Document	**Guidelines for *MASW, ReMi, ESAC* and *HVSR* acquisitions.pdf**
Last modified	Nov 2018
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WARNING

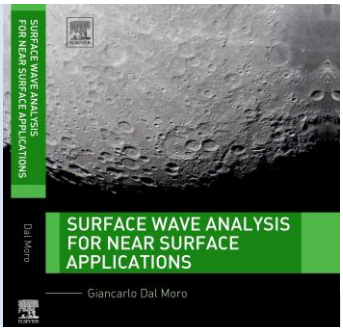
Buy and use horizontal geophones and jointly analyze Rayleigh (radial component) and Love waves!

Please, acquire the data strictly following provided guidelines and download and read the following old collection of case studies:

http://download.winmasw.com/documents/brochure_winMASW_EAGE.pdf

For more infos:

Surface Wave Analysis for Near Surface Applications
Dal Moro G., 2014
***Elsevier,* ISBN 978-0-12-800770-9, 252pp**
theory, field practice and advanced joint analysis



Basic guidelines for *MASW, ReMi, ESAC* and *HVSR* acquisitions

Foreword

The present document cannot be considered as exhaustive of the topic. What we need to know (both during field operations and in the data processing/analysis) can be fully understood only through a balanced synergy between a solid theoretical background and a long field practice.

As a consequence we recommend:

1. Robust theoretical background (books, articles and workshops)
2. Wide field practice in different soil conditions
3. Common sense (to acquire practicing the previous two points)

In general we strongly suggest not to do anything if you are not sure about.

Introduction

The acronym *MASW* stands for *Multi-channel Analysis of Surface Waves* and that clearly means that our aim is to analyze Surface Wave (SW) propagation in order to determine their dispersive properties (which will eventually allow us to reconstruct the vertical V_S profile).

The basic principle is that the lower the frequency (i.e. the longer the wavelength) the deeper the penetration (this is why we need 4.5Hz geophones). As, in most of the cases, deep layers are characterized by higher V_S velocities this will reflects in higher SW phase velocities for the low frequencies.

Please notice that SW propagation basically depends on V_S and thickness of the layers, being density and V_P almost irrelevant.

The so-to-speak classical *MASW* exploits Rayleigh-wave propagation (see Figures 1 and 2 to see how to generate and record Rayleigh waves). We strongly suggest to generate record and jointly analyze Love waves as well. This way data interpretation (thus the final V_S profile) will be much more robust also avoiding possible error in Rayleigh-wave spectra interpretation (which can be a be trickier to read – see Safani et al. 2005; Dal Moro & Ferigo 2011; Dal Moro 2012).

The joint acquisition and analysis of *MASW* (Rayleigh and Love) and *HVSR* is the suggested practice.

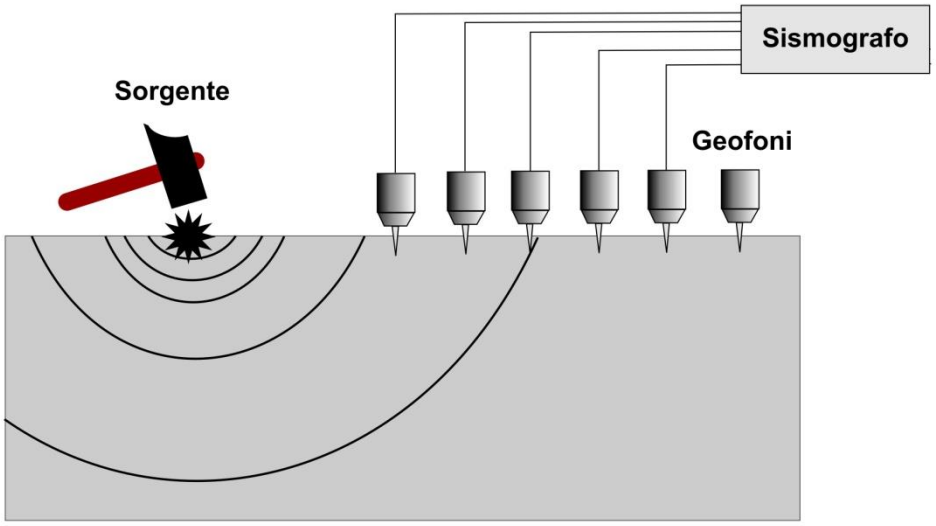


Figure 1. Seismic source. In order to acquire data useful for Rayleigh-wave analyses is necessary to deal with vertical-impact source (e.g. the very classical sledgehammer), while for analyzing Love waves (and/or SH-wave refractions) we must generate shear waves through a horizontal-component impact (see also Figures 2 and 3).

