Comparison of Dispersion Image Resolution Acquired Using Multichannel Analysis of Surface Waves with Different Source Energy and Stacking

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Abstract. Active MASW method is a promising method to determine the stiffness characteristics of the subsurface strata. The accumulation energy to obtain high-resolution dispersion image depends largely on the energy generated from the active source. From the results obtained, the influence of different source energy, source plate and number of stacking on the dispersion image resolution were significant. Heavier source weight (e.g. 7 kg sledgehammer) produced high-amplitude energy band and provides even lower frequencies. However, if lighter source weight (e.g. small steel hammer) was used, it needs to be coupled with rubber plate to increase the low frequency content, thus generate deeper depth of investigation. Finally, the use of rubber plate and stacking increased the resolution of the dispersion image especially at lower frequencies by significantly suppressing the ambient noise.

1. Introduction
The surface wave method is used to estimate the shear wave velocity profile of soil by measuring the variations in the propagation velocities of Raleigh waves with respect to frequency. Some of the popular surface methods include Spectral Analysis of Surface Waves (SASW) [1] and Multichannel Analysis of Surface Waves (MASW) [2]. The MASW method used multi-receiver approach, thus, exploits multichannel recording and processing technique to improve the SASW method drawbacks [3]. MASW method allows relatively large volume of investigation but causes significant drop in resolution with depth [4]. The data resolution was also governed by configuration which includes the source offset, receiver spacing, total array length, source frequency content, sampling time and source strength [4-6]. The resolution of the dispersion image was critical to distinguish between the fundamental mode and higher modes, as well as to allow correct dispersion curve plotting. The higher amplitude peaks along the energy trends provide possible pick for the phase-velocities point. Despite many studies conducted to determine the optimum configurations for active MASW survey, there are still no specific guidelines for different types of soil. Most of the findings have shown that the optimum configuration was site dependant. Therefore, this study focused on the investigation of the influence of different source energy, type of source plate and number of stacking. The findings from this study is expected to contribute in the determination of the optimum configuration specifically for soft clay site.
2. Materials and methods

2.1. Location of the study area
The study area was located within the Universiti Tun Hussein Onn (UTHM) main campus at Parit Raja, Johor. The area is located within the quaternary region which consists of marine and continental deposits such as clay, silt, sand, peat with minor gravel. Borehole data obtained by Agus et al. [7] delineated that the top 18 meters of the study area consist mainly of soft clay layer.

2.2. Multichannel Analysis of Surface Waves (MASW) methods
The method used in this study is the active MASW method. Figure 1 shows the overall illustration of active MASW processes. The seismic energy was generated using three different types of source weight (7 kg sledgehammer, 1.5 kg steel hammer and 0.5 kg rubber hammer) and two types of source plate (rubber plate and steel plate) were used as impact absorber. An array of 24 units of 4.5 Hz geophone receivers were assembled to record the wave propagation from the induced active source. Two sets of geophone cables were used with each connecting 12 geophones to the ABEM Terraloc MK8 seismograph. The distance between the receivers and the nearest offset (distance of the first geophone from the impact source) applied for all tests were 1 meter and 11.5 meters respectively. The total recording time to record the wave propagation was approximately 0.8 seconds with sampling interval 100 µs. Finally, the records obtained were analysed using the SeisImager and WaveEq software and the Vs profiles with depth were generated in one dimensional format.

![Figure 1](image_url). Overall illustration of active MASW method.

3. Results and discussions

3.1. Effect of source weight and source plate
The type of source weight investigated in this study were 7 kg sledgehammer, 1.5 kg steel hammer and 0.5 kg rubber hammer. While, the type of source plates used were steel and rubber. Figure 2 (a-f) and Figure 33 (a-f) shows the dispersion images obtained from the Tun Fatimah college and RECESS site. The results obtained for different source weight shown in Figure 4 (a-c) and Figure 35 (a-c) delineated that, the increase in source weight provides greater energy especially at lower frequencies, thus provides deeper depth of investigation. Taipodia et al. [8] also found that, the frequency spectra corresponding...
to the impact from heavier source shows an energy increase all over the frequency band which contributes to the higher resolution dispersion image and deeper depth of investigation. Greater source impact and higher lower frequencies content in the source signal leads to deeper depth of investigation [9]. Whereas, for the higher frequencies, changes in source weight does not influence much on the resolution, suggesting that, for very shallow investigation (<5 meters), small hammer was sufficient to be used as the source energy.

