APPLICATION OF HIGH-RESOLUTION SPAC TO IDENTIFY DEEP DIPPING LAYER IN NORTHERN BOGOTA

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Abstract

In linear construction, such as bridges, the spatial variability of soil properties plays an important role in defining their foundations. When it comes to lacustrine deposits of soft clays, such as those located in the Northern Bogotá, active methods have great resolution in the upper few meters, but they don´t have a good penetration. In those cases, passive surface wave methods have several advantages over active methods, allowing characterizing deep soil deposits.

We use SPAC survey methods in northern Bogotá, to delineate geological structure associated with dipping layers. This paper summarizes data acquisition and analysis of passive surface wave data. Seven 1 Hz geophones, added forty-one 4.5 Hz geophones were used to perform high resolution SPAC at three locations. Data acquisition mainly used an L-shape array with geophone spacing of 4 m. One lineal array was also measured to complete information in a narrow urban space. Recorded ambient noise data were processed using spatial autocorrelation method (SPAC) and clear dispersion curves were obtained at all locations. Minimum frequency from 0.8 Hz and maximum frequency from 20 Hz were clearly identified, that shows a great compromise between penetration depth and resolution. Dispersion curves obtained from the linear array are generally consistent with those obtained from L-shaped arrays. Non-linear inversion was performed and 1D Shear wave velocity (Vs) models were obtained. The method penetrated to a depth of 100 m and provided 100 m cross sections along the site of interest. The interpretation focused on identifying the change of colluvium and bedrock depth, which were found at 45 and 80 meter, respectively and shown a dip angle between 12 and 16 grades in western direction. Resultant Vs profiles are generally consistent with borehole logs and existing geological information.

Introduction

The results of a study to determine the spatial variability of lithology in the foundation of a pedestrian bridge in an urban area, located north of Bogotá, are presented. When it comes to pedestrian bridges, the Colombian construction code has the same requirements as for vehicular bridges, among which are both the depth of research, as well as an analysis of unidimensional or two-dimensional site effects.

In seismic site effect analysis, knowledge of the near surface shear wave velocity profile is crucial. Such velocity can be obtained from geotechnical and geophysical surveys by applying active seismic methods in situ, surface wave dispersion measurements and borehole measurements, as well as from geotechnical surveys and laboratory tests. In deep soil deposits such as those found in the Bogotá basin, traditional methods have limitations in terms of resolution, penetration depth and costs. Microtremor survey methods to evaluate the Vs profile at specific sites, are becoming more and more popular. Those methods use the constant ambient vibrations of the ground generated by human activities (at frequency $f \geq 1$ Hz) or natural phenomena (at $f \leq 1$ Hz) as the source of energy. The microtremor survey methods are noninvasive and their source of energy is continuous in proximity to urban agglomerations, which is very good for urban environment.

The bridge is located in the northern lacustrine zone of Bogotá, but less than a kilometer from the eastern foothills. According to geological information, in this area the tectonic effects have generated abrupt changes in rock depth, which increases considerably in an east - west direction (**Figure 1**).

