MASW method applied to study the seismic structure beneath a future metro station in Brasília: Preliminary Results

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In this paper the geophysical method MASW (Multi-Channel Analysis of Surface Waves) was applied to study the seismic structure beneath the location where should be built a station in the future northern section of the metro of Brasília. This method uses the dispersive characteristics of surface waves to define variations of S-wave velocities in the depth. The data used was previously acquired in a study applying seismic refraction. As results of this study some 1-D S-waves velocity profiles were obtained along the studied line. In our results we observed two distinct layers. The interface between those two layers is consistent with that one found with the seismic refraction results.

Introduction

The geophysics can be applied to guide geotechnical studies, always aiming to minimize the job time and cost. Geophysical acquisitions are performed near the surface and are indirect and non-destructible, which makes such methods a more affordable option than traditional direct soundings. However the geophysical methods will not substitute completely the use of boreholes, due to associated ambiguity and possible limitations (CAVALCANTI et al., 2011; COSTA and MALAGUTTI-FILHO, 2008).

Seismic methods using surface waves to generate shear wave velocity profiles (Vs) are relatively new. The MASW method (Multichannel Analysis of Surface Waves) has emerged as an evolution of SASW method (Spectral Analysis of Surface Wave), introduced by Nazarian and Stokoe (1983), which consists in analyzing dispersive characteristics of surface waves to generate subsurface profiles. The SASW method uses two receivers, a seismograph and a surface wave source, but the large amount of time required to perform a data acquisition and the low signal to noise ratio due to noise caused by body waves (direct, reflected and refracted waves) and higher modes makes this seismic technique laborious and resulting in low signal to noise ratio. The use of MASW solves the problem of the amount of time required for a data acquisition due to greater coverage of research and depths using multiple receivers without changing its configuration. Furthermore, the noise effect related to body waves and higher modes are minimized and the interest signal is highlighted.

The goal of this Paper is to use the MASW method to study the S-wave velocity distribution in depth in a location where should be built a metro station in the future northern section of the Brasilia metro. It is intended to compare the MASW results with the Seimetz et al. (2013) conventional seismic refraction results.

The Surface Wave Method

The methods that utilize surface waves are mainly based on dispersion properties. The dispersion phenomenon occurs in a heterogeneous and stratified medium, which presents different propagation values of seismic wave's velocities (Figure 1). The energy (or amplitude) of the surface wave decays exponentially with the increasing of depth (Gandolfo 2014). When seismic waves are generated near the surface of the Earth, P and S waves and surface waves are generated.

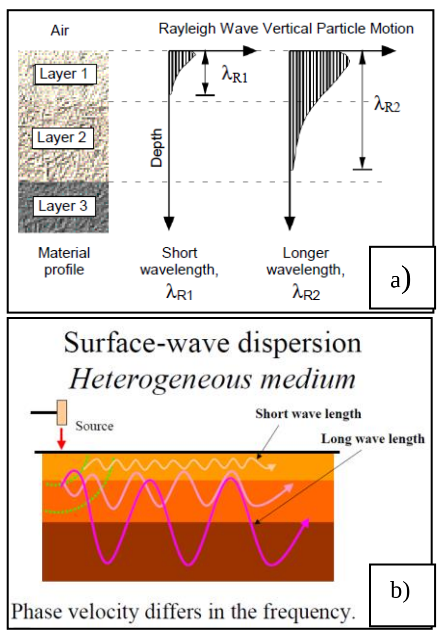

Figure 1 – a) Different wavelengths penetration depth (GEOVISION 2014). b) Different wavelengths propagation (HAYASHI, 2003)

Surface waves have distinct properties from body waves. Due to its different wavelengths it have different penetration depths and propagate with different velocities. It is generally said that the higher frequencies provides information of the shallow layers and lower frequencies provides information of the deep layers (Figure 1). The effective depth penetration of the MASW method is directly related to the seismic array length, and the effective depth penetration is described as the largest wavelength divided by two, admitting that the largest possible surface wave wavelength is equal to extent of our seismic array.

