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Determination of 1-D Shear-Wave Velocity Profileusing the Refraction Microtremor Method

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SUMMARY

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In most urbanized areas estimating shallow shear-wave velocity profile for engineering assessments by using current commonly used technique are too expensive. In these sites to overcome ambient noises, large sources are required. But most of the times these sources are destructive and usually use of them are banned. Louie (2001) overcomes these problems by using refraction microtremor (ReMi). He used standard P-wave recording equipment and ambient noise to determine shear-wave velocity profiles down to 30m depths. The combination of commonly available equipments, simple recording with no source, a wave-field transformation data processing technique, and an interactive Rayleigh-wave dispersion modeling tool exploits the most effective aspects of the microtremor. In the presence of waves which are travelling at high apparent velocity, body waves, air waves and higher-mode Rayleigh waves by applying slowness-frequency wave-field transformation, we can pick Rayleigh-wave phase velocity dispersion curve accurately.

In the south-west of Tehran land (Bordabad), we examine the application of this technique and determine shear-wave velocity up to 30m depths. Comparing this result with the result of geotechnical exploration shows the good correlation between them. This fact emphasizes the application of this technique in engineering assessments.

Introduction

The foundation of the refraction microtremor (ReMi) technique is built on two ideas. The first is that common seismic refraction recording equipments can record surface waves at frequencies as low as 2Hz. The second idea is that by using two-dimensional slowness-frequency (p-f) transform on ReMi record the separation of Rayleigh-waves from other seismic events become simpler and the true phase-velocities against apparent velocities are distinguishable.

ReMi was described by Louie (2001), where it is applied to obtain vertical S-wave profiles down to 100 meters for earthquake seismic site characterization.

The basic theory of this method is the same as spectral analysis of surface waves (SASW) and multichannel analysis of surface waves (MASW). The advantages of ReMi method including the following:

The same simple equipments, used for refraction survey are used. It does not require any source, traffic and other vehicles provide the data for this method.

Background Theory

The processing steps in ReMi technique are three: Velocity Spectral Analysis, Rayleigh Phase-Velocity Dispersion Picking, and Shear-Wave Velocity Modeling.

Velocity Spectral Analysis

P-tau transformation or slant stack, described by Thorson and Claerbout (1985), is the basic of the velocity spectral analysis. This transformation takes a record section of multiple seismograms, with seismogram amplitudes relative to distance and time (x-t), and converts it to amplitudes relative to the ray parameter p (the inverse of apparent velocity) and an intercept time tau. (Louie, 2001)

One-dimensional Fourier transform in tau direction on each p-tau trace is the next step.

In p-f analysis the dispersive waves have distinctive slope. Other events such as body waves do not have such slope. The p-f spectral power image helps to identify where such waves have significant energy. Applying the p-f transform to many channels recording, capable us to analyze Rayleigh wave dispersion.

Rayleigh Phase-Velocity Dispersion Picking

In order to normalize the spectra of noise records, we calculate spectral power ratio and add this calculation to McMechan and Yedlin's (1981) analysis.

Phase velocities are picked at the frequencies in which the spectral ratio has a peak. These points clearly locate the dispersion curve. Picks are not made at frequencies without a definite peak in spectral ratio, often below 4Hz and above 14Hz where an identifiable dispersive surface wave does not appear. (Louie, 2001)

In p-f image the energy appears. The appeared energy is wrapped around by picking along a lowest-velocity envelope in order to put limitation on phase-velocities and inverted velocity profile, too.

This technique yields the velocities of fundamental-mode in dispersion curve, in spite that it is possible that the higher-modes of Rayleigh waves have phase velocities greater than fundamental-modes. Higher-modes may be as energetic as the fundamental ones, but their dispersion trends on p-f images are separate.

Shear-velocity modeling

Determining shear-wave velocity profile from the p-f image and dispersion curve is a non-linear inversion modeling using a least square method.

Survey design and data acquisition

The same equipment used for ReMi is also used for seismic refraction to determine one- dimensional S-wave velocity.

Equipment used

Rucker (2003) suggested a multichannel seismograph capable of storing up to 16,000 samples per channel at sample intervals as long as 1 to 2 milliseconds in SEG2 or SEGY format can be used to collect ReMi data. 4.5 Hz single vertical geophones and recording cable also needed. The high frequency geophones are used for shorter arrays with shallower depth of investigation, and the low frequency geophones are used for longer arrays with greater depth of investigation. The maximum depth of resolution is about one-third to one-half the length of the array (Louie et al. 2002).