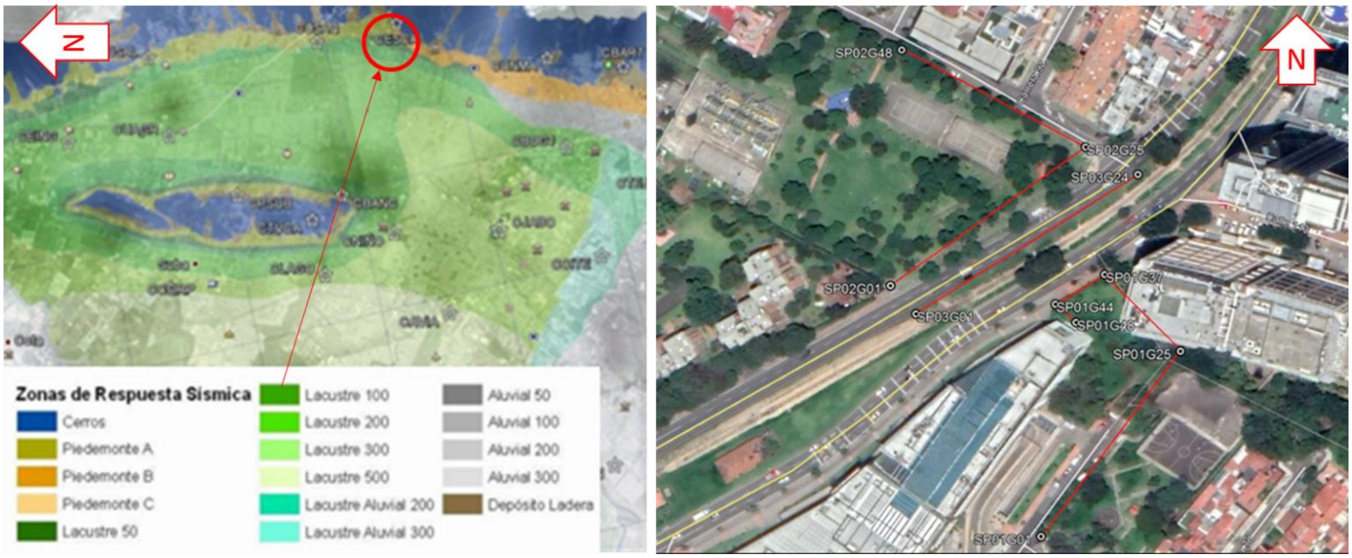

Figure 1: Site location and seismic response map zonation of Bogotá city (Ingeominas, 1997; Google Earth, 2019)

Background and proceedings

In this study, we used SPAC analysis. The background theory about those methods is not discussed here, but can be found in Aki (1957) y Tokimatsu (1997).

Microtremor observations were recorded in September 2019, using a maximum 240 m aperture array composed of 48 receivers located at the surface has been considered. The minimum distance between receivers is 3 m. At each site we used 41 4.5 Hz (RT Clark) and 7 1Hz (OYO Geospace) sensors in L shape configuration. This can be one of the most convenient arrays when working in highly urbanized areas.

In most cases the sensors recorded 60 minutes of continuous noise, sufficient to ensure reliability in the observed coherency spectra computed with a limited number of sensors. From these records, dispersion curves were obtained using a standard SPAC processing, with surface plus software developed by Geogiga®. Figure 2 shows a typical array used for this research.

Results & discussion

The upper part of **Figure 2** shows the dispersion curves obtained for three SPAC performed at the site. It is important to note that dispersion curve has a high resolution even at frequencies lower than 2 Hz. It can be noted that there are variations in the three curves, which moves to lower frequency values towards the SPAC located to the west. The most important thing is that when using 48 channels, it has a high resolution up to frequencies of 20 hz, allowing you to identify higher modes in the shallower layers.

The lower part of **Figure 2** shows the inverted Vs profiles for each SPAC. The empty circles show the values of Vs obtained from correlations with the NSPT. From surface and up to approximately 3 meters deep, a layer with average Vs of 140 m/s was identified, which corresponds to anthropic fills. Underlying this layer and up to approximately 20 meters deep, average Vs of 100 m/s, allow to establish the presence of very soft silty clays of the Sabana formation. Below this layer, Vs increase to 150 m/ s, which can be attributed to the presence of granular materials of alluvial-colluvial origin. This layer extends to a depth of 40 meters on average. At a greater depth, Vs values of 280 m/s and 615 m/s are observed, which corresponds to the presence of the colluvium and the weathered rock, respectively.