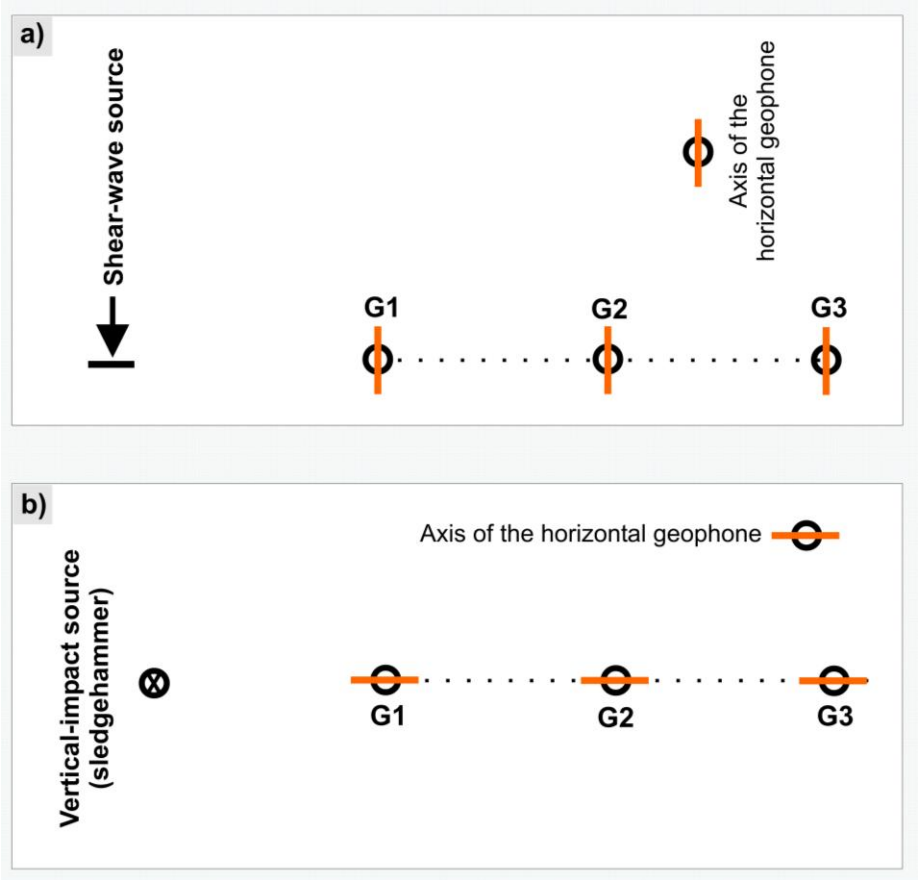


Figure 2. Data acquisition using only horizontal-component geophones: a) geophone array for SH-wave refraction and Love-wave dispersion analysis; b) geophone array for Rayleigh-wave analyses (radial component). Please notice that Rayleigh waves can be detected also using vertical-component geophones (which cannot be used for detecting Love waves).

Love waves, due to the very clear dispersion curves they produce (Rayleigh component may suffer from complex energy distribution among the different modes, annoying scattered signals

etc), they are an **extremely** useful tool for getting a more robust data interpretation and vertical V_S profile.

Acquiring Love waves is quite simple. The procedure is absolutely similar to that adopted for the acquisitions performed for SH-wave refraction studies.

Please notice that just by rotating the horizontal geophones by 90° it is possible (just using horizontal geophones) acquiring datasets useful both for Rayleigh and Love analyses (see the scheme in Figure 2).

