RELATIONSHIP OF SHALLOW SEISMIC REFRACTION RESULTS VERSUS LITHOLOGY IN A RAILWAY PROJECT PLAN (NORTHWEST PORTUGAL)

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ABSTRACT

The method of seismic refraction is widely used in many applied Geology fields and problems today. Although it has some limitations, in the case of detecting a lower velocity bounded layer, this method is well tailored to a crystalline environments where, more often, weathering degree is highest on the surface and gradually decreases in depth and thus can aid in associating the weathering degree to velocity. Some relationships have been made to establish a connection between velocities and the elastic properties of rocks. In recent years seismic refraction methods have evolved in terms of improved equipment, especially by means of better seismographs, but particularly due to better inversion techniques that consider the subsurface as a more heterogeneous environment. The later are commonly known as travel time tomography techniques. In crystalline environments this is useful due to the occasional heterogeneity of the near surface but also because of the gradual character of velocity change as opposed to sudden velocity breaks at boundaries that were associated with intercept time methods and even GRM.

With this in mind we sought, over the years, to apply this method to projects throughout Portugal. In the northern part it is even more adequate due to the dominant granitic and schistose environments that we encounter.

In the past few years High Speed railway networks have been planned to integrate with the European network, already existing in some countries namely Spain and France among others. The project requires detailed planning for excavation in hilly and mountainous terrain due to both engineering and environmental considerations.

We had access to a seismic refraction dataset, acquired by a local geophysical company, comprising of around a 190 individual 60m profiles and we interpreted them with a travel time tomography technique. Each section easily permits the filtering of velocity domains and we considered the 800m/s as an empirical limit to separate geotechnical soil from soft rock. Afterwards, by georeferencing in GIS every test over the corresponding lithology, we were able to establish, through simple descriptive statistical parameters, defining characteristic relationships between each lithological group and the geophysical results. These relationships could surely be useful for the sustainable development of the project in this highly variable geologic environment.

Keywords: Seismic refraction, GIS, rock mass, travel time tomography

INTRODUCTION

The method of seismic refraction is widely employed in many applied Geology projects throughout Portugal. Although it has some limitations, in the case of detecting a lower velocity bounded layer, this method is well suited to characterize crystalline environments where, more often, weathering degree is highest on the surface and gradually decreases in depth [6]. Thus it can aid in associating the weathering degree with velocity and the actual depth to that velocity boundary. We therefore intended to assess if there was also real relationship between lithology in the case of a certain statistically significant data set.

SEISMIC REFRACTION

In recent years seismic refraction methods have evolved in terms of improved equipment, especially by means of better seismographs, but particularly due to better inversion techniques that consider the subsurface as a more heterogeneous environment. These inversion techniques are commonly known as travel time tomography techniques [4]. In crystalline environments this is useful due to the occasional heterogeneity of the near surface but also because of the gradual character of velocity change as opposed to sudden velocity breaks at boundaries that were associated with intercept time methods [5] and even GRM [3]. The advantages of such a methodology can be better understood by observing the seismic profiles in figure 1. These clearly exhibit as velocity the same gradual character of weathering.

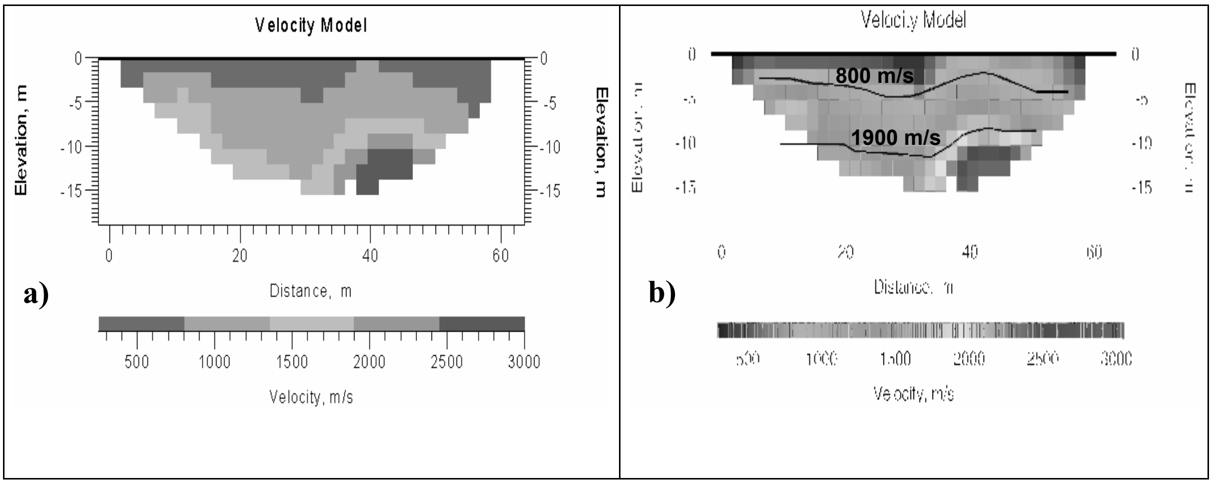

Figure 1- Example of the results of a seismic refraction profile interpreted with travel time tomography. The first (a) is a simplified five shaded level that was used to obtain the average depth in each profile. The second (b) is the detailed velocity version with an interpolated line through the requested transitions.