The velocity of propagation for each wavelength is called phase velocity and it is dependent of the velocity of the shear wave (Vs) in the medium, and slightly influenced by the velocity of propagation of the compressional wave (Vp). Furthermore, the phase velocity depends on the density (ρ) and Poison ratio (σ). It is generally assumed that the Rayleigh wave (ground roll) velocity is 92% of the S-wave velocity (Stokoe et al. 1994), thus:

$$Vs = \mu/\rho \quad (1)$$

and in Poisson's Solid

$$\frac{Vp}{Vs} = \sqrt[2]{3} \approx 1{,}73 \quad (2)$$

Analyzing the dispersion of surface waves is possible to develop S-waves velocities profiles near the surface following three main steps (Figure 2): acquisition of ground roll wave data, construction of dispersion curves (processing) and inversion of S-wave velocities

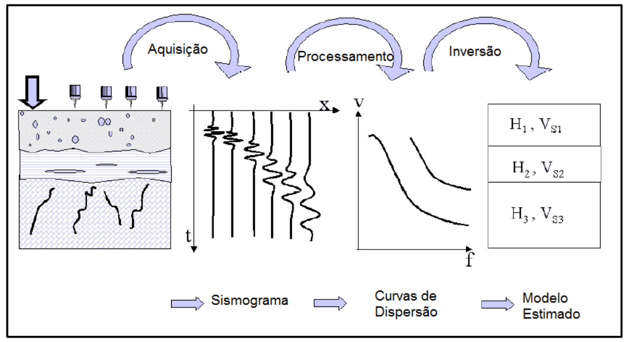

Figure 2 – Main steps of MASW method (modified from Strobbia, 2003)

Studied Area

The city of Brasilia is located between the south latitudes 15º30' and 16º03' and the west longitudes 47º25' e 48°12'. The study site is inside of the expansion area of the Brasilia metro, next to the Asa Norte Block 116 (SQN 116). The investigated section has a total length of 590 meters (SEIMETZ et al, 2013).

