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Estimation of the Dispersion Curve for Soil Layers with Lateral Heterogeneity Using Continuous Wavelet Transform

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Abstract： The MASW method is the normal method regarding surface wave testing, but it requires 12 or more receivers to measure the phase velocity for statistical redundancy. Therefore, the SASW method has potential for use because only two receivers are required. A time-frequency domain analysis is used to extract a dispersion image of Rayleigh waves and select a dispersion curve from the seismic signals of two receivers during surface wave testing. The signals are transformed by continuous wavelet transform, and the products of the transformed signals of the two receivers are summed at the same slowness over the intercept time to construct a dispersion image. This method is unnecessary empirical judgment in the unwrapping of phases and a significant number of receivers. To examine the applicability of the method on evaluating the dispersion curve for soil layers with lateral heterogeneity, two synthetic examples of surface wave testing are discussed. The method is applicable for extracting a dispersion image for lateral heterogeneity soil layers. A high-resolution dispersion image is generated in this study by increasing the interval of the receivers.

STUDY METHODS

This paper uses a time-frequency domain analysis for estimating the dispersion curve of the Rayleigh wave for lateral heterogeneity soil layers using two receivers.

The main process to derive dispersion curve

STEP 1： A pair of SASW time series data, $v_1(t)$ and $v_2(t)$, by a pair of receiver is transformed into time-frequency domain, $w_1(t, f)$ and $w_2(t, f)$, by the CWT.

STEP 2： Take temporal plots of the two transformed signals, $w_1(t, f_a)$ and $w_2(t, f_a)$, at a certain frequency and normalize these signals using the maximum transformed value of the receiver, as shown in Fig. 1.

STEP 3： It applies the slant stack summation to the two plots for different slowness. The summed value along a single slowness trace is assigned to the appropriate point in the frequency- phase velocity coordinates. Repeat this step until all of slowness are analyzed.

STEP 4： Repeat the Steps 2-3 for different frequency, and the 2D dispersion image of the two receivers is obtained.