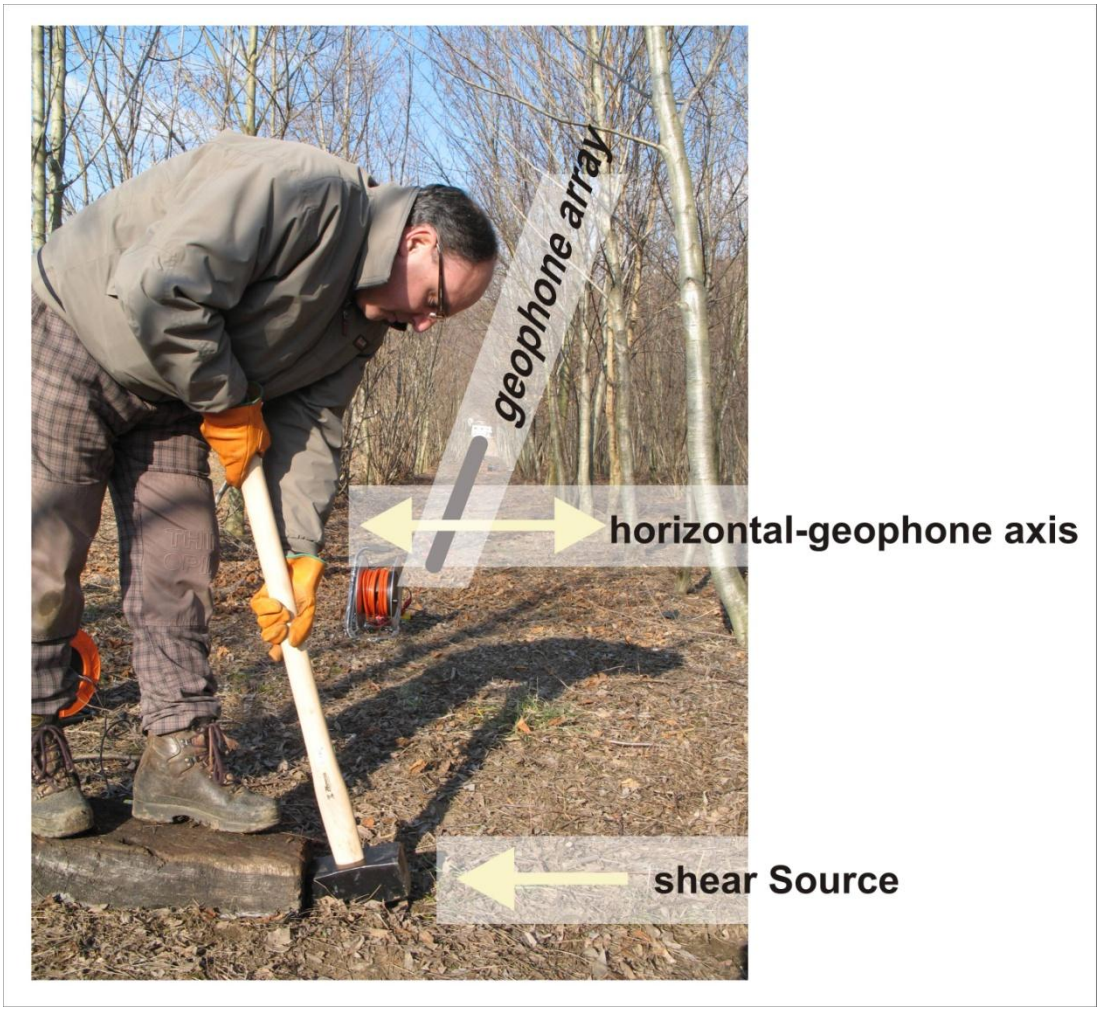


Figure 3. Data acquisition for SH-wave refraction travel time determination and Love-wave dispersion analysis (shear source and geophone-axis perpendicular to the array – see Figure 2 as well).

***MASW* acquisitions (Rayleigh and Love waves)**

Source in a *end off configuration* (see Figure 1). Suggested two acquisitions with different minimum offset (e.g. 5 and 10 meters from the first geophone).
Remember that for the lowest frequencies (related to the deepest layers) it is important to have a geophone array as long as possible (e.g. 24 geophones with 3m geophone spacing).

