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1. SCOPE OF THE WORK

Geophysical surveys are non-invasive techniques for subsurface investigation and the proposed system consisting of a methodology known as MASW (Multichannel Analysis Surface Wave). The MASW technique is able to perform a detailed and high resolution image and parameterization of the subsurface condition.

Thanks to the proposed geophysical survey it will be possible to determine the geological sensitivity of the investigation area, by increasing the knowledge of the known geological features and the remains that can be eventually verified.

- Determine soil stiffness properties;
- Shear wave velocities for site classification (based on subsurface conditions and determine the seismic Site Classification (VS30);
- Detecting and define the subsurface geological hazards (cavities, weak zone and soft loose soil formation);
- Understand the nature and composition of the soil as the features of geotechnical concern;
- Assessment of site as acceptable for construction, locating mapping of adverse strata and give recommendations.

The seismic values interpreted through MASW technique can be reported, listed and mapped with a high degree of precision.

2. REFERENCE DOCUMENTS

- Manual for instrument;
- ASTM D6429 (Standard Guide for Selecting Surface Geophysical Methods);
- Several scientific publications;
- Project Drawing;
- Specifications.

3. STRATEGY

A preliminary phase of the work consists of gathering some known bibliographic data regarding the subsurface lithological characteristics of site area under investigation and to perform some useful correlations between the acquired geophysical data and the realistic geological model of the area. At this stage, it is important to have some borehole drilled in the same area to be able to directly calibrate the acquired geophysical data.

*3.1.*MULTICHANNEL ANALYSIS SURFACE WAVE *(MASW)*

In the seismic surveys, mechanically generated impulse from a source of energy is applied at a specific point on the earth surface to produce surface waves consisting of Rayleigh and Love waves in addition to longitudinal and transverse waves.

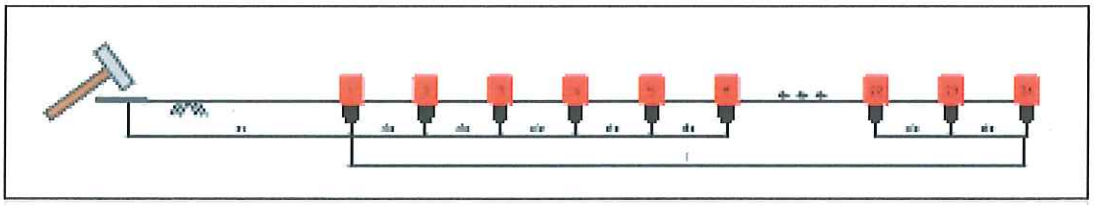

Figure 1 Illustrates MASW measurement profile.
Line up of 24 geophones with equal spacing and source positioned at an offset.

The propagation of velocity of surface wave (phase velocity) in a layered system and the depth of investigation, depends on the frequency generated at the source and on the elastic properties of subsurface strata.