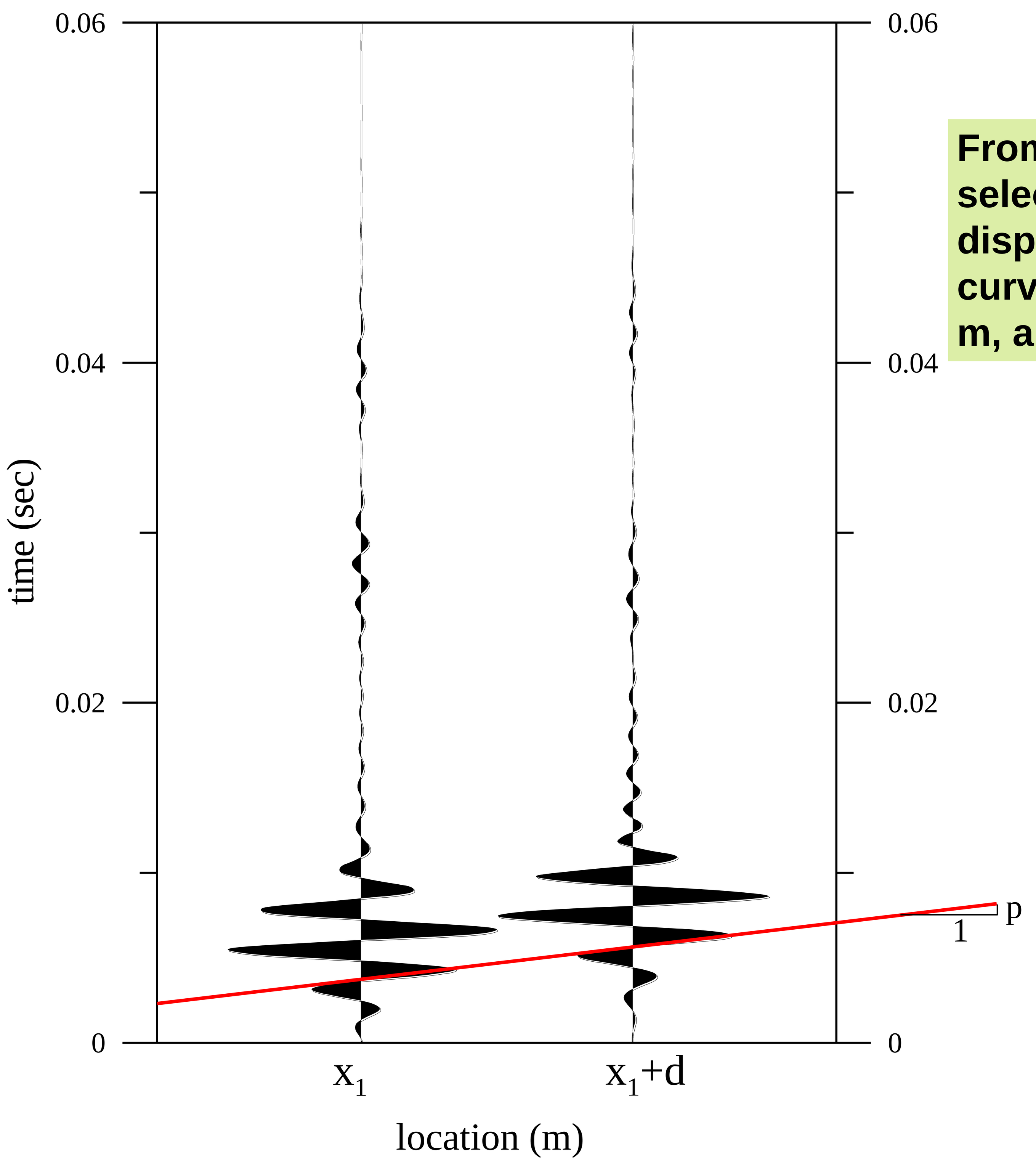

Fig. 1 Typical temporal plots of a pair of receivers

STUDY RESULTS

Model A: A two-layer model with a vertical fault

- The thickness of the upper layer of soil on the left side of the vertical fault is 5 m, and on the right side of vertical fault it is 3 m (Fig. 2). The distance between the vertical fault and the source is 15 m.

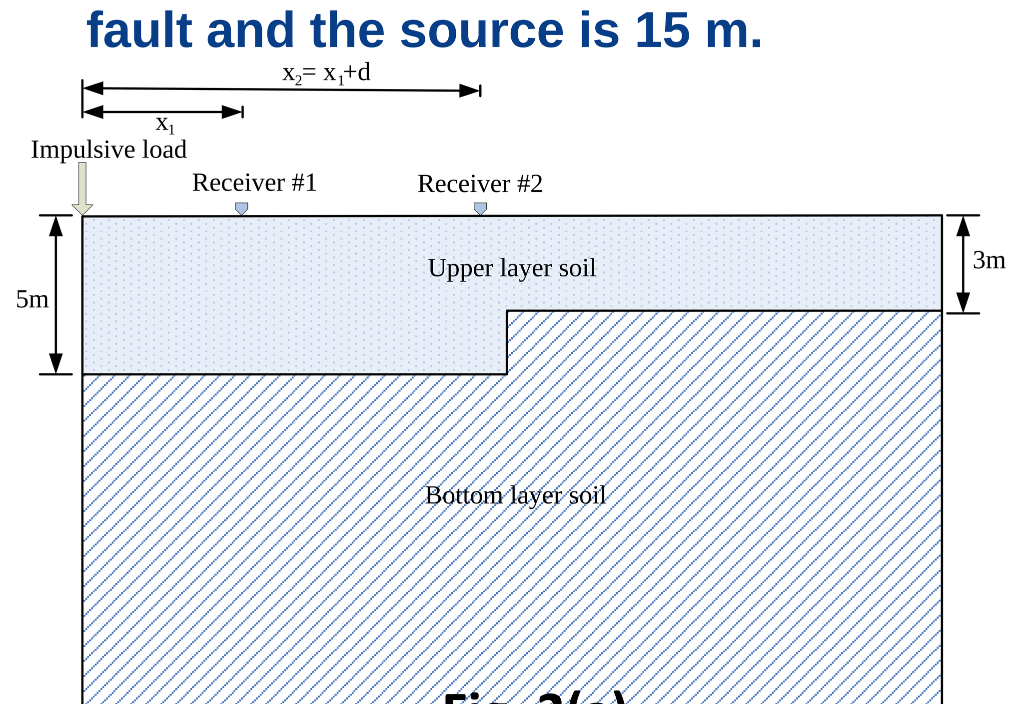

Fig. 2(a)