ROCK MASS WEATHERING AND SEISMIC VELOCITY

Rocks mass weathering classifications have been made, by numerous authors (Figure 2), whose classes are mostly based on a set of criteria that match a certain range of change in the mineralogical and mechanical behaviour and within a certain group of rocks. These changes, as seen in figure 2, are somewhat gradual in nature. On the other hand some relationships have also been made to establish a connection between velocities and the elastic properties of rocks [2]. However more often, due to the complexity of the relationship process, we rely on empirical correspondences based on years and volumes of experience. Examples of such are the Atkinson diggability graph [1] (Figure 3) and the Caterpillar tractor company seismic velocity versus ripability performance graphs [8] (Figure 4).

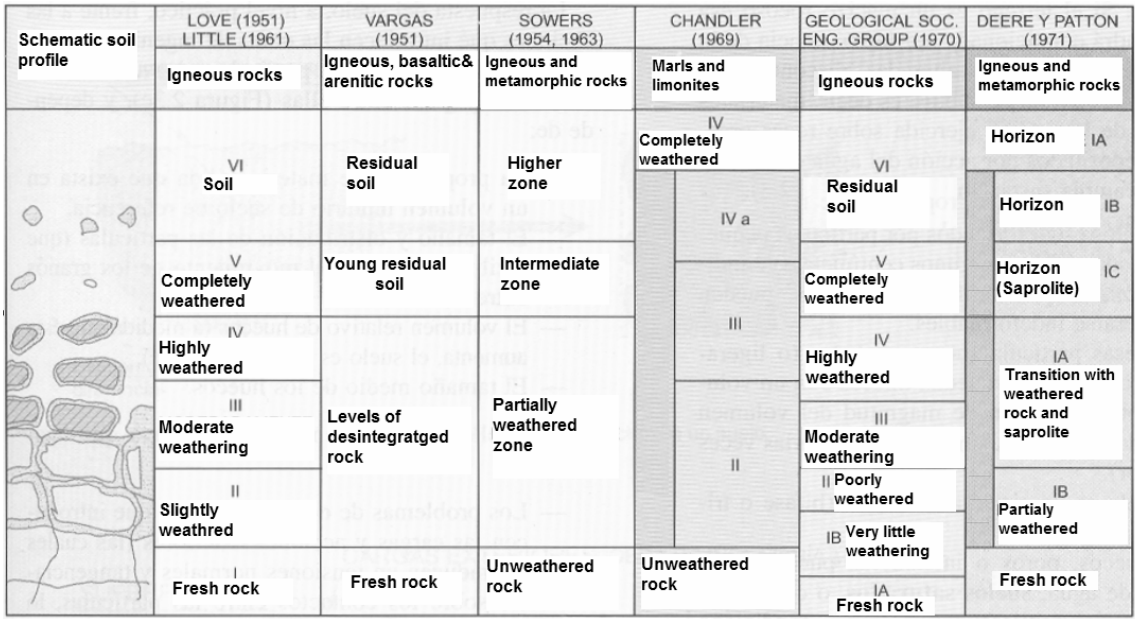

Figure 2 – Typical weathering profiles from different authors (adapted from [7])

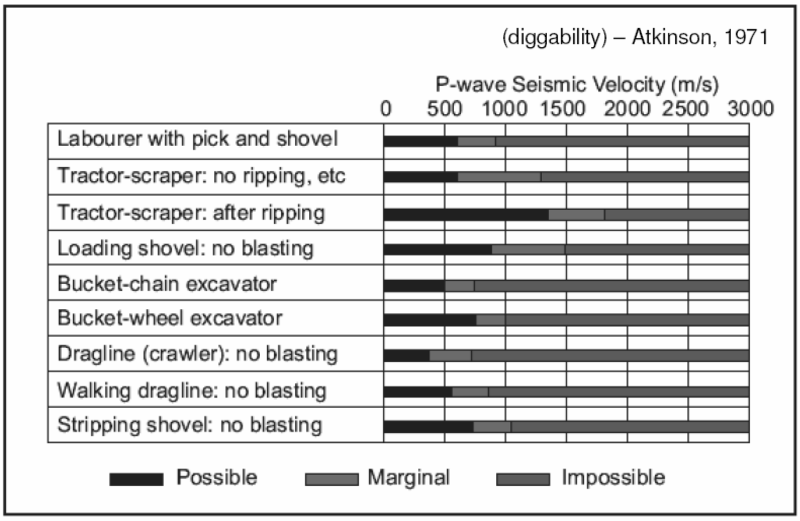

Figura 3 – Diggability or excavabability as a function of seísmic P wave velocities for certain machinery (adapted from [1])

