OPERATIVE GUIDE

MASW SEISMIC

MASW surface seismic procedure

- **General**

Geophysics exploration with surface waves allows to get S waves propagation velocity into the ground in a simple and less expensive way.

MASW method (*Multichannel Analysis of Surface Waves*) allows to determine Vs30 speed profile overcoming some limits of refraction method such as velocity inversion.

A limit to its application can be presence of significant slopes (>20°) both of topography than different elastic discontinuities. Survey does not require long time of acquisition and provides good results also in presence of noise.

Rayleigh waves, in a stratified means are dispersive, propagating with different velocities and group velocities; they are registered along geophones array after artificial energization and then are analyzed through complex computing techniques based on recognition of soil multi-layer models.

Although signal generated by a vertical point source generates also P and SV waves, *Rayleigh* waves contribution predominates because they carry about 2/3 of generated energy and because they are subject to lower geometric attenuation compared to P and S waves, given that they propagate according to spherical wave directions.

S waves analysis through MASW method is performed through spectral processing of seismogram, after Fourier transformed which provides signal spectrum.

In this domain, named transformed domain, signal related to S waves is distinguished by other signals such as P waves or air waves.

Observing frequency spectrum it is possible to notice that S wave propagates at variable speed according to its frequency, as a result of dispersion phenomenon. Once performed *picking* on *f-K* spectrum or on dispersion curve obtained by field data, through inversion process it is possible to get speed profile with depth that allows to define Vs30 parameter.

Generally active method allows to get phase velocity (dispersion curve) within frequency range of 5-10 Hz and 70-100Hz.

The whole process includes three subsequent steps:

a) recording of field data of surface waves (“ground roll”)
b) generating a dispersion curve (graphic of phase velocity compared to frequency);
c) inversion of dispersion curve to get Vs vertical profile.

Inversion of dispersion curve is then iteratively realized, using experimental dispersion curve as reference both for direct modeling and for minimum square procedure.

- **Recording modality**

Proper instruments shall be made of at least following components:
- 12 channels digital seismograph (better if 24 channels), with recording stack possibility, signal gain (in amplitude) and minimum 16 bit dynamic of A/D converter;
- for soil characterization tests, 12 (better if 24) vertical geophones with frequency equal or lower than 4.5 Hz;
- energization system to be chosen according to survey scale, usually an hammer with plate on the ground; oleo-pneumatic and/or gravity pulses seismic energizers, vibrating sources (vibrodyne) or seismic rifles can be also used.
- metric rib for a correct positioning of receivers.

Recording targets are to provide data related to surface waves propagation in a frequency band as much wide as possible, because this allows to get information on deep layers properties which influence low frequency components and to describe with proper resolution more superficial layers, which significantly influence high frequency components in particular. This implies that correct recording parameters in space and time must be chosen.

Recorded signal duration (temporal length) must be sufficient to allow pulse emitted from source (wave train) to propagate from one side of the array to the other and to naturally reduce signal on all receivers; this operation typically requires 1-2 seconds. For long arrays, time can increase.

Sampling interval must ensure estimation of interesting harmonic according to sampling rules.

Being interesting part of recorded signal typically under 100 Hz it is recommended not to select sampling frequency lower than 200 Hz (see *Nyquist* theorem). Proper sampling interval is within the range 0,5 ms and 2 ms in order to get about 1000 samples per second.

Recordings must be performed with linear *arrays* with geophones severely placed on a

straight line. Receivers must be placed at constant distance (spacing between geophones).

Given necessity to analyze in detail low frequencies (also < 20 Hz), it is recommended to use vertical geophones with shear frequency not higher than 4,5 Hz.

Given that processing analysis takes into account signal natural attenuation after its propagation into soil, when MASW superficial seismic is performed, geophones must be set all with same amplification (gain *db*).

Energization must be performed through instruments able to generate a signal relatively clean compared to background noise.

For not very long *array* a good source is an hammer beating on a metallic plate; in urban environments it could be useful not to beat in presence of noises caused by traffic nearby the array.

To increase signal-noise ratio, different energizations can be performed and then sum up obtained signals in arithmetic way.

Source position must always be external to the array and always aligned to it.

It will be placed before the first geophone at a distance so as to approximate to receivers a plane wave form; data processing phase does not provide exact values if source is too close to first geophones, so theory of plane wave form is not valid.