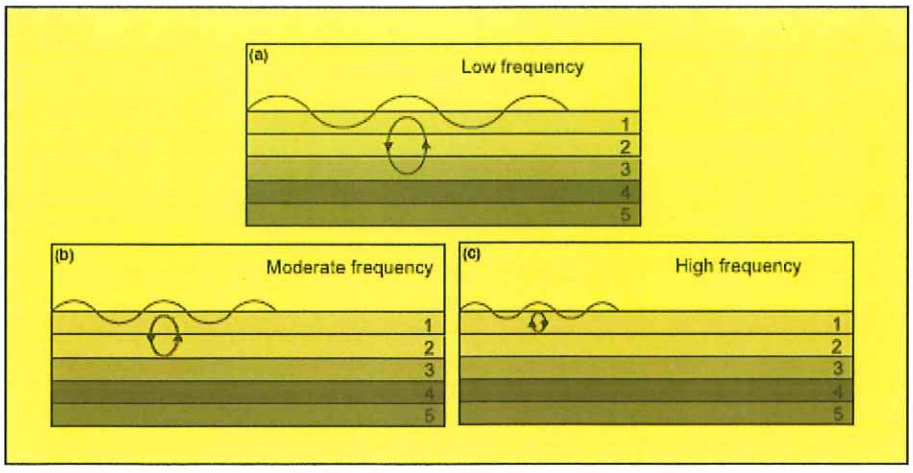

Figure 2 Depth of propagation of Surface Waves with the different Frequency

This induces dispersion or change in the shape of the wave train as it goes from the source. The curve giving the variation of the phase velocity c and wavelength λ or frequency f is called a dispersion curve. It reflects the geometry and the elastic properties of the system. The shear wave velocity of strata can be calculated from the dispersion curve obtained by assuming that the **shear wave velocity (V_s)** equal to **0.911 phase velocity (c) and layer thickness equals to (λ/2)**.

3.2 INSTRUMENTATION

For the execution of the work will be used the followed instrumentation:

a) Seismograph - The seismograph used is **AmbroGeo Echo 24/2010** channel box manufactured by Ambrogeo Instrument – Italy in a solid casing connected with PC compatible (Fig. 4).

Number of channels AD conversion	24+1 with differential input 24 bits
Dynamic range	130dB@ms PG=0dB 120dB@1ms PG=18dB
Cross talk Preamplify gain	>90dB 0,6,12,18,24,30,36,42,48,54,60,66,72dB
Frequency response	0 to 6kHz (30KSPS) 0 to 4,8kHz (15KSPS) 0 to 3kHz (7,5KSPS) 0 to 1,5kHz (3,5KSPS) 0 to 800Hz (2KSPS) 0 to 400Hz (1KSPS)
Acquisitionand display filter	Low Cut Out 10-15-25-35-50-70-100140-200280-400 Hz High Cut Out 32-64-125250 Hz Notch 50-60-150-180 Hz
Sampling Interval Record Length	32,64,128,256,478,956us 16000 samples
Stacking trigger accuracy Distortion (THD) Max Input signal	1/32 of sample interval 0,0004% 5Vpp, 0dB
CMR Noise Pretrigger data	110dB (fCM = 60Hz fDATA = 30kSPS) 0,25uV, 2ms 36dB 524ms@32us sample interval
Delay Temperature range	0 to 15 sec @1kSPS (max 16000 samples) -30°C +70°C
Power Continuous recording Output format:	12 Volt SEGY / SAF (SESAME ASCII FORMAT)

Figure 3: Technical specifications of Seiemograph

Figure 4: Ambrogeo ECHO 24/2010

b) Land streamer: 46 m cables with 24 take out mounted in land streamer configuration with 2 m interval space. (see Fig. 5).

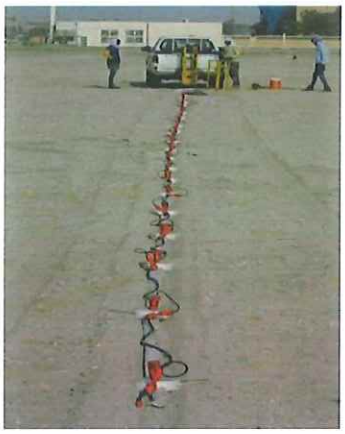

Figure 5: a) Multi Conductor Cable. b) Muller Takeout type.

c) Geophones: Geophone GEOV/ 4.5 Hz Vertical with 1 m cable.