In case you wish to evaluate possible lateral variations you can acquire some datasets moving the source on the opposite side of the geophone array.

Down here a summary table (during our workshops we explain in details why acquisitions must be done this way).

Minimum offset (mo): distance between source and first geophone	5-20 m Suggestion: you could acquire a couple of datasets by moving the source so to have 2 dataset with two different minimum offsets. You will choose the best dataset while analyzing the data.
geophone spacing (dx)	The point is the following: the length of the geophone array must be as long as possible. If the available space is for instance 75 meters and you have 24 geophones, then you can fix the geophone distance equal to 3m (with a minim offset distance equal to 5 m)
Geophones **(4.5 Hz)**	Rayleigh waves: vertical or horizontal (axis radial to the array) Love waves: horizontal perpendicular to the array (see Figures 2 and 3) **For active (MASW) data we strongly recommend to buy just 12 horizontal 4.5Hz geophones to acquire both Love and Rayleigh (radial component) waves.** **For details please see the Elsevier book "*Surface Wave Analysis for Near Surface Applications* ".**
Record time/length (s)	2 seconds are usually sufficient (it is essential that the full surface wave trend is entirely recorded even at the very last channel/trace)
Number of channels/geophones	12-24 Less channels are sometimes sufficient The crucial point is anyway the total length of the array, possibly not less than say 50 meters, much better 70-90meters (to reach the suggested length just act by modifying the geophone distance)
***dt* (sampling rate)**	0.001s (1ms, 1 millisecond)
Important notes	No AGC (*Automatic Gain Control*) No filter Keep the same amplification/gain value for all the channels. Just be careful: do not saturate the channels close to the source and keep a good signal-to-noise ratio for the distant offsets (where the amplitude of the signal is necessarily lower) – see next paragraph

Tab 1. Summary table for *MASW* acquisitions.

Gain/Amplification

The amplification/gain should be the same for all the channels. This is not mandatory if you just need to deal with SW dispersion analyses (to estimate the V_S vertical profile). It is mandatory only to analyze seismic attenuation to estimate quality factors Q through Rayleigh-wave attenuation analysis for the very shallow part (say down to a depth of 10 meters).
Of course, in some case (if the site very noisy and the soil very attenuating) you might be forced to increase the amplification/gain of the distant offsets/channels (this is especially necessary when dealing with refraction studies where the amplitude of the first arrivals can be very small).

In case you want to analyze Surface Waves (*MASW* method) it is mandatory to avoid trace saturation/clipping (see Figure 4). In case on the field you notice such a kind of traces just lower the gain/amplification till you reach a result similar to that reported in Figure 5.

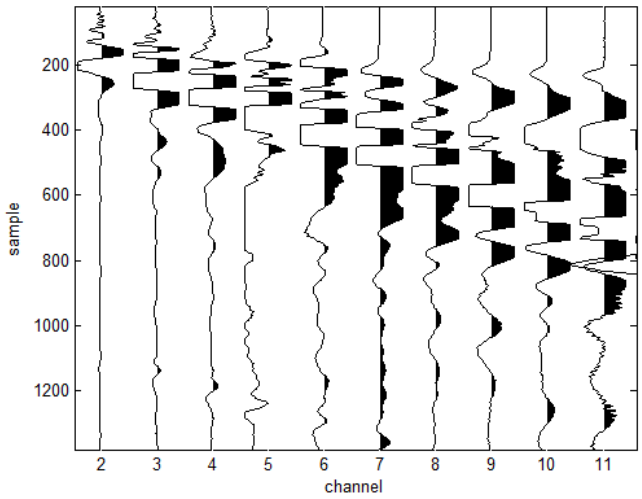


Figure 4. *Dataset* characterized by trace clipping (the amplitude is too high for the dynamic range of the seismograph: gain must be decreased).

Of course in case only 1 or 2 traces (out of 24) are clipped there is no problem!

Figure 5 reports an example of proper gain/amplification: no trace is clipped and the signal-to-noise ratio is extremely good even for the distant offsets.