Usually with 1 mt spacing between geophones, energizing at 3-4 mt from first geophone it is possible to get good results. In any case, if logistics problems don't allow to have this distance, it is possible to energize also at a distance from first receiver equal to geophone spacing (1 m). MASW methodology strength is to notably reduce effect of P and S waves in *near -field* (Rome, 2001).

To have more details and given difficulty of finding an ideal plane layers subsoil in nature, it is recommended to perform a second recording phase energizing on the other side of the array.

Usually it is recommended to perform MASW survey along two orthogonal arrays, to determine 1D profile of Vs velocities in two perpendicular directions.

In presence of a slope, the array must be placed along a level curve and not along maximum slope direction.

Typically superficial layers have more evident stratigraphic variations that will be analyzed through information present in high frequencies. Therefore with source double position

there will be variations in the first meters (high frequencies) but similar results at low frequencies.

Operating modalities on field will be described below.

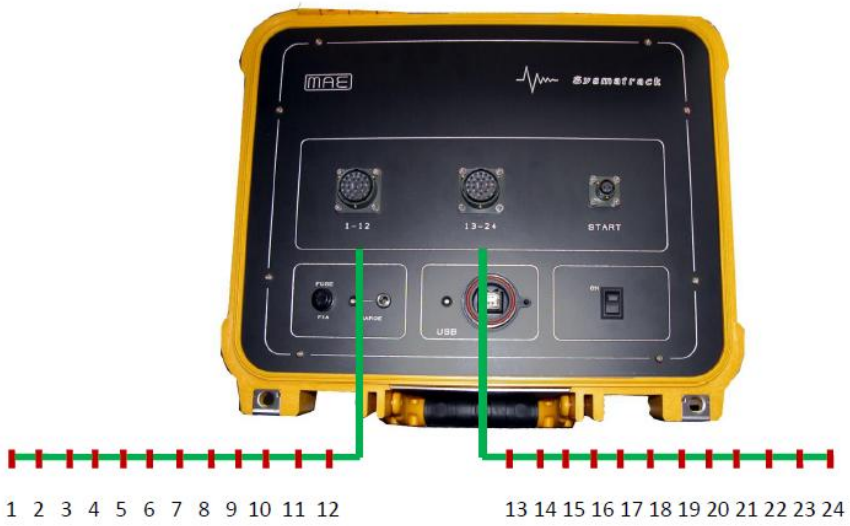
Extend metric rib for predetermined length and fix geophones with established spacing; they must be well joint with ground so as to minimize reverberation and improve signal quality.

Once placed geophones, connect them to cables paying attention to respect clamps dimensions which distinguish polarity (big with big and small with small).

It is recommended not to touch ground or other surfaces especially if wet with metallic connections.

Each cable has 12 takeouts. Seismic cable connector shall reach easily seismograph to which it is connected.

Regarding instrument position, it must be placed in the middle, between cables 1-12 and 13-24 as shown in picture. If using 12 geophones array, when space does not allow longer dispositions or for other reasons, receivers are connected to a single cable therefore instrument is placed at one side of the array.



Purex cables are represented in green color with spacing between takeouts which can be selected during configuration.
In red color geophones with related numbering are represented.

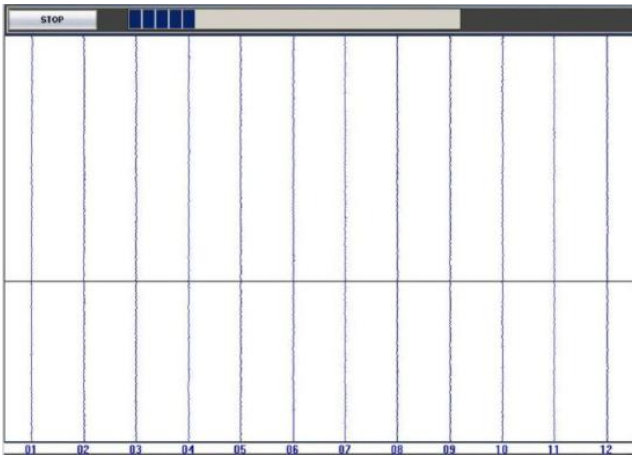
Once connected receivers and cables to instrument, place starter geophone (trigger) where hammering will occur and connect starter to extension cable which will be connected to instrument. Fix trigger at 5-10 cm distance from energization point.