Recording data

The ReMi data are acquired by collecting at least 20 background noise recording using a sampling length of 30 seconds each. A 2ms sampling rate is used and all filters are opened (Douglas et al. 2005).

In this study, microtremor records are recorded near the Bordabad municipality in south-west of Tehran land. The refraction microtremor experiment employed a 46 meter long linear array of 24, 4.5Hz vertical geophones with 2 meter spacing between each geophone. The data were collected with twenty 24 channels seismic profiles that each took 32 seconds long with 2ms sampling rate.

Data processing

The data were processed and modeled using SeisImager/SW (2006). As explained in the background theory section, the first step is to create a velocity spectrum from the noise record (Figure 1).

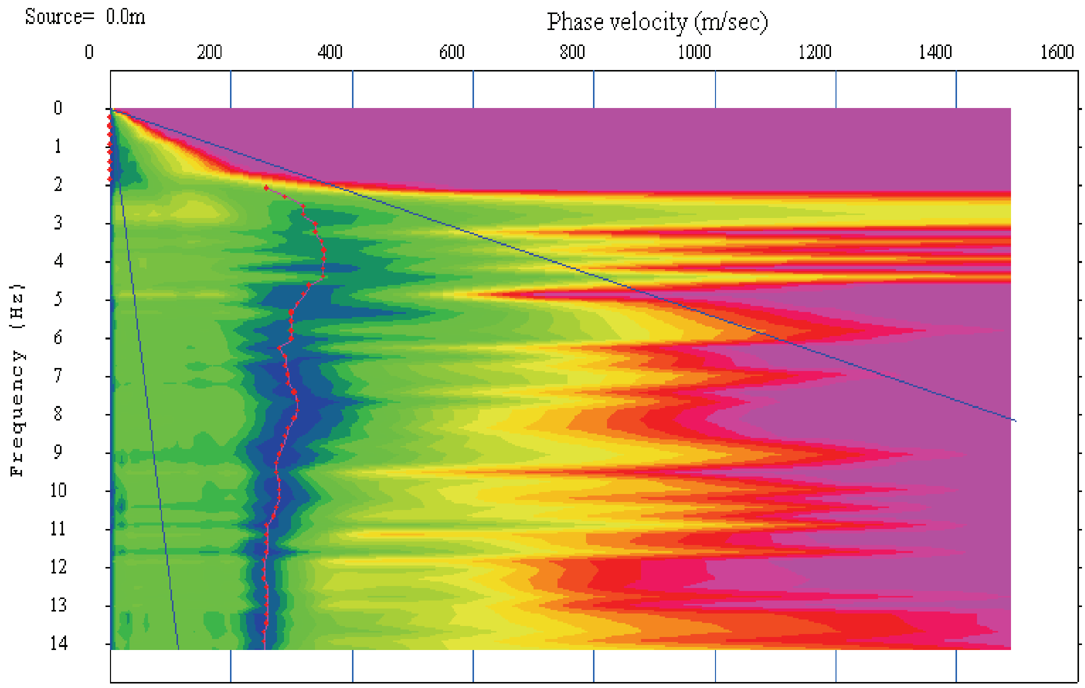

***Figure 1** velocity spectrum of noise records.*

This plot was generated using all 20 recording profiles. The surface wave energy is easily identified as the higher amplitude data trending from the bottom left-hand corner (low velocity and high frequency) toward the centre (high velocity and low frequency). The frequency range is to be fixed by two blue lines. It is not precise enough to determine the velocity on upper side of top line and left side of the line below.

In Figure 2 the Rayleigh phase-velocity dispersion curve was shown.

The one-dimensional shear-wave velocity profile has been presented in Figure 3. This profile reveals a low shear-wave velocity region which corresponding to a thick alluvium deposit.