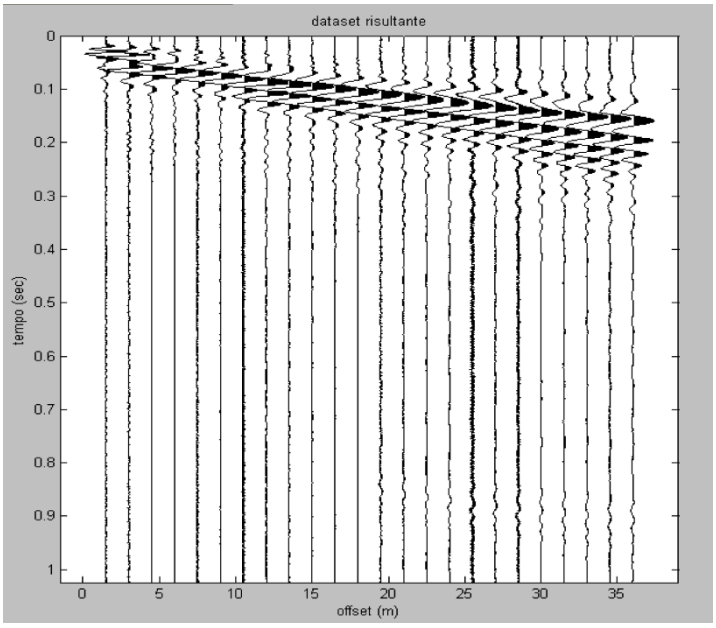


Figure 5. Dataset with a correct amplitude (gain values set to proper values).

Combining 2 datasets (to double the number of channels)

In case you have a 12-channel seismograph and want to have a 24-channel acquisition (in general terms you can double the channels of your seismograph) you can perform a double acquisition on the field and eventually proceed in their combination through the software *winMASW*.

There are 3 possible procedures to do that (see Figure 6). The first method reported (Figure 6a) is definitely the best one in terms of field procedures and accuracy of the dataset.

