EFFECTS OF REDUCTIONS IN NUMBER OF CHANNELS ON RAYLEIGH AND LOVE WAVE DISPERSION IMAGES ACQUIRED USING THE MULTICHANNEL ANALYSIS OF SURFACE WAVES (MASW) METHOD

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Abstract

The Multichannel Analysis of Surface Wave (MASW) method is widely used in research and practice to characterize subsurface conditions. Typically in this method, Rayleigh or Love wave are first generated using active impacts, and collected by a series of receivers. Then, the waveforms are processed to generate dispersion images that represent velocities of different frequency components in the medium of interest. The depth of MASW investigation is directly proportional to the total spread length of receivers, and one factor that controls the resolution of the dispersion images is the total number of receivers used to acquire the surface waves. It is believed that for a fixed spread length, the larger number of receivers increases the resolution. While this statement has been investigated in the literature for Rayleigh waves, little attention has been placed on the effects number of receivers on Love wave dispersion images. This paper presents results from a MASW survey that proposes to address the effects of channel quantity on Rayleigh and Love wave dispersion images with a particular emphasis on Love waves. MASW records were collected with the same fixed spread length (34.5 m) and were processed considering various receiver quantities (24, 12, 8, and 6). Results indicate that Love waves dispersion images seem to be less sensitive to reductions in number of receivers. As an example, the Love wave dispersion image acquired by considering 8 channels can practically be considered equivalent to that acquired with 24 channels. This paper summarizes site conditions, hardware configurations and testing procedure, followed by a discussion of dispersion images and conclusions.

Introduction

Multichannel Analysis of Surface Waves (MASW) has been widely utilized as a nondestructive testing method in many engineering/research applications (Park et al. 1999; Xia et al. 1999). MASW relies on dispersion of surface waves (Rayleigh or Love wave) to characterize the subsurface profile. In MASW, input signals are introduced into the subsurface and recorded by a series of receivers. In a layered medium, different frequency components travel at different velocities, which causes a signal to experience *dispersion*. An inversion process is then used to construct a profile of shear wave velocity (V_s) that matches the measured dispersion behavior. Therefore, a successful MASW survey depends on how clearly we can image the dispersion of surface waves. One of the parameters that controls the resolution of dispersion images is the number of receivers used over a specific spread length. It is well understood that the sharpness of dispersion images increases with increasing number of geophones used for recording (Park et al., 2001; Ryden et al., 2004). While this statement holds for both Rayleigh and Love wave MASW testing, little research has been carried out to evaluate the effects of less-than-ideal channel numbers on dispersion images. Some have suggested that for moderate array lengths, a 12-channel acquisition system is more than sufficient to collect quality surface wave data (Dal Moro, 2015). However, these recommendations are based on studies of Rayleigh waves dispersion behavior (Park et al., 2001; Ryden et al., 2004; Dal Moro 2015), and to the best of authors' knowledge, the effects of number of channels on Love wave dispersion images have been greatly overlooked. Correspondingly, this paper presents the results from a MASW survey performed using different numbers of active channels with both Rayleigh and Love waves. The dispersion images generated using various numbers of channels allows a direct comparison between the sensitivity of Rayleigh and Love wave dispersion images to such variations.

