Elaboration of a geotechnical model using geophysical methods: Case of the future northern section of Brasília metro - Preliminary Results

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Abstract

In this work we present the preliminary results in geophysics research using seismic refraction, resistivity and ground penetration radar, executed between the pathways of Eixo Rodoviário (DF-002) and Eixo Rodoviário W in the northern part of Brasília, where will be realized the future construction of the north stretch of the metro. The object of this study is to generate a geophysical/geotechnical model to provide a geological structure and mark areas with structural weakness. The geophysical results allowed identify three distinct geotechnical layers: Soil (depth < 3 meters), saprolite 1 (depth < 10 meters) and saprolite 2. In the resistivity results we show a conductive vertical anomaly, which we believe to be a weakness zone, however, is possible that this anomaly could be related with the presence of the gas station near the area.

Introduction

The importance of geophysical studies in geotechnical problems is the fact that their results can be used for guidance on what procedures may be adopted to minimize: time, cost, and even the occurrence of accidents at work. The main advantage of using geophysical methods for any type of application, is that these are indirect methods, in other words, provide information in subsurface geological structure, without the use of boreholes.

In engineering projects, the financial cost for the geotechnical surveys represents the highest part of the budget, which turns attractive the use of the geophysical techniques. There are several studies using geophysical methods in engineering problems, as in the detection of ancient foundations (e.g. BOUDREAULT et al., 2010) and planning on building a new neighborhood (e.g. KHALIL; HANAFY, 2008).

The geophysical methods commonly used in geotechnical studies are: seismic refraction (e.g. PRADO, 2000), resistivity (e.g. BRAGA, 1997; LOKE, 2004) and ground penetrating radar (e.g. DAVIS, ANNAN, 1988; PORSANI, 1999; GRANDJEAN et al., 2000).

This work used geophysical methods in a stretch of the Asa Norte of the Plano Piloto, Brasilia (**Figure 1**), with the objective to generate a geological model for the region based on physical measures, which may be used as additional information for the planning of the subway, and also with the objective of verifying the effectiveness of such methods in urban areas.

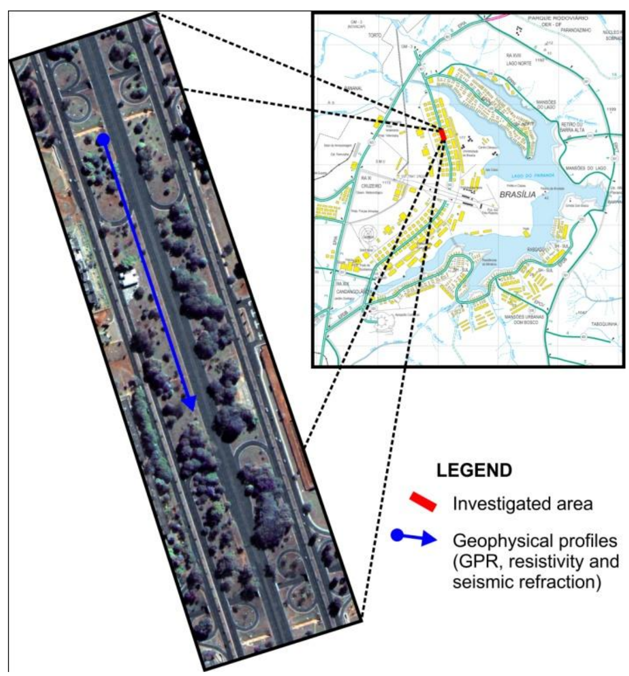

Figure 1. Location of geophysical investigations conducted between the blocks SQN 108 and 109, in the future northern section of the Metro, Brasilia.

Methodology

The expansion of the subway in the Asa Norte will be between the Eixo Rodoviário Norte (DF-002, known as

"Eixão"), and Eixo Rodoviário W Norte (known as "Eixinho W "). The data where acquired between these two pathways (**Figure 1**). The surveys where acquired on Sundays due to the fact that Eixão is closed by the city administration to the population, which brought down the level of seismic noise caused by cars traveling there, and also for security of procurement staff.

