

Synthetic Modelling Application in High Resolution Seismic Refraction Tomography

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Abstract: Seismic refraction tomography (SRT) involves more complex mathematic algorithms to fit more flexible model. In the field procedure SRT in generally needs more shot points than standard seismic refraction survey to obtain high resolution profile. In this study we are used 9 shot-points for inline and 10 shot-points for offset in purpose to obtained high resolution of seismic refraction tomography. During a recent geophysical test site, the subsurface material was mapped along survey line using seismic refraction method. Analyses of the site investigation data revealed that the studied site was made up of two layers of the subsurface. The upper layer has velocity values with range of 500 m/s to 1500 m/s which can be classified as unconsolidated surface deposits and mixtures of unsaturated sands and gravels. Meanwhile the lower layer has velocity values with range of 2000 m/s to 5500 m/s which is classified as compacted fine's soil due to high pressure of the overburden. Analysis of seismic refraction data demonstrated that refraction tomography software systems are able to reveal subsurface material which represented by their seismic velocity value. Furthermore, the velocity model obtained in this study is agreed with its synthetic modelling result as initial model. This validity and reasonable results was able to assist in interpretation of the seismic refraction method for the environmental study.

Key words: Mathematic algorithms • Seismic velocity • Synthetic modelling • Validity • Reasonable

INTRODUCTION

The seismic refraction surveying was the first major geophysical method to be applied in the search for oil bearing structures. Today, however, oil exploration relies almost exclusively on some variety of modern reflection seismographs. Recent progress in exploration geophysics has stemmed from the computer-assisted processing and enhancement of the data interpretation. Seismic refraction surveys are still used occasionally in oil exploration, particularly where they can assist in resolving complicated problems in structural geology. Although the application of seismic refraction method in the oil industry has diminished over the years, the method has found increasing use for site investigation for civil engineering. It is a valuable investigation tool well-suited for shallow surveys, particularly when used in conjunction with the exploratory drill.

The relatively recent advent of seismic refraction tomography techniques has provided a significant new geophysical tool. Several initial studies by [1-5] indicate

that refraction tomography performs well in many situations where traditional refraction techniques fail, such as velocity structures with both lateral and vertical velocity gradients. Recently, seismic refraction method has been used in environmental and engineering study. [6] present an approach of combination of electrical and seismic refraction analysis proved that these integrated study of the physical environmental data provided a reasonable compromise between measurement time and image resolution.

Seismic refraction tomography is a geophysical method of interpreting seismic refraction data, which uses a gridded, inversion technique to determine the velocity of individual 2-dimension blocks (pixels) within a profile as opposed to modelling velocities as layers. As a result, refraction tomography can, in some cases more accurately model and provide better resolution of complex velocity structure of the subsurface. One limitation of seismic refraction is the inability to concern the existence of certain layers, referred to as hidden layers or blind zones. This is due to insufficient velocity contrast of layer

thickness [7]. Another limitation of seismic refraction are incorrect depth calculation to certain layers where velocity reversals exist, i.e. where layer velocities do not increase with progressive depth [7]. A discussion of the strength, weaknesses and cost effectiveness of seismic refraction surveys is presented in [8].

This paper presents two examples of processing techniques for characterization of subsurface using seismic refraction. Motivation to have high resolution seismic refraction tomography, we used 9 numbers of inline shot-points and 10 numbers of offset shot-point with 2 meter geophone interval for this environmental study.