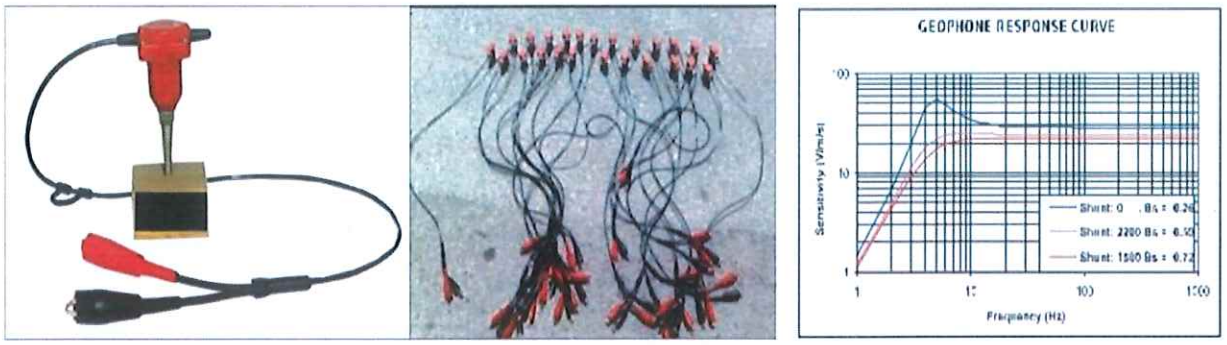

Figure 6: Geophones 4.5 Hz and response Curve.

3.3 FIELD ACQUISITION

The survey lines will be marked on the ground as per survey design at 10 m spacing.

In case the site conditions not allow the concerned survey design (i.e. Topographical conditions, unavailability of space due to man-made structures) then maximum effort will be made to increase the scope of investigations to produce satisfactory results of subsurface geology and the MASW lines may restricted at least to understand the subsurface prevailing conditions.

In filed data acquisition 24 geophones are connected to seismic cables mounted in a land streamer at takeout keeping 1-2 meter spacing between each geophone.

The source offset depends directly on the field conditions to suppress the surrounding effects in order to increase the Signal to Noise (S/N) Ratio, so in the first day of acquisition we will make the site test. The shot interval will be 6-8 meter along the lines and will be subjected to the Consultant requirement.

Seismic energy is provided by a source (shot) located on the surface; for shallow applications this normally comprises of 10 kg hammer striking a steel plate and one shot gather is recorded for each shot position on a seismograph and mass drop mutable from 70 to 120 kg can be used in case the presence of noise; if it is necessary, the record will be executed with a stack of more shots. After the first position, the entire configuration of shot and 24 receiver spread will be shifted forward: the shifting will be decide after the test. This movement allows simulation of a 24 channel roll-along acquisition mode moving one receiver spread ahead of the other. Shot point started from first place and continue to up to the end of surveyed line. The sample interval will be 1 msec with 1.024 samples for a record length of 1 sec approximately. During the acquisition all the filters are kept opened.

The investigation depth will reach 20-25 m b.g.l.

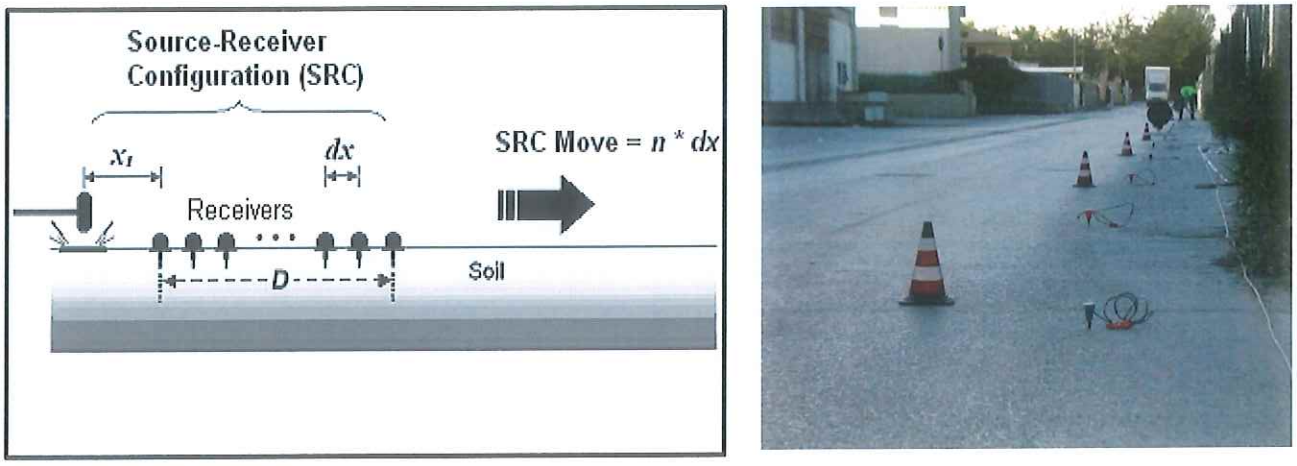

Figure 7: Example of geometry of acquisition.