In this work were used three geophysical methods: seismic refraction, resistivity and ground penetration radar (GPR).

Seismic Refraction

The seismic refraction method is based on the propagation of mechanical waves generated by artificial sources, such as hammer, seismic rifle, among others. These waves are detected by receivers (geophones) fixed on the ground. This method allows determining an average mean speed of seismic wave's propagation of the medium; it is possible to distinguish layers with different elastic characteristics, and providing an estimate of the depth of the interfaces that separate these layers.

To implement the refraction method in this paper were carried out three profiles in sequence, each where 115 meters long, totaling 345 meters (**Figure 1**). We used 40 Hz geophones with 24 channels, spaced five meters between each one. The positions of the sources for each line were -25, -5, 57.5, 120 and 140 meters considering the first of each geophone as position zero. A sledgehammer, with eight kilograms, was used as source, hammered 30 times against a steel plate at each point in order to increase the signal/noise ratio by summing the signal generated by each impact of the sledgehammer with the ground. The equipment used for data acquisition was a Geometrics Geode brand. For the data processing program was used SEISIMAGER 2D (OYO Corporation).

Resistivity

This method is based on the fact that the environment presents a resistance to the passage of electrical current. They are normally used by four electrodes (two current and two potential) for the measurements of current flow and the electric potential generated by it. Knowing the position of the electrodes on the surface, and obtaining the readings of current and potential, it is possible to measure the electrical resistivity of the medium.

For this work we used the multi-electrode resistivity SYSCAL PRO 72 (manufactured by Iris Instruments) with 60 electrodes. The electrode arrangement selected was dipole-dipole; it showed better sensitivity to the bedrock (Loke, 2004). We also used the procedure of roll-on 120 meters, leaving the profile with a total length of 415 meters (**Figure 1**). The spacing between the electrodes was 5 meters and the acquisition protocol enabled the imaging of 30 levels deep (40 meters). The data were processed and modeled with the software RES2DINV (Geotomo Software).

Ground Penetrating Radar (GPR)

The Ground Penetrating Radar (GPR) transmits and receives electromagnetics pulses to generate images of the subsurface. The images are generated by measuring the travel time of reflected waves at the interfaces between the medium. The frequency of electromagnetic waves in the GPR equipment ranges from 10 to 2500 MHz. The lower the frequency, the greater the depth of penetration, and the higher the frequency, the more detailed the image (higher resolution), but with a shallower depth.

The data acquisition in this work was used a GPR SIR 3000 (manufactured by Geophysical Survey System, Inc) connected to a shielded antenna of 200 MHz. The spacing between the traces was 2.5 cm, and a time window of 250 ns. The GPR profile has a total length of 415 meters (**Figure 1**). The data were processed using the software ReflexW 5.5 (SANDMEIER, 2010), and the conversion speed of the electromagnetic wave was 0.09 m/ns (obtained after adjustment of hyperbolic points diffractor found in the section of GPR).

Results

Seismic Refraction

The results showed high levels of seismic noise due to car traffic in Eixinho W, besides the presence of pedestrians and by the small movement of trees due to wind, generating low frequency noise. These noises made it difficult to determine the first arrival of seismic waves to the farthest geophones located from the source, generating a lot of ambiguity in the marking phase.

In the seismic profile resulting (**Figure 2**) identified two layers. The first presents an average speed of 359 m/s, interpreted as the speed of the soil. Its depth varies between 2 and 15 meters. The second layer has an average speed of 1190 m/s, interpreted as saprolite 1 (mantle of alteration) low iron (C1), with depth ranging from 2 to 25 meters. The composition of the soil and saprolite 1 should be linked to packages of purple slates that occur in Paranoá Group (BLANCO, 1995).

Resistivity

The resistivity 2D section (**Figure 3**) represents a medium with heterogeneous characteristics. The thin layer on the surface of the profile was interpreted as the soil, with high resistivity (greater than 1000 Ωm) and with depths between 1 and 3 meters. Just below, there is another geoelectrical layer with an average resistivity of 350 Ωm and with an average thickness of 9 meters, which is interpreted as saprolite 1. The third layer is more resistive (above 1000 mΩ) and is interpreted as the saprolite 2.

