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# CHARACTERIZATION OF CASCAIS COUNTY SURFACE FORMATIONS USING MICROTREMOR MEASUREMENTS

Joana F. CARVALHO[1], Paula TEVES-COSTA[2] and Luís ALMEIDA[3]

Cascais is a coastal town located in a privileged place of Portugal. Its distance from Lisbon takes only 30 minutes by car. It is surrounded by a lot of cultural places and also has amazing beaches. The Cascais County is sub-divided in four different parishes – Alcabideche, Carcavelos e Parede, Cascais e Estoril, São Domingos de Rana – which together sums a population of approximately 206,000 people with a rising tendency.

The social and demographic characteristics of Cascais and the damaged caused by the 1755 earthquake and tsunami, make this town a place that deserves our attention concerning the seismic risk exposure.

In this paper we present a study of soil characterization based on the analyses of seismic refraction measures with the Refraction Microtremor technique (ReMi) (Louie, 2001) to evaluate shear wave velocity profiles on different sites in Cascais County. We tried to reach all the parishes in order to measure at least one seismic profile in each one, taking in account the different surface geological formations.

Mainly, Cascais County is characterized by the occurrence of sands, limestone and marls formations (Ramalho et.al. 1999). Based on this information we selected the places to perform the measures trying to focus on softer formations more susceptible to site effects occurrence (Table 1).

Table 1: General information about the seismic refraction profiles.

| Number of seismic profile | Location | District | Geological Context |
|---|---|---|---|
| 1 | Carcavelos | Carcavelos e Parede | Areolas de Estefânia (sandstone) |
| 2 | Caparide | São Domingos de Rana | Benfica (sandstone, mudstone and conglomerate) |
| 3 | Areia | Cascais e Estoril | Marine Terraces deposits |
| 4 | Alcabideche | Alcabideche | Rodízio (sandstone, conglomerate) |
| 5 | Alcoitão | Cascais e Estoril | Cresmina (sandstone and marl) |
| 6 | Alapraia | Cascais e Estoril | Alluviums deposits |
| 7 | Pai do Vento | Alcabideche | Regatão (sandstone, pelite and dolomite) |
| 8 | Oitavos | Cascais e Estoril | Cabo Raso e Guincho (limestone) |

Soil characterization is a very important issue from the seismological point of view, especially when talking about an area exposed to seismic occurrences. Among all the properties of the soils, shear-wave velocity ($V_s$) is considered to be the single best indicator of stiffness, in part because of its direct relation with shear and strain properties of the soils (Galiana-Merino et al. 2012). Nowadays there are many geophysical techniques which could be applied to estimate $V_s$ profiles at a site (e.g., borehole seismic techniques, Spectral Analysis of Surface Waves (SASW), Multichannel Analysis of Surface Waves (MASW), Refraction Microtremor (ReMi)), each one with advantages and drawbacks.

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[1] Young Researcher, Instituto Dom Luiz of Lisbon University, Lisbon, j.filipa-carvalho@gmail.com

[2] Professor, FCUL-DEGGE & Instituto Dom Luiz of Lisbon University, Lisbon, ptcosta@fc.ul.pt

[3] Young Researcher, Center of Geology of Lisbon University, Lisbon, lotich@gmail.com

Mostly, the choice of which technique we should to use is strongly conditioned by the nature and ambient conditions of the problem that we confront.

ReMi is a relatively new method considered by many authors cheaper and quicker than the other techniques. It is also a superficial geophysical method easily adaptable to the urban seismic noise that allows to generate more data in less time without damaging neither the floor nor the buildings. Our intention was to produce seismic signals due to human activities such as traffic, also known as a cultural seismic noise, and that's why we thought that ReMi was the best technique to use in our study.

This non-intrusive method could be explained in a simplified way using some principal steps. First of all we had to register the vertical component of noise, which is dominated by Rayleigh waves. After this process it is necessary to separate these waves from the others, which were also registered, using p-f transform, where p means slowness and f means frequency. When we only have Rayleigh waves we are able to obtain the velocities diagram and it is then possible to pick manually the dispersion curve. Finally, the inversion of dispersion curve will provide the 1D velocity model.

Seismic profiles used were all linear, each one with 24 geophones of 4.5Hz, connected to a digital acquisition system Seistronix RAS24. Seismic signals are registered and directly transmitted to a portable computer. This is one of the advantages of this kind of acquisition because it is possible to evaluate the quality of the data on field. If the data appears to be ok we can move on to next acquisition; if not, we just have to repeat it. Geophones spacing ranged between 1.5 to 3.0 meters, depending on the available area to install the material. Figure 1 presents a map with the approximated location of the seismic refraction profiles performed.