3.4 Limitation of MASW Survey

The general limitations of the geophysical MASW method are as follows;

- Surface waves are best generated over a 'flat' ground at least within one receiver spread length (D) then; overall topographic variation within an entire survey line should not matter. However, any surface relief with dimension greater than 10% of 'D' will cause a significant hindrance to the surface waves generation.

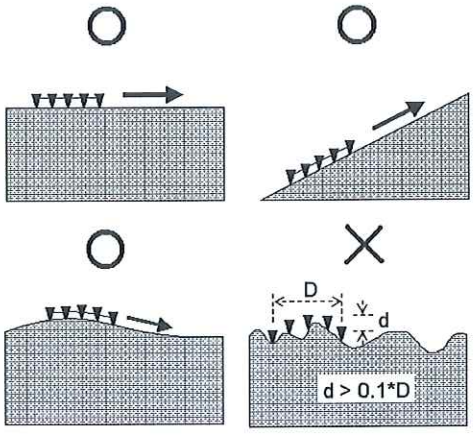

Figure 8: (taken from Kansas Geological Survey KGS)

- Highly irregular surface topography adversely affects MASW as shown in the above figure and in these areas normally refraction or reflection seismic is recommended as S-waves are independent of morphological changes.
- The theoretical foundations of the method MASW refer to a half space laminated with parallel and horizontal , then a limitation to its applicability could be represented by the presence of significant slopes more than 20 ° , both of the topography and of the different elastic discontinuity .
- MASW method require linear topographies and floor layers parallel but very easy to perform in localized or confined environment as compared refraction seismic where large space is required for geophone installation.

3.5 Processing (Data Analysis)

After field acquisition the data will be processed with advanced software called SURFSEIS rel. 5.2 manufactured by KGS (Kansas Geological Survey).

The following processing steps are performed.

- Edit shot gather;
- Conversion data into processing format;
- Assign field geometry;
- Defines the surface waves travel (**t**) time and distance (**d**) on computer (**T-D** Domain).
- Transform data from **T-D** domain to Frequency (**F**) –Wave number (**K**) domain
- Pick Peak Frequency and Wave No. Values
- Calculate phase velocity (**c**) = **f** (frequency)/**λ** (wave length) to produce phase velocity dispersion curves.