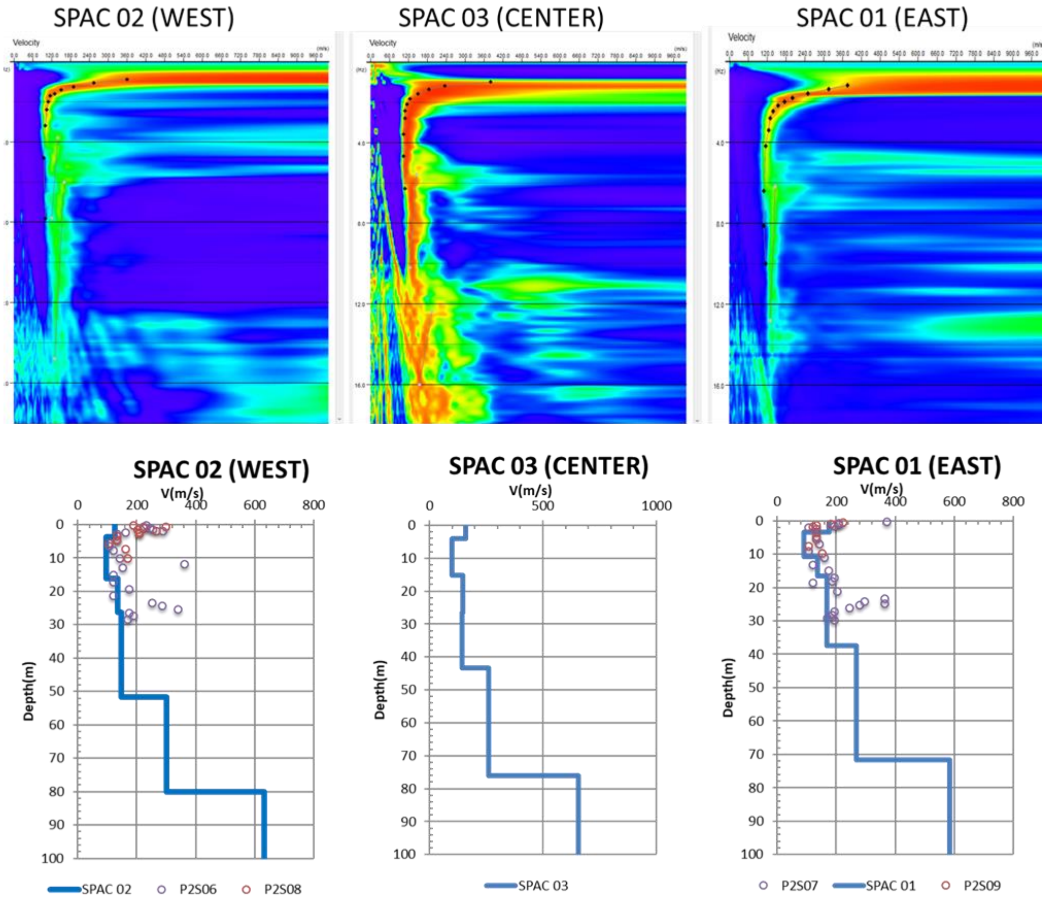

Figure 2: Power spectrum and dispersion curves (Up) and Vs profiles for each SPAC (Bottom).

Figure 3 shows the geological interpretation of the Vs profiles. For this interpretation, previous information was provided on a borehole with continuous recovery, located in the center of the longitudinal profile. Soil laboratory tests and facies analysis to determine the origin of each geological formations were also performed. There is a very good correspondence in the results of the velocity profiles obtained with SPAC survey methods and the geological information obtained for borehole loggings.

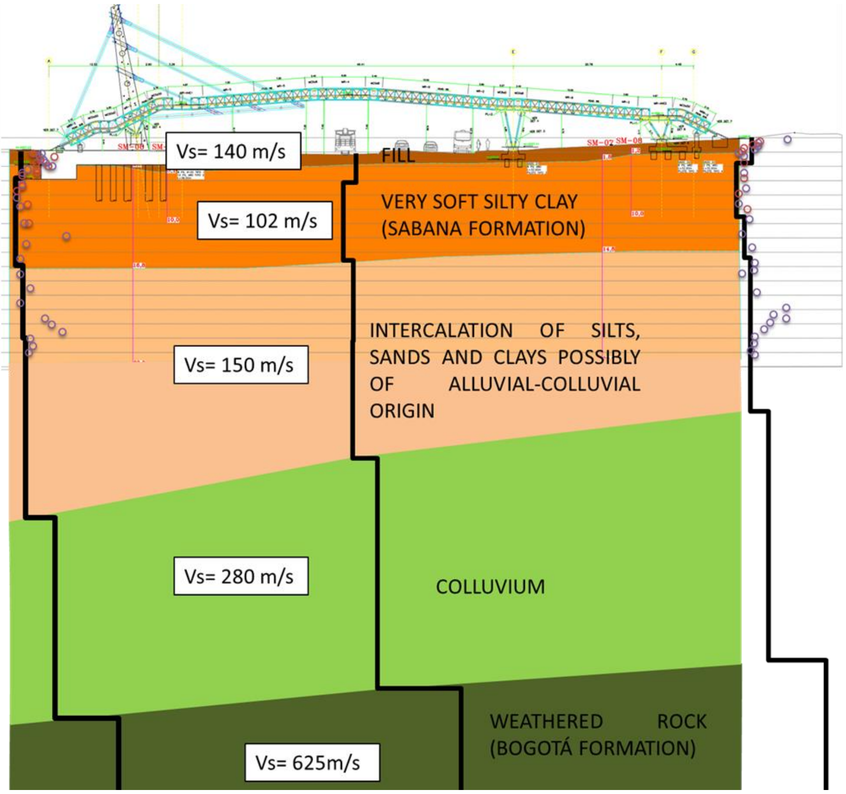

Figure 3: Geological interpretation of Vs profiles for the bridge site.

Conclusions

The results obtained show that the High-resolution SPAC surveys are very useful to obtain the velocity profiles of shear waves, especially for deep soil deposits, such as those located in Bogotá city. Combination of multiples survey has enough resolution to identify deep dipping layers in the soil.

The method penetrated to a depth of 100 m and provided 100 m cross sections along the site of interest. Colluvium and bedrock depth, were found at 45 and 80 meters, respectively and shown a dip angle between 12 and 16 grades in western direction. Resultant Vs profiles are generally consistent with borehole logs and existing geological information. Results showed that SPAC method can be used for a better characterization of the spatial variability for deeper layers in the Bogotá basin, quickly and cheaper.

References

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