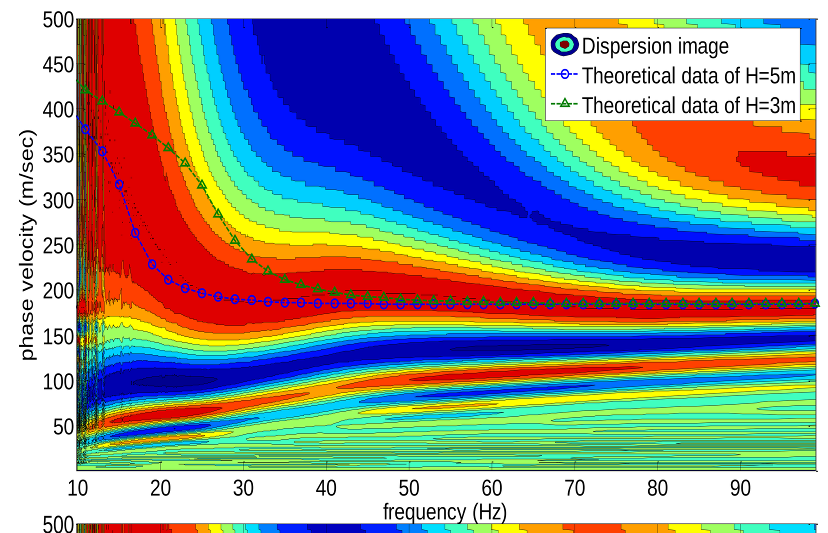

Fig. 2(b) x_1=10m; x_2=14m

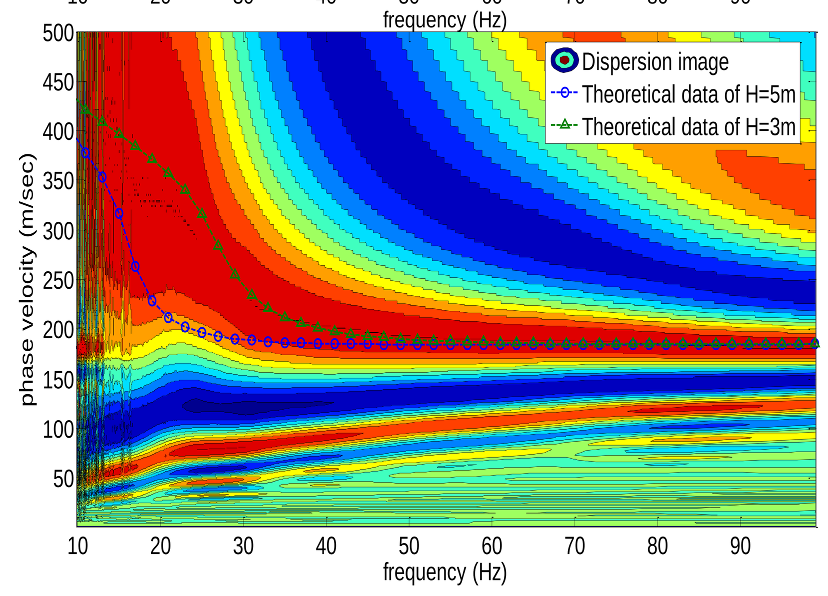

Fig. 2(c) x_1=20m; x_2=24m

From Fig. 2(c), The estimated dispersion curve approaches the theoretical curve in the thickness of the upper layer soil of 3 m, a green dashed line with circle.

Model B: A two-layer model with an inclining interface

- The thickness of the upper layer of soil varies linearly from 5 (on the left side) to 3 m (on the right side), the dispersion images are shown in Fig. 3(b) and (c).

From Fig. 3(b), the estimated dispersion curve selected by the high-amplitude distribution of the dispersion image approaches the theoretical curve in the thickness of the upper layer soil of 5 m, a blue dashed line with circle.

