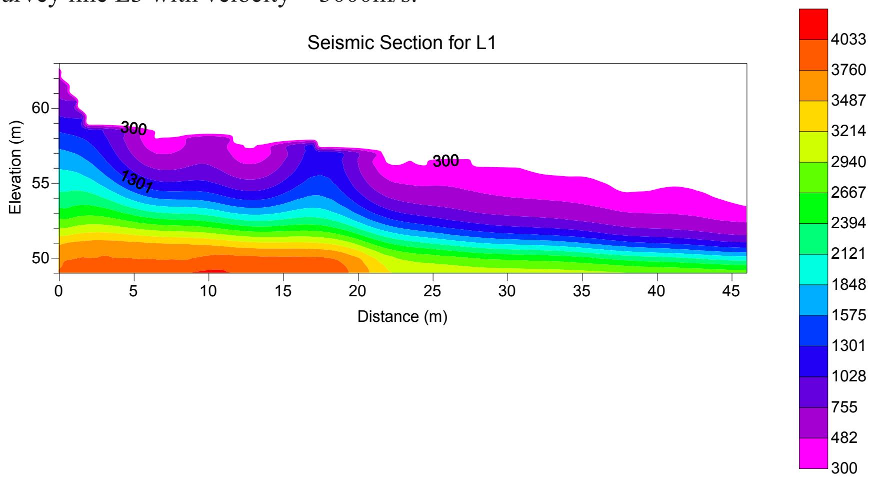

Fig. 3. Seismic tomography section for survey line L1.

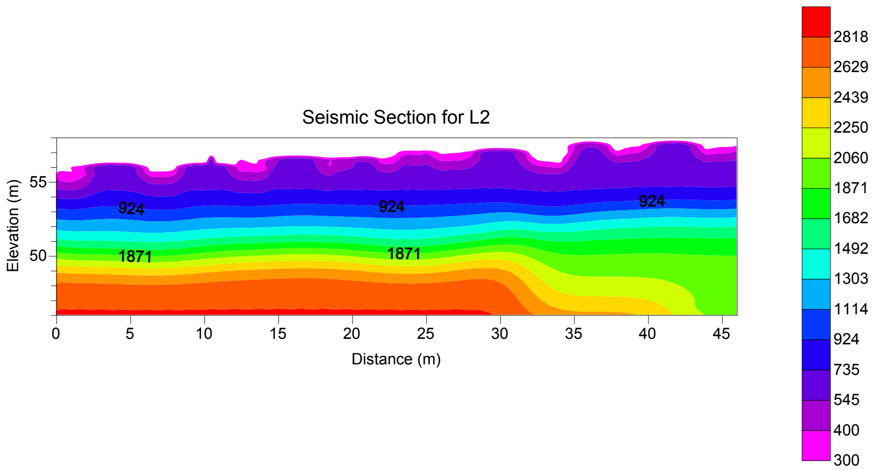

Fig. 4. Seismic tomography section for survey line L2.

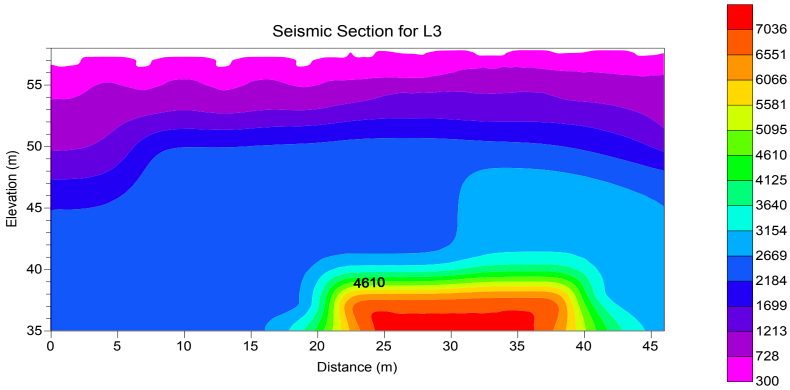

Fig. 5. Seismic tomography section for survey line L3.

6. Conclusion

Seismic refraction tomography method is a cost effective means to obtain generalized subsurface information for geotechnical characterization over large area. By performing seismic refraction tomography, the bedrock structure, velocity distribution and depth underlying layers can be obtained in more detailed.

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