MATERIALS AND METHODS

Seismic refraction is a geophysical principle governed by Snell's Law. If a layer, in which the waves have a velocity V_1 , is underlain by another layer with velocity V_2 , then Snell's law can be given in Equation (1).

$$\frac{\sin i}{\sin r} = \frac{v}{v} \quad (1)$$

Where; i is incident angle and r is refraction angle

The compressional wave that travels directly from the source to a receiver (geophones) is a body wave travelling very close to the surface. The velocity of the wave (V_1) is the distance from the source to the receiver (X) divided by the time (t) it takes to travel directly to the receiver (Equation 2).

$$V = \frac{X}{t} \quad (2)$$

The equation for the straight line represents the direct arrival on the graph travel-time (Figure 1). Therefore, Equation 2 changes to Equation 3.

$$t = \frac{X}{v} \quad (3)$$

Seismic data were recorded using a 24 channels ABEM Terraloc MK8 seismograph with 24 geophones of 14Hz, 2 seismic cables, a roll of trigger cable, a striker plate and 16 lb seismic hammer to generate seismic source. In this study, we have deployed geophones with 2m interval with 9 inline shot-points and 10 offset shot-points (Figure 2). SeisOptim software used in this study is based upon a Monte Carlo-based optimization scheme described

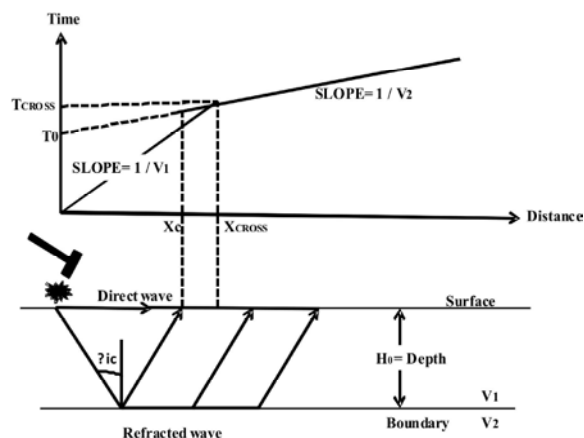


Fig. 1: A schematic diagram of compressional wave and travel time curves (After: [9])

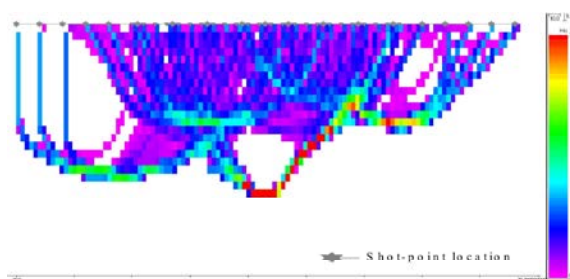


Fig. 2: A schematic diagram of survey (raypart) seismic refraction tomography applied in this study

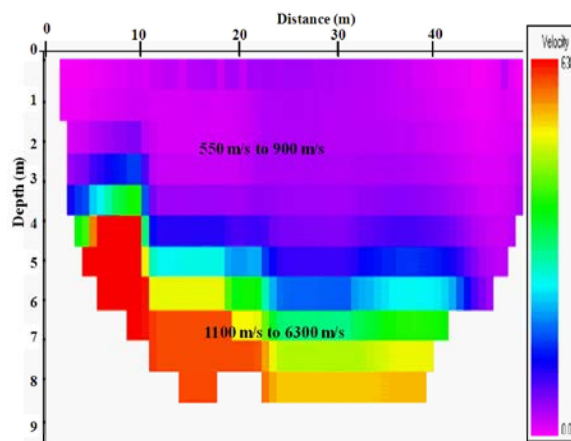


Fig. 3: The synthetic velocity model for the test site.

by [10]. For forward model, a finite-difference solution of eikonal equation [11] computes first-arrival travel times through the velocity model. Inversion is accomplished via a generalized simulated annealing global optimization algorithm. [10] demonstrate that the simulated annealing inversion algorithm is independent of the initial model. By default, a constant velocity is assigned to the model by

SeisOptim to begin the optimization. Alternatively, the user can input results from a previous run as an initial model or fully specify an initial velocity model.

The synthetic model of the velocity model of the test site was carried out in this study is the result of forward modelling the seismic response of an input earth model, which in term of 2D variation in physical properties. This paper presents are modelling synthetic method which uses a gridded, inversion technique to determine the velocity of individual 2-dimension blocks (pixels) within a profile as opposed to modelling velocities as layers. Figure 3 shows the synthetic model of the velocity model for the test site. This approach is used to examine the seismic response of the geological section.