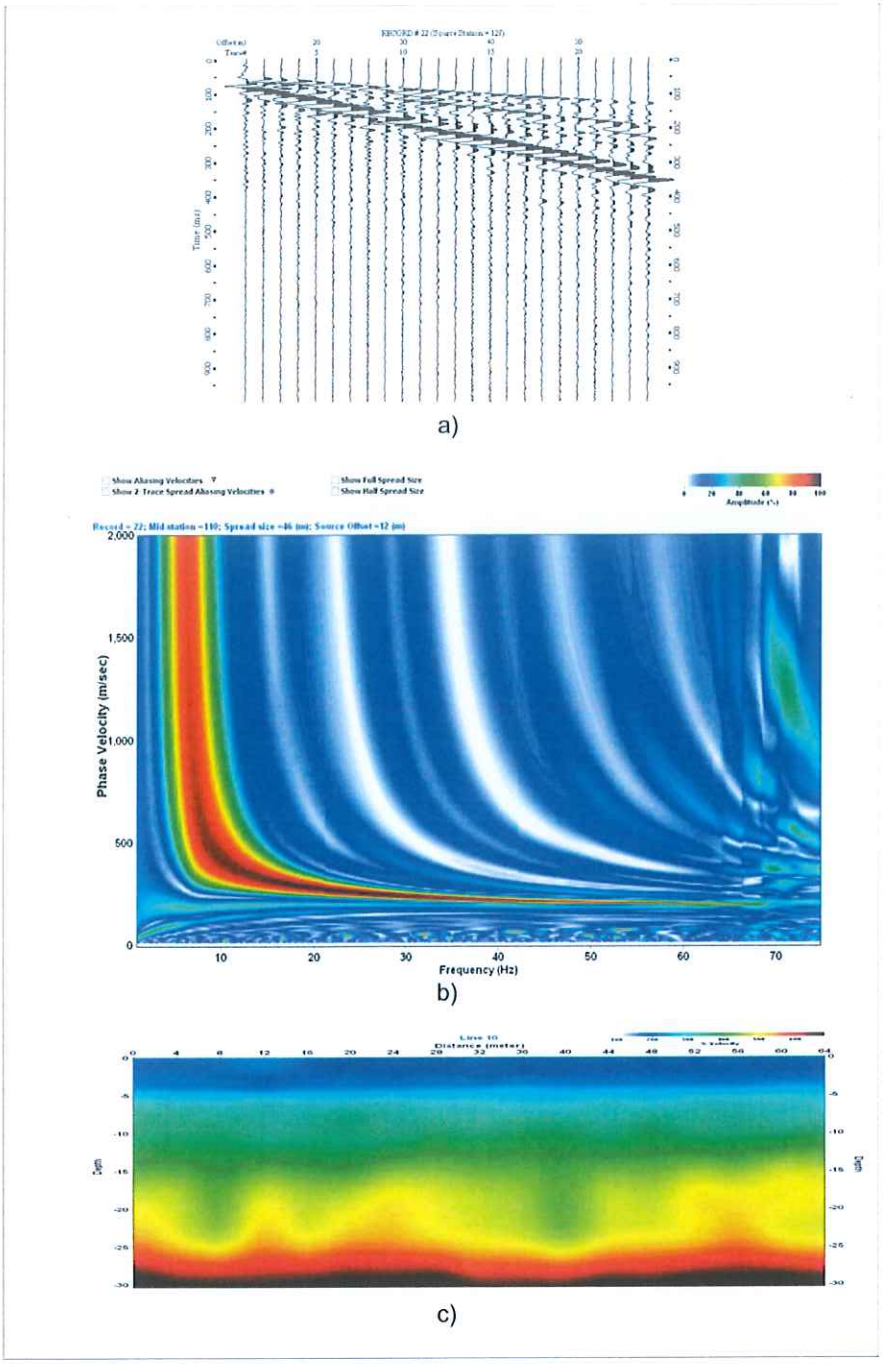

Figure 9: Exemple of processing: a) Field data; b) Dispertion curves) final section.

Construct 2D Vs map from the inversion using an appropriate 2D shot gather; the remaining gathers are converted and combined into a single file with sequentially increasing field records. Station numbers for source and receivers are assigned to each record in the combined files; all the geometry encoded records are recompiled into the equivalent roll-along mode data set. Several records are selected from different locations

along the surveyed line and their dispersion characteristics; application of a band pass filter on the original 24 trace common shot gather and calculate the F-K transform, velocity spectra.

Each record is analyzed to generate a dispersion image with the fundamental mode dispersion trend identified and a signal dispersion curve extracted based on the image identified. After the dispersion curves have been extracted, they are inverted to generate one dimensional (1D) Vs profile from each dispersion curve. The Vs profiles so calculated are assigned the station location in the middle of the receiver spread. When all the profiles 1D are obtained, a 2D interpolation is used to have the final 2D Vs map.

4. FINAL REPORT

Final Report is submitted as per the requirement of the Consultant. The minimum contents of the report are as the followings:

- Preface include the Data Area, Client Data, scope of the work, synthesis of quantity of the work performed;
- theoretical concepts in brief;
- Acquisition mode and instruments utilized;
- Processing Data;
- Results;
- Conclusion with recommendation.

Appendix:

- Master Plan;
- Site Plan and location of surveys done;
- Results with Sections and interpretation;
- Photos.

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