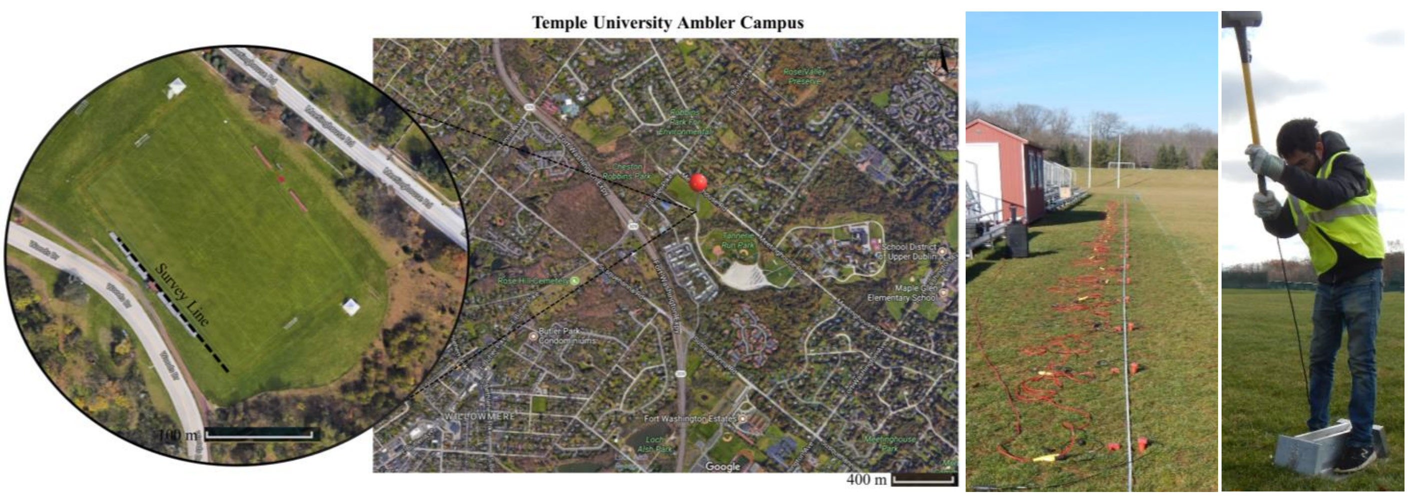
Field Testing

The testing site for this project was located at the southern soccer field at the Temple University Ambler Campus (Fig. 1-a). A 24 channel Geometrics Geode system was used for both the Rayleigh and Love wave testing. In both cases, multiple source offsets were used, though the results from only one of the offsets are presented in this paper. Generally, the data acquisition parameters were consistently maintained between Rayleigh and Love wave testing to allow better direct comparison of results. Additional details of data acquisition are presented in Table 1.

Table 1: Rayleigh and Love wave data acquisition parameters

Data Acquisition Parameter	MAS_RW	MAS_LW
Number of channels	24	24
Geophones	4.5 Hz vertical component	10 Hz horizontal component
Receiver spacing (dx) (m)	1.5	1.5
Source offset locations*	±3dx, ±6dx, ±12dx	±3dx, ±6dx, ±12dx
Impact hammer (lb)	20	20
Impact base plate	30 cm aluminum plate	Hor. Aluminum source (Fig. 1-c)
Number of averaged stacks	4	4
Sampling interval (ms)	0.125	0.125
Recording duration (s)	2.048	2.048

* Only offset -6dx is discussed in this paper.



(a) (b) (c)

Figure 1: (a) Southern soccer field at Ambler Campus (Google Maps®) (b) MAS_RW and MAS_LW setup (c) horizontal aluminum impact plate in action (inspired by Haines et al. 2007).

Results and Discussion

In all cases, the phase shift method (Park et al., 1998) was used to generate the corresponding dispersion images from the recorded waveforms. A series of Rayleigh wave dispersion images were generated from the waveform recorded using the -6dx source offset by considering different number of channels (24, 12, 8, and 6) (Fig. 2). In this manner the total spread length was kept constant while intermediate channels were removed from the record and the corresponding dispersion images were produced based on altered record. Figure 3 includes the dispersion images from Love wave data generated using the same manipulation of the recorded waveform. The two thin blue straight lines on each of the overtone images represent the minimum and maximum wavelength limits at each phase velocity considering spatial aliasing as discussed in Park et al. (1999) and Park et al. (2001). As a general recommendation, caution must be practiced when dispersion curves are constructed by picking data points located out of these two limits.