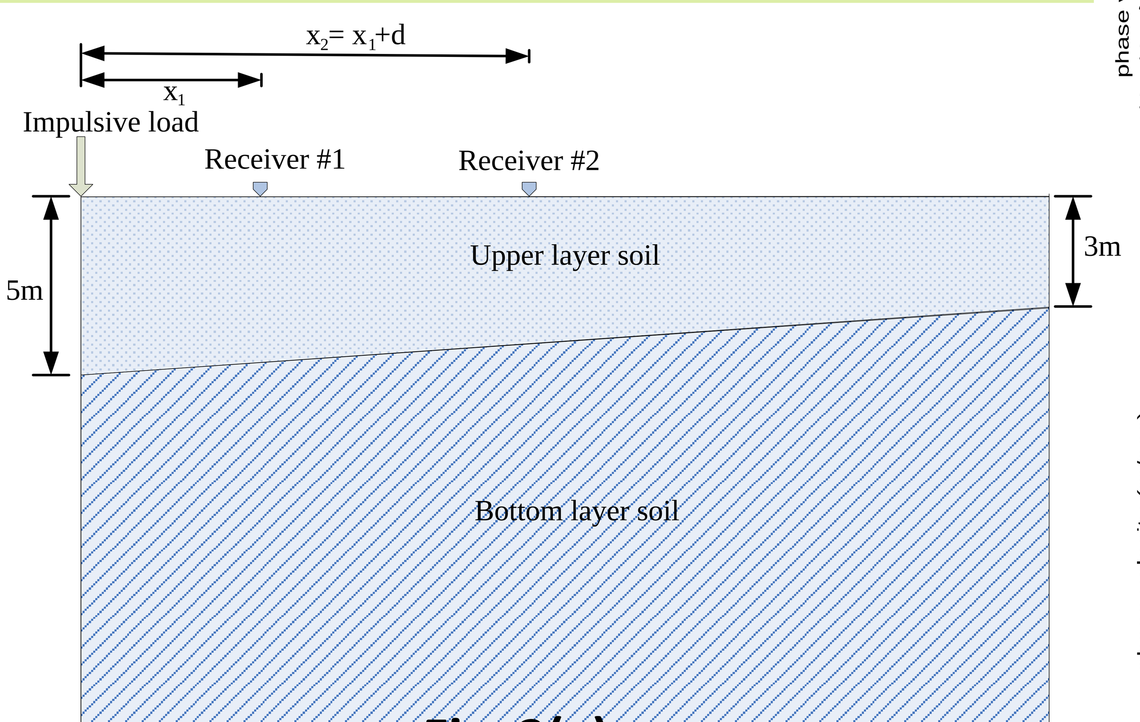

Fig. 3(a)

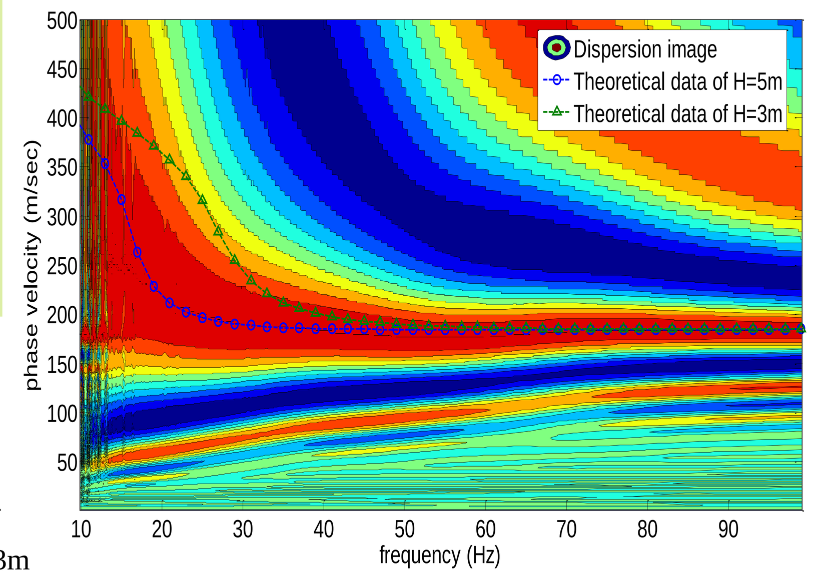

Fig. 3(b) x_1=5m; x_2=9m

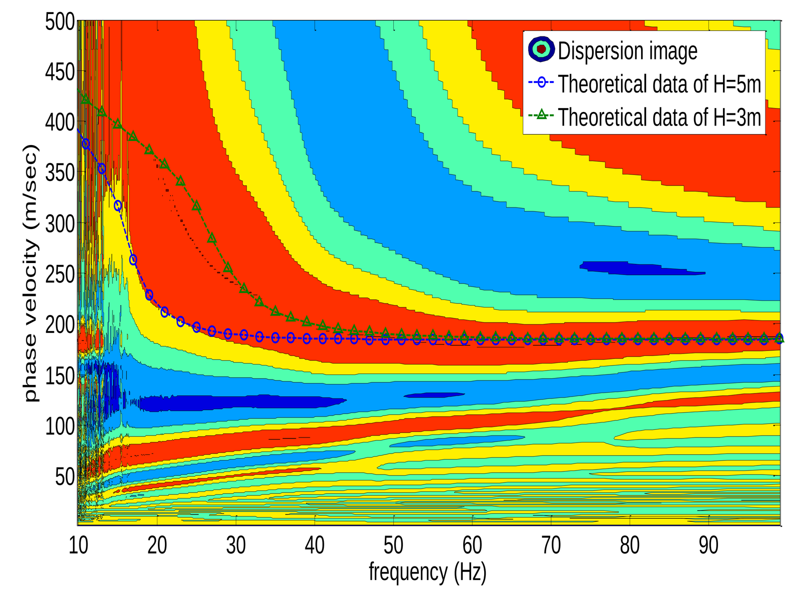

Fig. 3(c) x_1=25m; x_2=29m

Conclusions

- The estimates of the phase velocities by using the CWT method and the theoretical solutions of these synthetic examples are in excellent agreement.
- A high-resolution dispersion image is generated in this study by raising the interval of the receivers.
- The results of the study suggest that the nearer source-to-receiver offset is a non-significant parameter for extracting a dispersion image in surface wave testing.