RESULTS AND DISCUSSION

The seismic refraction test described above was processed by the analysis systems and P-wave velocity tomogram was produced. To provide uniformity to the results, tomograms from analysis system was exported to the Surfer graphical software and the data was plotted with a consistent set of special and velocity scales. By way of example, Figure 4 presents the optimum velocity tomograms for the end-to-end survey line. For each set of travel time data, multiple runs of the analysis system were conducted to exercise the model.

In this study, we show that the synthetic velocity model is nearly matched to the final result of velocity tomography model for the test site. Base on interpretation for the velocity tomography model (Figure 4), there is two main velocity layers which can be classified as layer one or upper layer and the lower layer. The upper layer has velocity values with range of 500 m/s to 1500 m/s which can be classified as unconsolidated surface deposits and mixtures of unsaturated sands and gravels. Meanwhile the lower layer has velocity values with range of 2000 m/s to 5500 m/s which is classified as compacted fine's soil due to high pressure of the overburden.

In this study also we tried to compare the velocity analysis using two commercially-available refraction tomography software systems to produce seismic refraction results. The second analysis scheme used in this study is FIRSTPIX V4.21 was used to pick the first arrival time and GREMIX15 software for velocity analysis and depth calculation using the Generalize Reciprocal Method (GRM). GRM calculates refractor depths for each geophone location using overlapping refraction arrival times from both forward and reverse shots, warranting multiple shots along seismic profile. Multiple numbers of

shot-points along the seismic profile will permit interpretation of changing interface depths and layer velocities. The result obtains using this analysis scheme is compared with the SeisOpt software in order to verified and have reasonable interpretation for the test site. The comparison of these two tomography velocity analysis shows that there is a good correlation which the upper layer by GREMIX15 (Figure 5b) has velocityrange within the upper layer by SeisOpt (Figure 5a). However, the lower layer slightly miss where GREMIX15 velocity analysis (Figure 5b) gives velocity range of 1300 m/s to 3000m/s. Whereas, the lower layer given by SeisOpt velocity analysis (Figure 5a) gives velocity range of 2000 m/s to 5500 m/s.

The SeisOpt velocity models in particularly display some strange features within the lower half. These features typically occur in regions of low ray path coverage. Meanwhile the GREMIX15 velocities model unable to display the contouring such as SeisOpt velocity scheme. However, GREMIX15 velocity scheme able to give the reasonable result as SeisOpt software.

Following refraction data collection and analysis, invasive ground proving information was collected at the site to provide partial verification of the refraction test result interpretations. Soil characterizations were conducted at the test site in purpose of gain further information of the subsurface and assist in our interpretation. In this study, the moisture content, W (%) and grain size analysis (gravel, sand, clay and silt) were determined in order to obtain the soil characterization of the test site. Figure 6 below shows that the variation of their values in percentage. Base on the result, it shows that they are having the same pattern for all three tested specimen. The upper layer of the test site is made up of same material.

CONCLUSION

Seismic refraction is a useful geophysical tool for subsurface environmental study. Initial studies by [12]and [13] indicate that refraction tomography and site investigation performs well in many situations. The velocity structure and their depth can be estimated from the velocity analyses of seismic refraction data. Seismic refraction equipment is also portable and relatively inexpensive. Seismic refraction is also non-destructive method for environmental survey. Seismic refraction tomography is method of interpreting seismic refraction data, is well suited for subsurface investigation of areas dominated by complex shallow structure, velocity

gradients and variable topography. Nonetheless of the technique used to interpret the seismic data, multiple numbers of shot-points along the survey line was able to provide greater data coverage and potentially more accurate velocity models. This paper presents two examples of processing techniques for characterization of subsurface using seismic refraction. It is prudent to perform both reciprocal as well as topographic analyses as the different velocity models can complement one another and when in agreement, it able to increase confidence level in the seismic refraction interpretation. This synthetic model can be apply in statistical and induced polarization method [14] for environmental study especially in tropical region.

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