Clearly such a trick is not possible for passive acquisitions

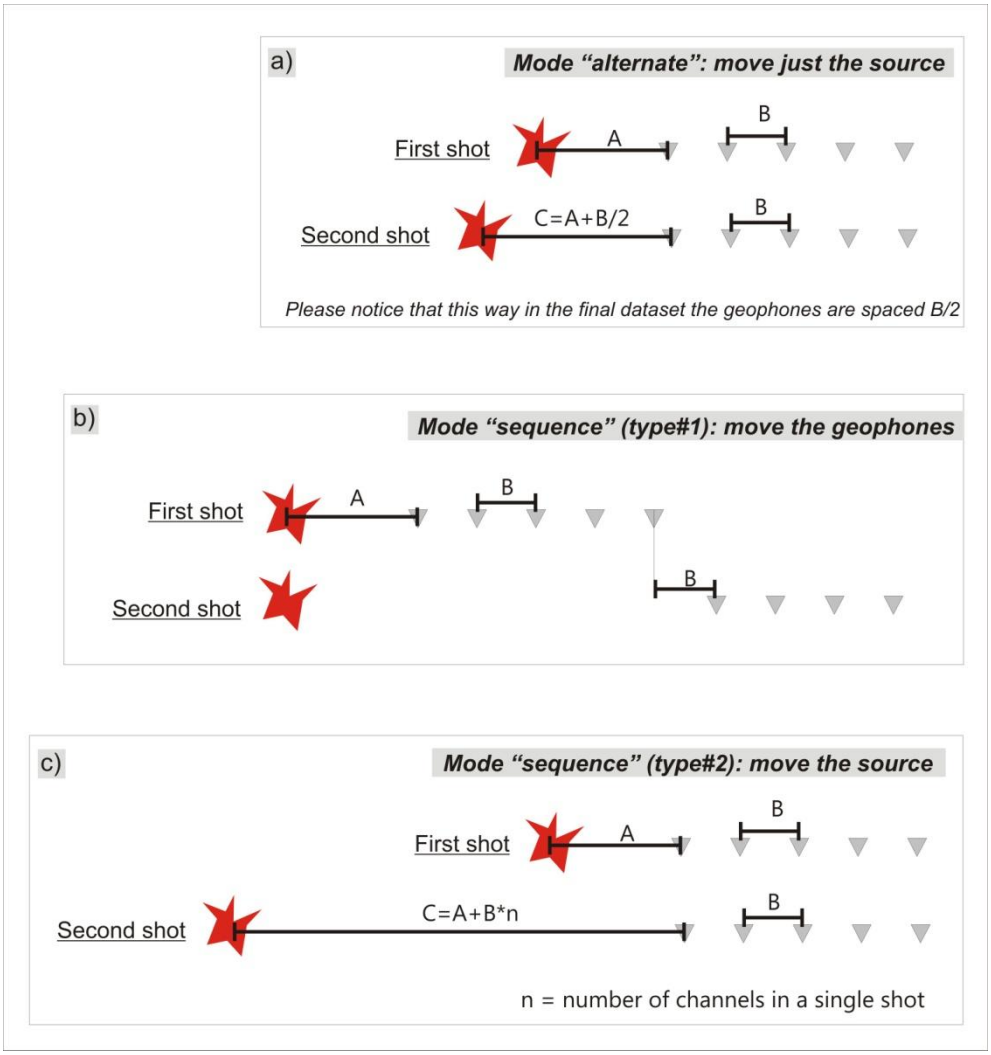


Figure 6. Three ways to combine 2 *datasets* (to obtain a final dataset with double number of channels).

A couple of notes on the process of *dataset* combination

1. Clearly, the combination of 2 or more datasets is useful for any kind of seismic study (reflection and refraction as well).
2. A *dataset* got from the combination of 2 datasets (to double the number of channels) is perfectly fine for most of the possible analyses (reflection, refraction, SW dispersion analysis) but not for attenuation (aimed at evaluating the quality factors Q) studies.

Acquiring data for *ReMi* analyses (for Rayleigh-wave analyses only)

Few important points:

1. the geophone array should be as long as possible (not less than say 69m – i.e. 24 geophones spaced each 3m or 12 geophones 6m spaced).
2. vertical 4.5Hz geophones (*ReMi* acquisitions only allow for Rayleigh-wave analyses – for this kind of (passive) acquisitions horizontal geophones can be used by with some cautions).
3. Record time: 10-20 minutes, divided into 10-15 files (each file must be not less than 30seconds and not more than 1minute long)
4. Sampling rate: 2msec
5. In case there is a particular source of "noise" (such as a motorway or an industrial facility) orientate your geophone array perpendicular to it.

Acquiring data for *ESAC* analyses

see *winMAW* manual

downloadable from our web site – http://www.winmasw.com/

HVSR acquisitions

(necessary a calibrated 3-component geophone)

Just a couple of recommendations (search for the SESAME project guidelines for further information - http://sesame-fp5.obs.ujf-grenoble.fr/):

1. record time: 20 minutes (minimum)
2. sampling rate: 8 msec (125 Hz)
3. first trace UD (vertical), second trace NS component, third trace EW component

Recommended (minimum) equipment to start working seriously

In the Elsevier book *Surface Wave Analysis for Near Surface Applications* we explain why

12 horizontal geophones (for Rayleigh + Love waves + SH-refraction)
+
one 3-component geophone (for HVSR and much more)
+
winMASW-3C (joint analysis of Rayleigh+Love+HVSR)

Note

If you send us your data for *MASW*/*ReMi*/*ESAC* (and *HVSR*) analyses, please remember to give us the necessary ancillary information: geophone distance, minimum offset and sampling rate.
If you acquired your data for passive analyses (ESAC/ReMi/HVSR/MAAM) please also indicate the orientation of the array with respect to main noise sources such as streets, industrial facilities etc.
It is also necessary to give us information about the local stratigraphy (in order to better constrain the inversion).
In case little or no stratigraphic information are available Vs30 value is still reliable while V_S for each single layer is hardly provided.

Please also provide us a photo of the site and geophone array.

Some References

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Download here the *winMASW* manual

www.winmasw.com