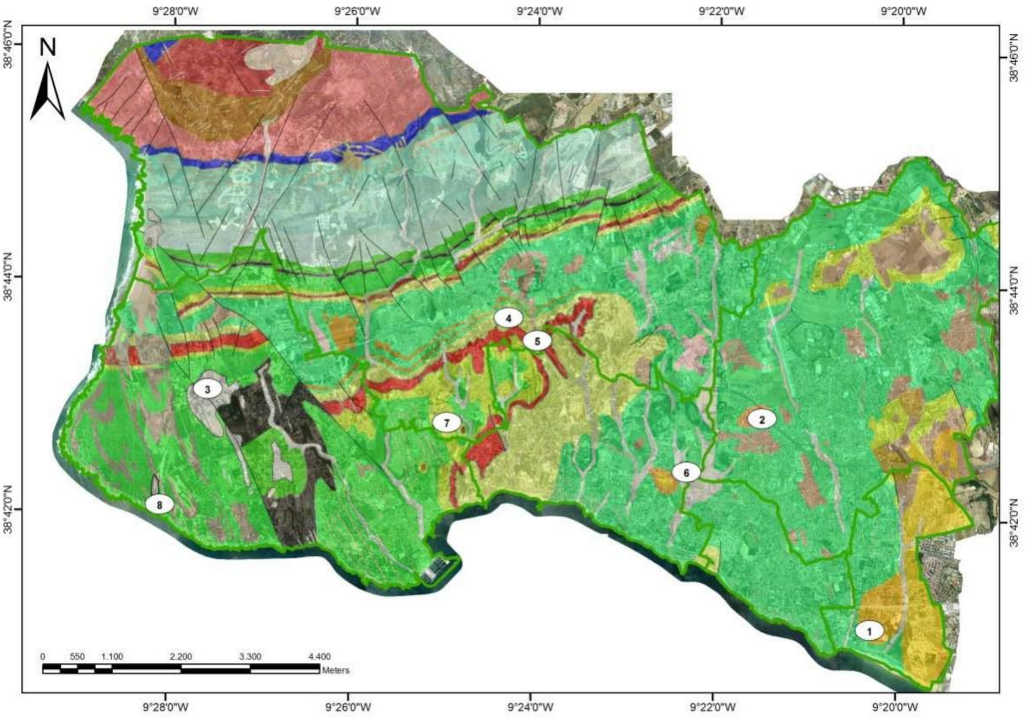

Figure 1: Location of seismic refraction profiles over the geological map.

One disadvantage of this technique is the space constrain, especially in urbanized areas. For this reason and also because some selected places were far away from anthropogenic noise, we were obliged to use a sledgehammer as an artificial seismic source.

Data were processed with SeisOpt ReMi v.4.0 software which divides the analysis in two steps. First we obtain the dispersion curve (Figure 2) using ReMi Vspect module and then we perform the inversion of this curve, and consequently construction of 1D velocities model, using ReMi Disper module (Figure 3).

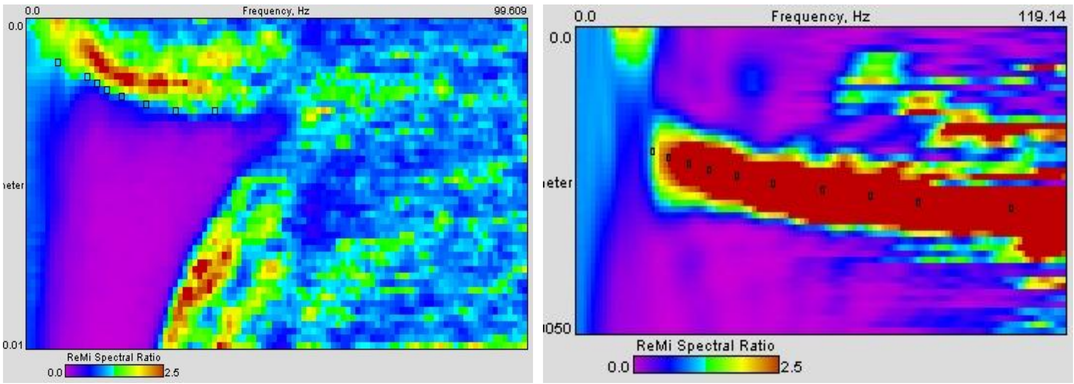

Figure 2: Velocities diagrams using an ambient seismic noise source (left) and using an artificial seismic source (right) and its respective "picked" dispersion curves.

For each site a set of measurements were performed. Once the data processing is finished we obtain a velocity profile for each measure. The results were grouped in order to present the velocities models that indicate not only Vs velocities but also the layers thickness.

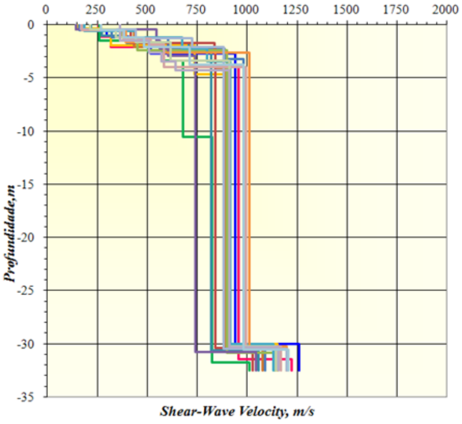

Figure 3: Set of velocities profiles obtained for Oitavos site.

Figure 3 shows a five layers model up to 33 meters deep. It is possible to distinguish some superficial layers, composed by embankments and soft formations, followed by a stiffer formation, the Cabo Raso e Guincho formation (see Table 1). As soon as the model is constructed, it is possible to calculate the mean value of $Vs_{30}$, which for Cabo Raso e Guincho formation it's about 854 m/s. According to the EC8 classification (IPQ, 2010) this soil belongs to type A and should be composed by rock or other rocky formation with a maximum of 5 meters of softer material on the surface.

A carefully analysis of all acquired data allows us to construct 1D velocities models and to estimate mean values of $Vs_{30}$ to main surface formations of Cascais County. This study may also be used as a supporting tool on the planning of urban development of Cascais County.

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