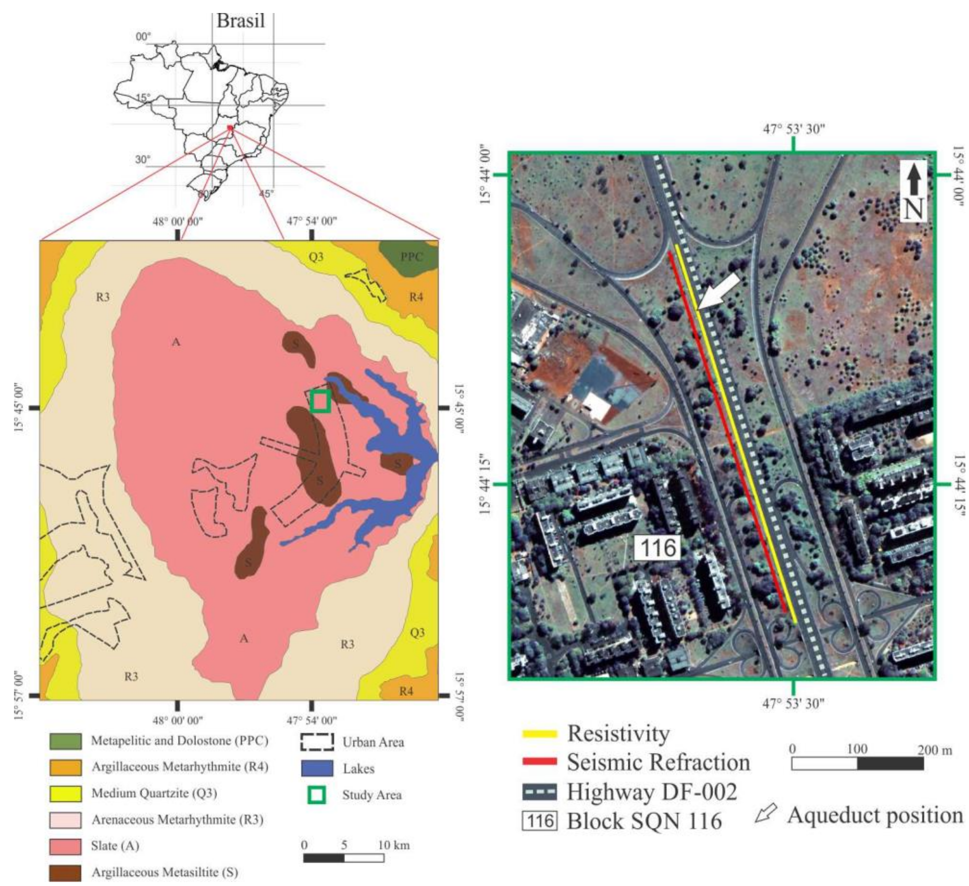

Figure 3 - Location of seismic line indicated by the red line (SEIMETZ et al., 2013) and Simplified geological map of the Paranoá group (FREITAS-SILVA and CAMPOS, 1998; modified by SEIMETZ et al., 2013).

The predominant soil in Brasilia is the Red Latosol (EMBRAPA, 1978). A regionally study of Brasília was made by Freitas-Silva & Campos (1998). The study area is located inside of the Paranoa Group (Figure 3), where occur only two geological units of this Group: Argillaceous Metasiltite (S), Slate (A).

Methodology

The data acquisition occurred only on Sundays because the traffic in the highway DF-002 is normally interrupted by the city administration for the leisure activities of the citizens. The idea was to reduce the level of seismic noise caused by car traffics and also to spread the instruments crossing the access path to DF-002, also interrupted in those days.

To implement the refraction method in this work six profiles were performed in sequence, each profile with length of 94 meters, having a total length of 584 meters (Figure 1). During the acquisitions were used 48 channels with geophones of 14 Hz, spacing two meters between them. The positions of the seismic sources for each line were -2, 47 and 96 meters away from the first geophone. A sledgehammer with eight kilograms was used as source. It was hammered 20 times against a metallic plate at each shot point in order to increase the signal/noise ratio by summing the signal generated by each impact. The equipment used for data acquisition was a GEODE seismograph (Geometrics Inc).

Results and Discussions

Figure 4 shows an example of the acquired seismogram, the obtained dispersion curve, interpretation of the velocity spectrum (dispersion curve) and 1D S-wave velocity model. The software used for data processing and inversion was Seisimager/SW.

In our results we observed two distinct layers with different S wave velocities. These results are comparable with those obtained by seismic refraction method by Seimetz et al. (2013) in the same area. The first layer was interpreted as soil and embankment, since the study area is located in the construct-influenced area of the DF-002 highway. The second layer was interpreted as the weathering mantle (saprolite). Figure 5 correlates the area geological model created by Seimetz et al. (2013) with our 1D S wave velocity profiles.

The first layer had a Vs velocity average of approximately 200 m/s, followed by a transition zone having a Vs velocity between 210-250 m/s and finally the layer with saprolite have an average Vs velocity of 270 m/s. The interface between the soil layer and the saprolite layer was identified between 4.5m and 7m which agrees with the previously results of seismic refraction.

As the S wave does not propagate in liquid media, we can confirm that the observed interface refers to the geological material in the subsurface and not to the top of the water level as suggested by Seimetz et al., 2013.

We had problems with the sixth line data that was inadequated to process, perhaps due to problems during its acquisition and it presented unwanted noise. The time window of 500 ms used in our data acquisition was not ideal, since we may have lost longer wavelengths which propagate reaching greater depths, and consequently, our data do not provide to detect deeper structures.

Conclusions

The MASW method showed satisfactory results to map shallow geological structures when compared to other geophysical methods normally applied in geotechnical problems, such as seismic refraction and resistivity. Our generated models quite approached to the seismic refraction results obtained by Seimetz et al. (2013). Based in our results we concluded that the seismic interface observed in both seismic methods do not represent the top of the water level, indicating only the changing of the geological context.

For the acquisition using the MASW method, the used data time window was small, causing loss of the long periods, limiting the depth of investigation.