In presence of flooring, asphalt, cement, or when it is difficult to fix geophones, aluminum tripods are used because they can provide good sensitivity to each single receiver.

Once completed line mounting, seismograph can be turned on and acquisition *software* will automatically start; it is recommended to advise a second operator to prepare for hammering or for shooting if using seismic gun.

Before performing measurement, check correct connection of geophones. That control is automatically implemented by instrument itself simply accessing to GEOPHONES TEST menu. The result of this operation is visualization of a screen similar to the one shown in below picture. Once concluded test, working geophones will be green while not working will be red. If some receiver is not properly connected, remove it and check its status.

It is possible to analyze background noise. In the visualized screen, selected channels from configuration menu are present (ex. 12 in picture). Consecutive recordings will be performed without waiting for trigger signal therefore visualization won't be fluid due to waiting for filling of recording memory. It is possible to perform a measure clicking on button ACQUISITION or go back to main menu with button STOP. Operation is proper in noisy sites such as urban backgrounds because it allows to select best moment for energization.



At this point, once configured recording parameters in configuration board of the instrument, we are ready to record .seg2 file which will be prepared for elaboration.

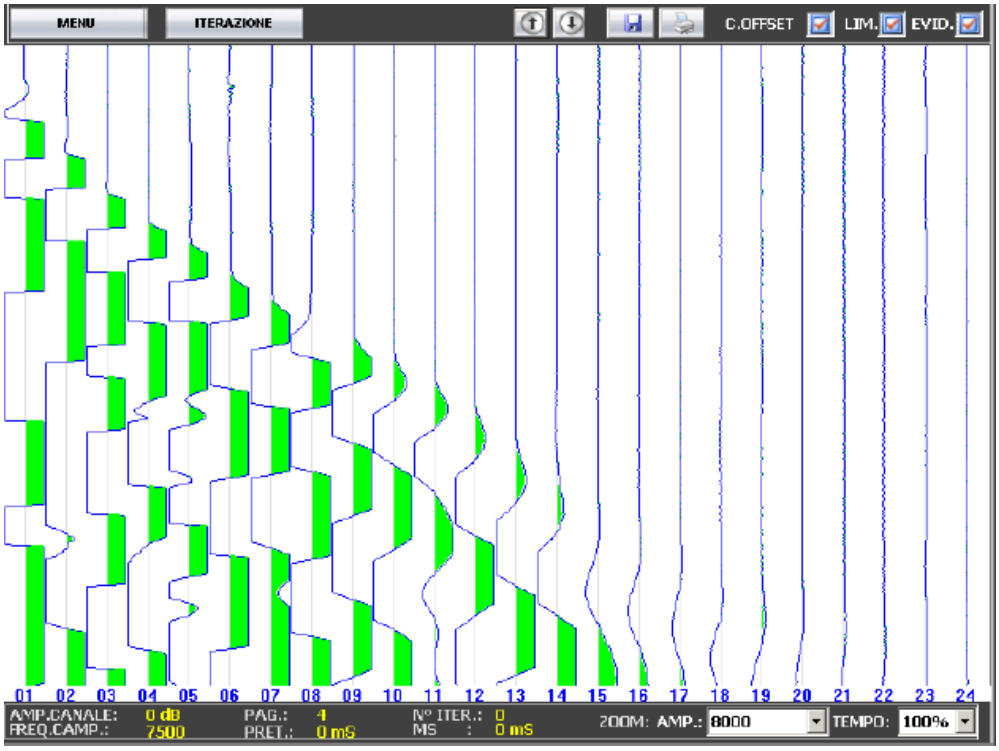
From clicking of recording button and hammering, seismograph records a file for each shooting. Once selected channels to use (12-24) for MASW surveys proper configuration is the following:

- **Sampling frequency: 1000 samples per second**
- **Page number: 4 (2 seconds duration)**
- **Trigger sensitività: 208 mV**
- **Pre-trigger: disabled**

Gain must be the same for each geophone and it is recommended to select 6 db or 12 db, especially if array is not very long.

In "fast" soils, good results can be obtained also selecting 0 db; high gain in some cases can give signal "saturation" problems.

By clicking on ACQUISITION button in main menu, instrument will wait for trigger signal and, after few seconds, a screen showing recorded signals will appear.



On wave shapes obtained it is possible to operate in order to better visualize seismograph, acting for example on times axis or on amplitudes.

Data saving on instrument can be done filling field module and related directory where file must be saved, or on external memory.