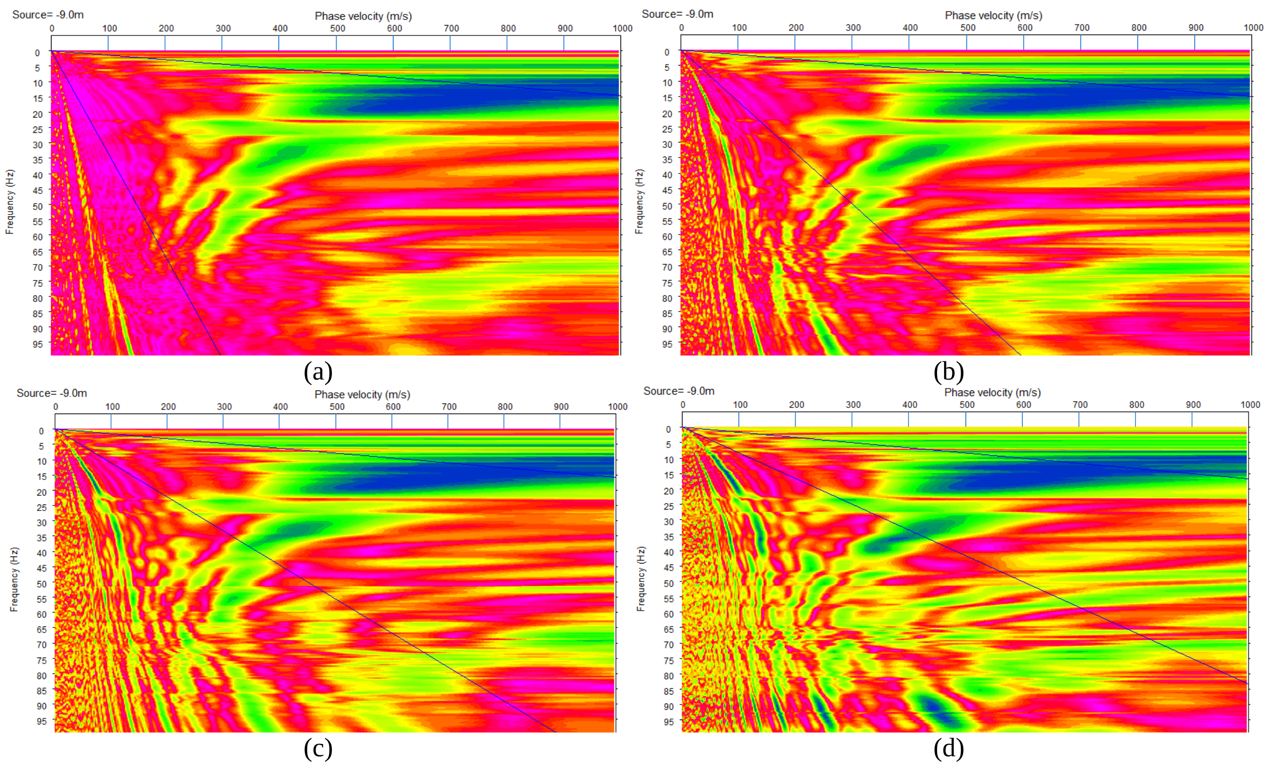


Figure 2: MAS_RW Dispersion images generated for a shot gather at offset -6dx considering various number of channels (a) 24 channels (b) 12 channels (c) 8 channels (d) 6 channels.

It is clearly evident in Figure 2 that the resolution of the Rayleigh wave dispersion images is negatively affected in an appreciable manner as the number of channels is reduced for a given survey length. However, this resolution deterioration is relatively insignificant when only half of the original 24 channels are involved. In other words, if the wavelength limits are removed, a user most likely interprets the dispersion images in Figures 2-a and 2-b in the same manner even though the latter only includes 12 channels. This observation agrees well with previous recommendations that assert the use of 12 channels may be sufficient for moderately sized array lengths (Dal Moro, 2015). In contrast to Rayleigh waves, the Love wave dispersion images seem to be much less sensitive to reductions in the number of receivers for a given array length. Again, neglecting the wavelength limit suggestions, the dispersion image from a 6-channel record (Fig. 3-d) can be practically considered equivalent to that from a full 24-channel record (Fig. 3-a). In both images, the fundamental mode is clearly evident over the same overall frequency range.