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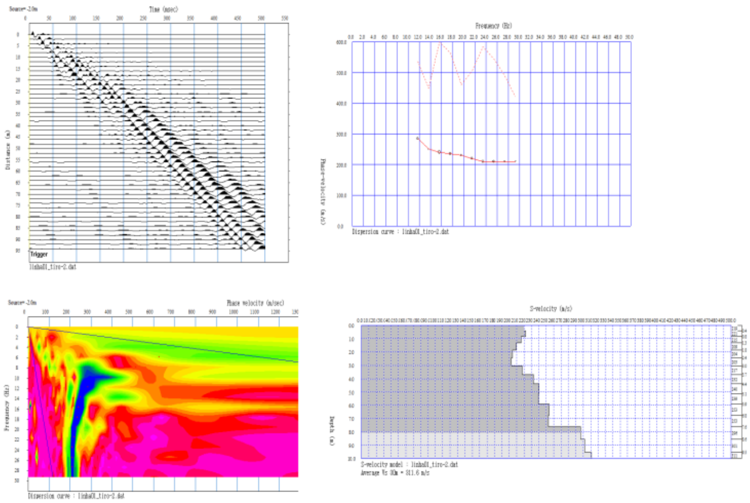

Figure 4 –Seismogram, interpreted dispersion curve, velocity spectrum and 1D S-wave velocity profile.

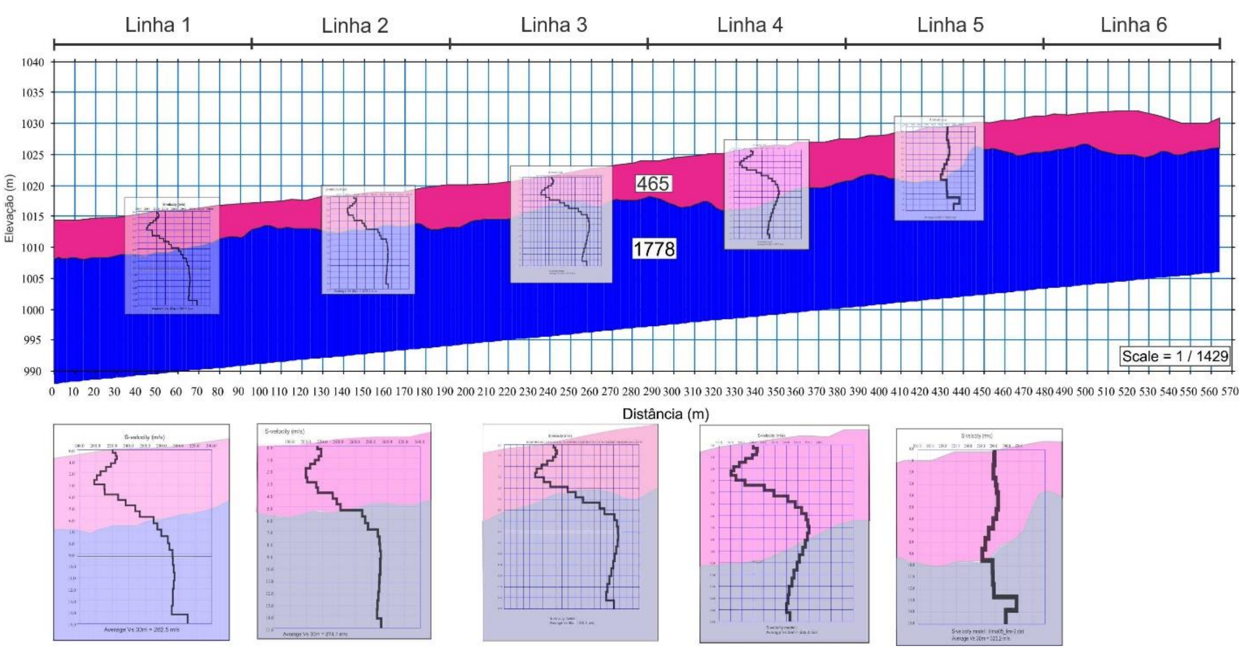

Figure 5 – Comparation between the MASW method results and seismic refraction results by SEIMETZ et al. (2013)