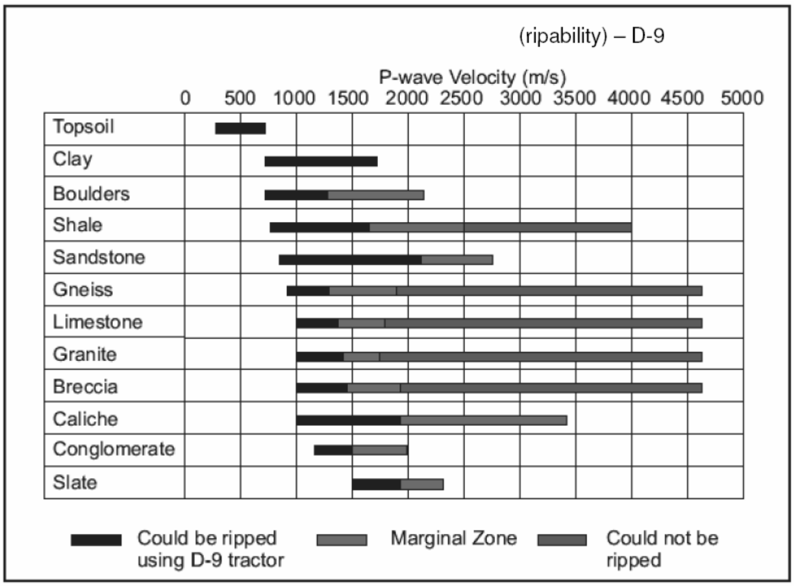

Figura 4 – Rippability as a function of seísmic P wave velocities for certain machinery (adapted from [8])

METHODOLOGY

The data set used for our study, made out of about 190 individual profiles, was grouped from various sub-projects carried out over the years by a geophysical services firm based in Portugal. The individual seismic profiles were all carried out in the same standard way, in other words, with the same lengths (60m), number of geophones (24) and same number of shots (3) thus guaranteeing comparable results.

As previously referred in the beginning we chose to invert each profile, with a travel time tomography routine (SeisOpt@2D), upon which we measured the average depth, in each individual profile, to the 800m/s boundary. This velocity limit establishes a value that agrees with both the ripabillity table (Figure 4) and especially with the diggability values (Figure 3).

After compiling the results in a table each of them was georeferenced in a GIS application whose base was the Portuguese lithological GIS map [9] and the result of which can be seen in figure 5. Later an operation of intersection between seismic refraction points and lithological domains permitted the filtering of results per rock units. We should however emphasize that each filtered lithological population was not the same. The lowest population was the Triassic sandstones followed by the non consolidated sedimentary rocks. We also had in our GIS database different metasedimentary units. Thus to simplify our analysis and to make our study more comparative we decided to group together the different metasedimentary rocks. This was done because, in terms of field observation, they exhibit a certain mechanical similarity. The different granitic rocks were, on the other hand, classified together in this version of the map and did not require any type of grouping operation.

Figure 5 - Lithological GIS map overlaid with the georeferenced seismic refraction points (notice the points within the rectangle area)

RESULTS AND CONCLUSIONS

From the GIS filtered data we obtained the results resumed in tables 1 and 2. From these tables we can observe that granites have the deepest weathering profiles of all and that metamorphic rocks together with the Triassic sandstones have the shallowest. The highest average depth was attributed to sedimentary rocks whereas the highest variability exhibited by the granites.

Our approach aim was not to discuss if the deterministic approach is better or more correct than the empirical relationship method but instead to assess the correlation of results with lithology.

Table 1 - Average depth, in meters, for each of the mapped lithologies

Lithological Type	**Average depth (m)**
Aluvium	7.5
Sand and gravel deposits	5.7
Sand, pebbles, weakly consolidated arenites, clays	7.0
Arenites and arcosic arenites	4.9
Red sandstones (“Silves” formation), conglomerates, marls, limestones	5.3
Quartzites	3.7
Schists, anphibolites, micaschists, greywakes, quartzites, gneiss	4.9
Schists, greywakes	4.8
Schists, greywakes (“Xisto-grauvaquico” complex)	6.0
Conglomerates, schists and shales	1.4
Granitic rocks	6.5

Table 2 - Statístical results of the four grouped lithologies (values in meters)

	Non consolidated sedimentary rocks	**Metasedimentary rocks**	**Triassic Sedimentary rocks**	**Granitic rocks**
Average Depth (m)	7.6	4.9	4.1	6.5
Standard deviation	2.4	2.0	2.5	5.1
Minimum depth (m)	2.2	1.4	1.0	2.3
Maximum depth (m)	10.7	8.8	7.0	15.3

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