At positions 160 to 190 meters we observed a conductive vertical zone, which at first was interpreted as a fracture zone, due to its depth. New profiles were acquired in other areas along the Eixinho W and the conductivity anomalies were also detected nearby gas stations. Due to these new results we believe that this anomaly isn't related to a facture zone. In each gas station exists daily activities of car wash, which were close to the profiles. For this reason we could attribute this anomaly as to water percolation into the soil. However, this anomaly may also be related to the metallic gas tank of each gas station, but in this case exists a depth inconsistency, because the tank is buried in a swallow depth (around 10 meters), and the observed anomaly appears until 35 meters depth.

Ground Penetrating Radar (GPR):

The GPR results (**Figure 4**) allowed only imaging the surface layers (up to 7 meters) due to high electrical conductivity of saprolite layer 1. However, as expected, the GPR allowed the identification of surface interference (underground pipes).

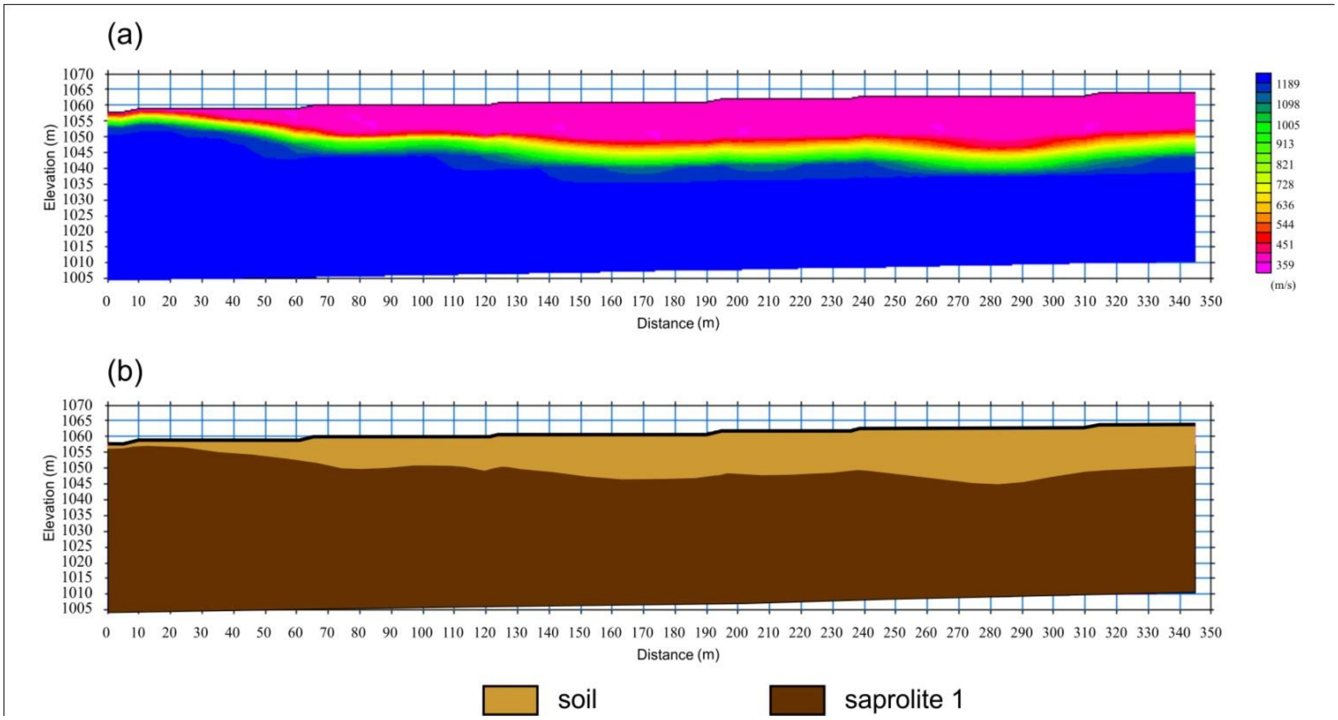

Figure 2. (a) Velocities model of P-wave obtained with the method of seismic refraction. (b) Geotechnical model prepared from the results of seismic refraction.