![Dispersion images](image_url)

**Figure 2.** Dispersion images obtained using steel plate at Tun Fatimah college, UTHM; (a) 0.5 kg rubber hammer, (b) 1.5 kg steel hammer, (c) 7 kg sledgehammer, and using rubber plate; (d) 0.5 kg rubber hammer, (e) 1.5 kg steel hammer, (f) 7 kg sledgehammer.

The comparisons between steel plate and rubber plate revealed that, rubber plate generate greater resolution dispersion image especially at lower frequencies and higher low frequency content compared to the steel plate. Coe and Asabere [10] also agreed that the use of rubber materials on the source plate produced appreciable shift in low frequency energy accumulation relative to steel plate. The use of rubber plate also was able to compensate the lack of energy obtained using smaller source energy. The dispersion image resolution obtained using small steel hammer was improved significantly when using rubber plate compared to steel plate.
Overall, despite the changes in source weights and source plates, high signal-to-noise ratio dispersion images were produced at both soft clay locations compared to previously investigated peat soil area. The high signal-to-noise ratio might be governed by the homogeneity of soft clay materials. The soft clay materials were also stiffer compared to the peat soil allowing consistent impact source stackings. Thus, the impact energy generated was much stronger and able to travel longer distance with minimum energy loss which contributed to high resolution dispersion image.

3.2. Effect of number of stacking
The process of combining several numbers of dispersion images from various shots is known as stacking. According to Olafsdottir et al. [5], stacking process prior to inversion analysis is beneficial. The number of stacking was governed by the type of soil tested. More stacking was usually needed for softer materials and lesser on the hard materials. In this study 1, 5 and 10 stackings were compared. Figure (a-c) and Figure (a-c) shows the dispersion images obtained for both sites. The findings showed that the increase in the number of stackings relatively increased the resolution of the dispersion image.
at both lower and higher frequencies. Taipodia and Dey [11], Park and Shawver [12], Neducza [13] also found that the stacking increased the resolution of the dispersion image and improved the accuracy of the extracted fundamental mode curve. The wider bandwidth of dispersion becomes narrower relative to the increase in stacking numbers especially at the lower frequencies. Thus, it eases the plotting of the dispersion curve. For the soft clay condition, 5 stackings were sufficient as further increase produced constant and slightly deteriorated of the dispersion image resolution. Overall, stacking improved the resolution of the dispersion image by suppressing the ambient noise [8].

Figure 4. Dispersion images obtained using different number of stacking at Tun Fatimah college, UTHM; (a) single stack, (b) 5 stacks and (c) 10 stacks.

Figure 5. Dispersion images obtained using different number of stacking at RECESS, UTHM; (a) single stack, (b) 5 stacks and (c) 10 stacks.

4. Conclusions
An investigation to understand the effect of different source weight, type of source and number of stackings on the dispersion image resolution was conducted. The following conclusions can be made
from the findings obtained: (i) Heavier source weight (7 kg sledgehammer) leads to greater energy accumulation and higher resolution dispersion image compared to smaller source weight, (ii) the use of smaller weight (e.g. small steel hammer) need to be coupled with rubber plate to increase the low frequency content, thus increase the depth of penetration. (iii) Stacking could increased the resolution of the dispersion image by significantly suppressing the ambient noise. For soft clay location, 5 stackings were sufficient as further increase in stacking does not reveal noticeable change in dispersion image resolutions.

5. References

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Acknowledgments

The authors would like to thank the Universiti Tun Hussein Onn Malaysia (UTHM), and Ministry of Education Malaysia for their generous grant of this research, TIER 1 (U840) research grant, GPPS grant Vot number H009. The authors also would like to extend their gratitude to Research Centre for Soft Soil (RECESS) for allowing the use of research equipment and facilities.