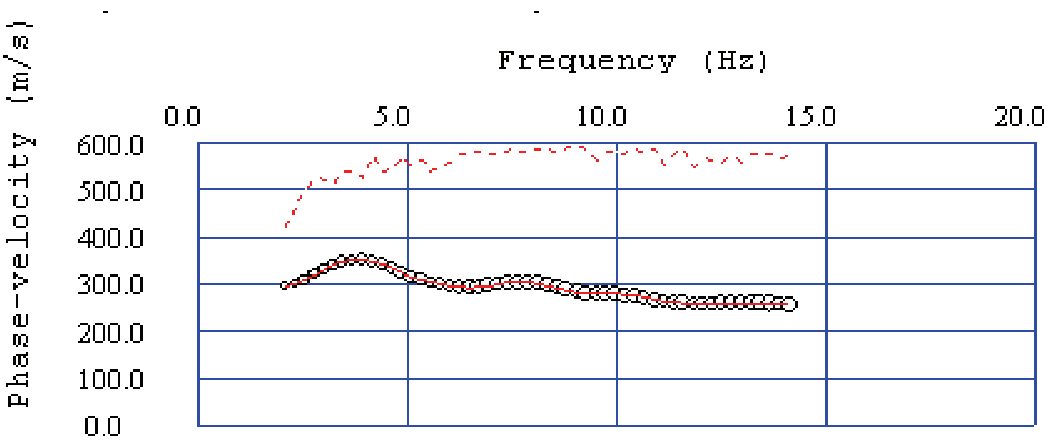

Figure 2 *Rayleigh phase-velocity dispersion curve*

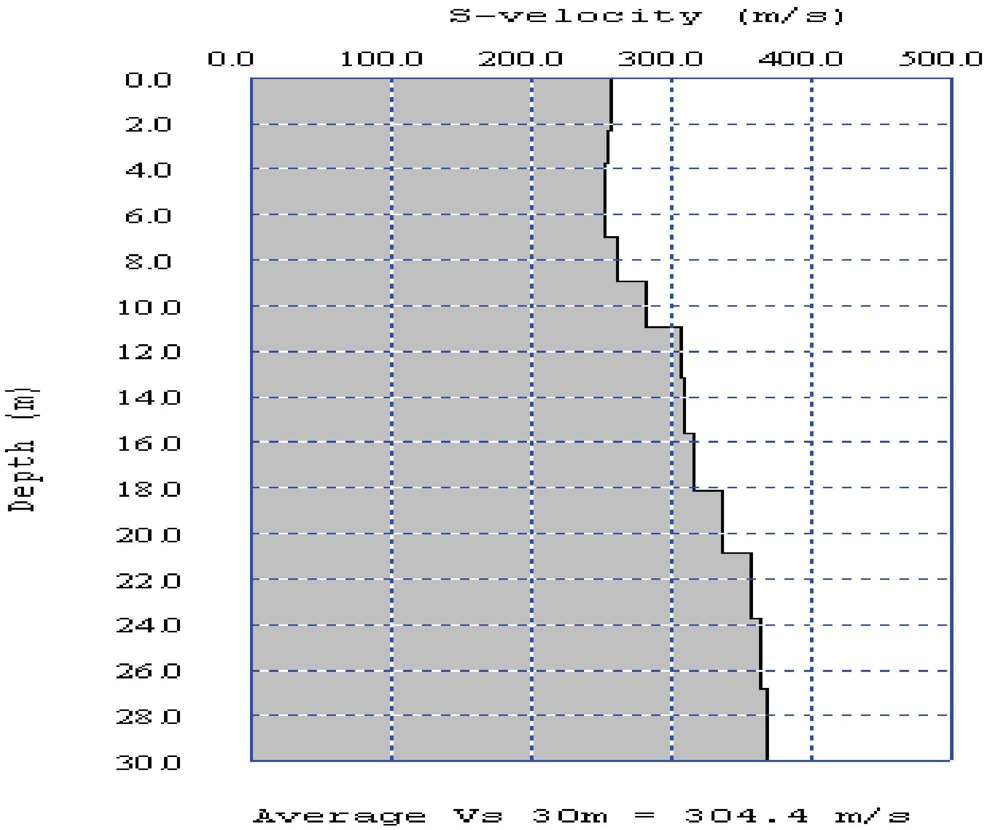

Figure 3 *Shear-wave velocity profile.*

This result is well-adapted to the result of a geotechnical exploration. The SPT number in 30m long borehole also declare an alluvium low velocity layered up to 30m depth (Table 1).

Conclusion

Determining shear-wave velocity profile by applying microtremor technique is now very fast and inexpensive. This technique is applicable in most urbanized area with busy transportation corridors.

By using this method the problem of providing source, which is less destructive, is solved.

Another possible application of this technique is, there is not any problem or hesitating in determining the first arrival time of shear-wave in refraction survey.

In the end, there is no need to drill a hole for estimating shear-wave velocity by downhole survey and therefore the cost of survey decreases.

Table 1 *Geotechnic data.*

Depth (m)	SPT No.		
	15 m	15 m	15 m
2	6	8	9
4	8	9	10
6	4	5	6
8	10	11	14
10	8	12	20
12	8	10	11
14	10	11	13
16	10	15	20
18	7	8	9
20	20	13	18
22	10	11	12
24	20	22	19
26	5	6	8
28	10	11	13
30	10	16	20

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