Conclusion and Discussion

The results of seismic refraction showed the difference between the soil and the saprolite 1. However note the need to acquire new seismic data with a source more powerful in order to increase the signal/noise ratio and reduce ambiguities during the marking of the first arrivals of the third layer observed with the other methods. As the main difficulty in interpreting the data is related to the high noise level.

The resistivity results allowed to define the main geoelectrical layers occurred in the profile. The top layer has a high electrical resistivity, which may be a consequence of the low water content in the pores, since the acquisition was made in the dry season. The second geoelectrical layer presents a low resistivity, and must be related to the saprolite 1. Alves (2009) described this layer as a clayey package, which explains the electrical behavior mentioned above.

The third geoelectric layer must be related to the saprolite 2, which corresponds to a more compacted material package due to the chemical weathering of the slates of the Paranoá Group. The conductive anomaly that occurs in the resistivity section has been interpreted as a zone of water percolating of the soil. We believe that this anomaly is due to the presence of car wash at each gas station located next to our profiles.

The GPR results showed less efficient for this study, since the objective depth is 40 meters. The electromagnetic signal has been attenuated due to the high conductivity of saprolite 1, but was efficient to identify the interference surface. And it could be applied to location of existing underground pipe.

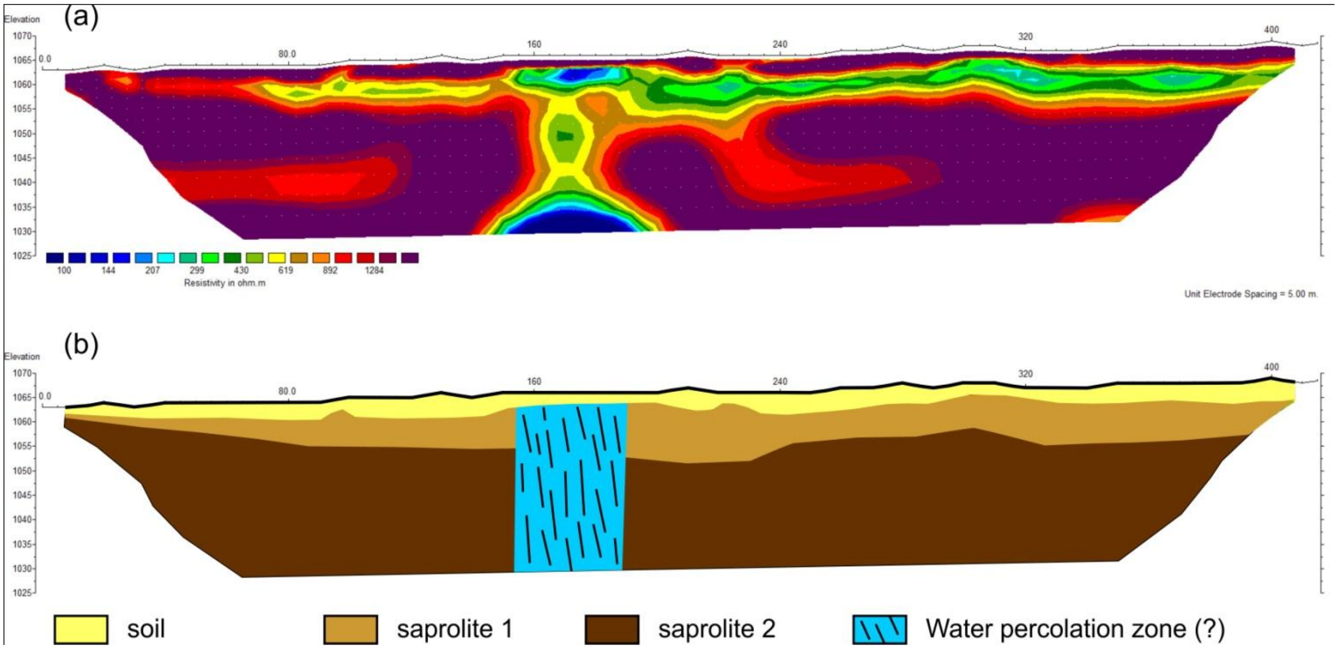

Figure 3. (a) Electrical model obtained after the modeling of 2D resistivity data. (b) Geotechnical model prepared from the results of 2D resistivity, showing the layers of soil, saprolite 1 and 2 and a possible percolation of the water into the soil.

