GEOTECHNICAL CHARACTERIZATION BASED IN COMBINED MECHANICAL AND GEOPHYSICAL METHODS. A CASE STUDY

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1. INTRODUCTION

Geophysical methodologies for geotechnical characterization have been increasingly used in the last two decades. The development and use of seismic (cross-hole, down-hole, SASW, MASW, etc), electric resistivity and electro-magnetic methods highlighted the potential of its use for this purpose. The combination of these methods with mechanical (bore-hole) characterization can provide an adequate geotechnical mapping and also an efficient geotechnical parameter acquisition. Herein, an application of this approach is presented, which is related to the characterization of the massifs intercepted by two alternative solutions for a road tunnel with a maximum depth of 600m (Tunnel of Marão, Portugal) performed by MOTA-ENGIL Geotechnical Department for cost estimation purposes. The geology of the area is rather complex represented by schists, quartzites, grauwackes and granites (with important saturated levels for water supply) and the survey ought to be performed in no more than one month. The selected survey methodology consisted in two electrical resistivity profiles, one with an extension of 6625m and 760m of depth of investigation (base solution) and another 3180m long and 540m of investigation depth (alternative solution). The obtained resistivity results were calibrated by mechanical parameters obtained in five mechanical bore-holes with 50m depth, using Hoek & Brown Criteria.

2. OBTAINED RESULTS, INTERPRETATION AND MODEL CALIBRATION

The geophysical obtained data was carefully analyzed together with the available geological information, which led to the differentiation of 5 different zones as presented in Table 1.

Table 1 – Resistivity zoning.

Zona	Resistivity (Ω.m)	Characteristics
1	< 500	Highly weathered massif with water inflow
2	500 - 1200	Weathered massif with water inflow
3	1200 - 2000	Weathered massif with low water inflow
4	2000 - 3000	Medium weathered massif
5	> 3000	Unweathered to slightly weathered massif

In Figure 1 the respective interpretative model associated to the base solution is presented.

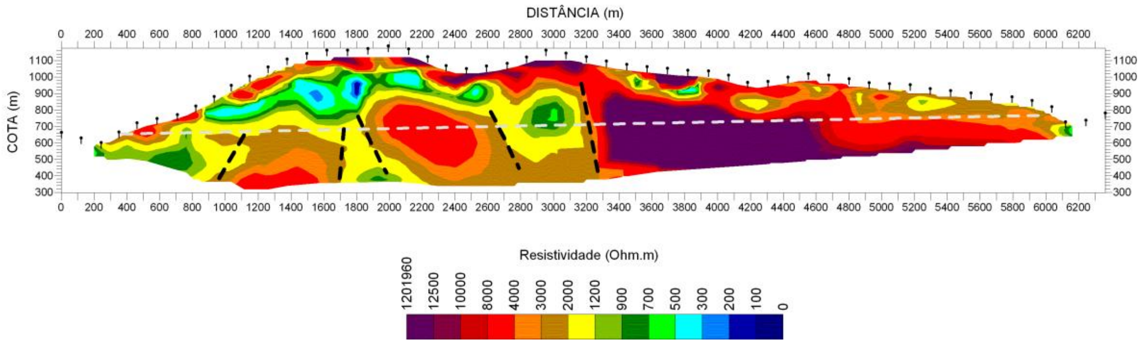

Figure 1 – Interpretative model of the longitudinal section of base solution

On the other hand, results arising from mechanical survey and laboratorial tests were indexed to each of the previous defined zones, as it is presented in Table 2 (GSI stands for Geological Stress Index while RCU represents the Uniaxial compressive strength)

Table 2 – Mechanical Characteristics of the massif

Litologia	W	Resistivity (Ω.m)	GSI	RCU (MPa)
Black Schists	W_2	>3000	60 – 80	90
	W_3	2000 – 3000	50 – 60	45
	W_{4-3}	1200 – 2000	30 – 50	10
Quartzite	W_{3-2}	>3000	50 – 60	25
	W_{4-3}	2000 – 3000	30 – 50	15
	W_{5-4}	1200 – 2000	20 – 30	10
Black Schists	W_2	>3000	60 – 80	100
	W_{3-2}	2000 – 3000	50 – 60	60
	W_{4-3}	1200 – 2000	30 – 50	20
Black Schists (highly fractured)	---	---	20 – 30	12.5

Departing from this combination it was possible to use the resistivity as an index parameter for mechanical response overcoming the impossibility of having 600m depth bore-holes in this phase of the project. In table 3, an example of results related to one of the 7 defined profiles, where the parameters m, s, and α are parameters of Hoek & Brown Modified Criteria (1994) and the deformability modulus was obtained by Hoek et al. (1994)

Table 3 – Results on profile PB4

Profile	Depth (m)	RCU (MPa)	m	s ($x10^{-4}$)	α	E (maciço) (Gpa)
PB 4	0 – 100	25	4.00	67	0.504	3.9
	100 – 120	10	1.40	2	0.531	0.2
	120 – 160	7	0.96	1	0.551	0.1
	160 – 200	15	2.30	13	0.511	0.9
	200 – 240	25	4.00	67	0.504	3.9
	640 – 700	15	2.30	13	0.511	0.9

Simulation of the tunneling construction was then studied by using Phase2 engineering software (RocScience), leading to important conclusions and considerations with fundamental impact in the cost estimation. An illustration of these analyses is presented in Figure 2.

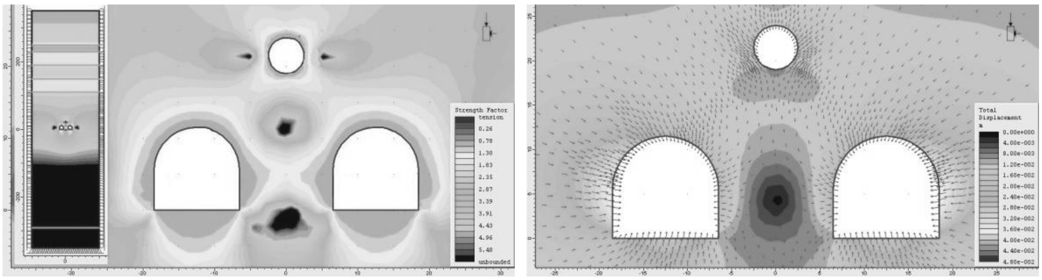

Figure 2 – PB4 simulation: a) Safety Factor; b) displacements

REFERENCES

Hoek, E. (1994). Strength of Rocks and Rock Masses. *ISRM New Journal 2 (2), pp. 4-16.*

Hoek, E. & Brown, E.T. (1997). Pratical Estimates of Rock Mass Strength. *International Journal of Rock Mechanics and Mining Sciences. Elsevier, Vol. 34, nº 8, pp. 1165-1186.*