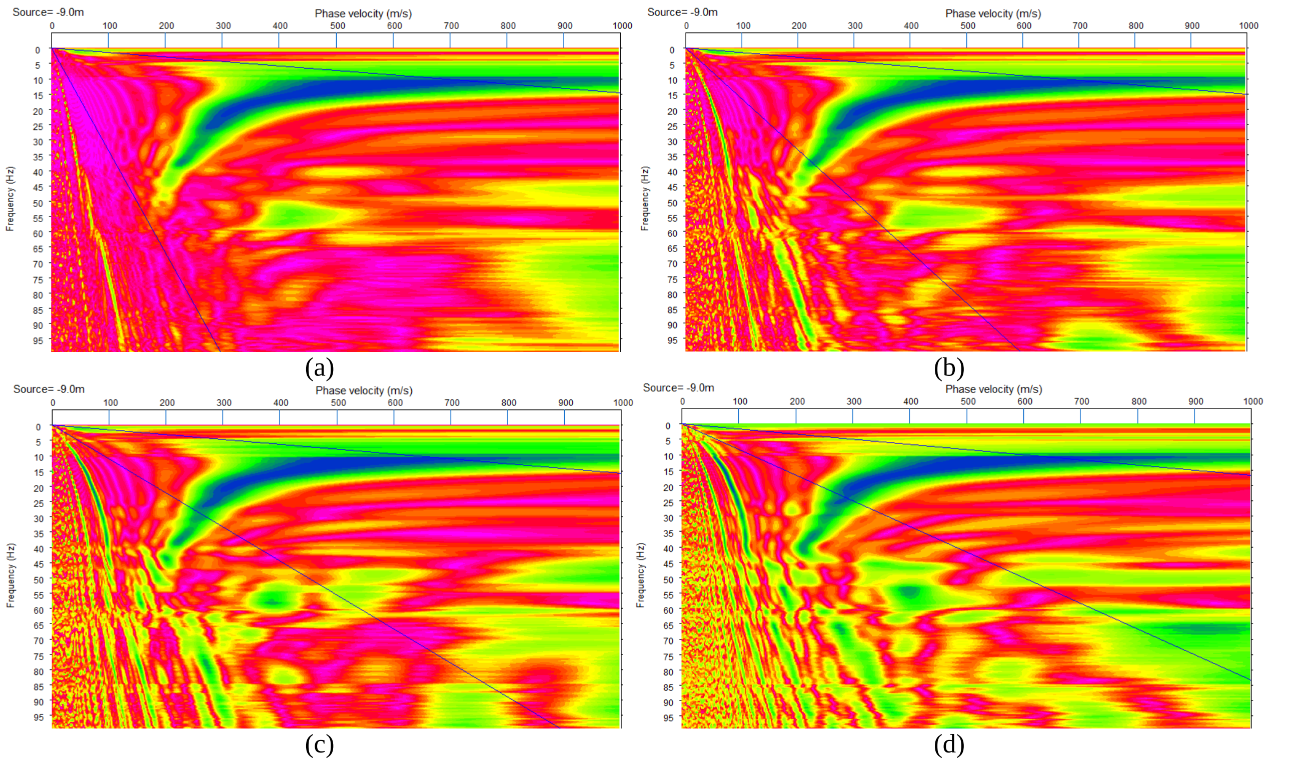


Figure 3: MAS_LW Dispersion images generated for a shot gather at offset -6dx considering various number of channels (a) 24 channels (b) 12 channels (c) 8 channels (d) 6 channels.

Conclusions

The resolution of dispersion images is a key factor that defines the level of success in an MASW survey, and is a function of various parameters. Among the contributing parameters is the total number of receivers deployed in an array. It is widely believed that "*the more geophones, the better*". This study presents dispersion images of Rayleigh and Love waves constructed with different number of receivers while the total spread length is kept constant. Results indicated that Rayleigh wave dispersion images are more sensitive to channel reductions than Love wave dispersion images. In this particular study, a 12-channel acquisition system collecting Rayleigh waves yielded practically the same dispersion image (and therefore resolution) as a 24-channel system. On the other hand, a Love wave dispersion image generated with only a third of the original receiver count was almost comparable to the original dispersion images in terms of its fundamental mode. The practical implications of these findings, especially those related to Love waves, could be beneficial to practitioners and save a considerable amount of equipment mobilization efforts during preliminary MASW surveys.

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