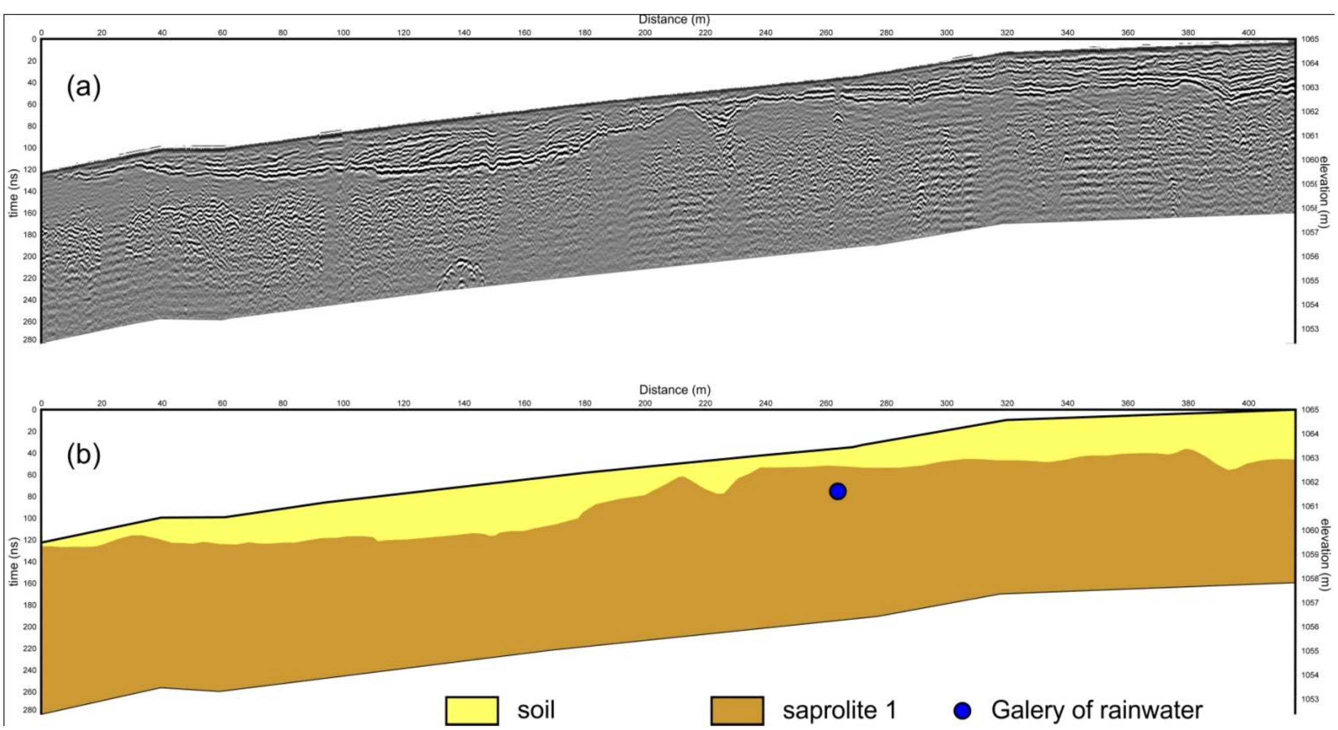

Figure 4. (a) GPR section showing the main reflectors up to 7 meters deep. (b) Geotechnical model prepared from the results of GPR, showing the layer of soil surface and a gallery of rainwater.

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