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GEOPHYSICAL TESTS OF THE SMELTER SLAG DEPOSITS AT THE CONSTRUCTION SITE OF FACILITIES IN BOR

Dušan Tašić[1a], Dragan Ignjatović[1b], Vanja Đurđevac[1c], Dragana Savić[2a]

[1] Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia
[2] Geoing Group d.o.o, Kraljice Marije 25, 11000 Belgrade, Serbia
[1a] dusan.tasic@irmbor.co.rs, https://orcid.org/0000-0001-8005-9640;
[1b] dragan.ignjatovic174@gmail.com, https://orcid.org/0000-0003-2333-6853;
[1c] vanja.djurdjevac71@gmail.com, https://orcid.org/0000-0002-7973-0916;
[2a] dragana967@gmail.com, https://orcid.org/0009-0002-3396-9435

Abstract

As a part of preparation, the geotechnical foundations for construction the SS plant and associated landfill, at the location of the TIR circle in Bor, the geophysical tests of the field, built mainly of deposited smelter slag, were performed. This material is a technological creation and has specific geomechanical characteristics. In order to single out the zones with approximately the same geotechnical characteristics within this environment, as well as to single out the parts due to possible occurrences of deformations and fault zones in the field, the refraction seismic tests were used.
Keywords: *smelting slag, geophysical surveys, refraction seismics*

1. INTRODUCTION

At the location within the TIR plant in Bor, on the site of the former slag dump, it is planned to build facilities of an integral system for sludge processing (SS plant) and the associated landfill. For the purposes of creating the geotechnical foundations and conditions for construction the designed facilities, during March 2024, a certain amount of geophysical testing of the engaged terrain was carried out.

Smelter slag (Figure 1) is produced as a by-product in the metallurgical conversion process of copper concentrate in the Smelter in Bor [1]. As a geotechnical environment, it generally has the favorable geomechanical characteristics for a direct foundation of facilities on it. However, there is a distinct heterogeneity of this material in terms of physical-mechanical and deformation parameters by depth. Geophysical tests of the terrain were aimed at determining the physical and mechanical properties of the lithological environments that make up the researched terrain and, if possible, to determine the fracture and fault zones. The required testing depth was 10 m, and depending on the power, even deeper.

Figure 1. *Smelter slag - open profile in a construction excavation*

2. FIELD TESTS

Geophysical tests were carried out using the seismic method in a refraction variant. The tests included the routes of 6 profiles (Figure 2) marked with: R-1a, R-1b, R-1c, R-1, R-2 and R-3. The length of the R-3 profile was 60 m, while the other profiles were 120 m long.

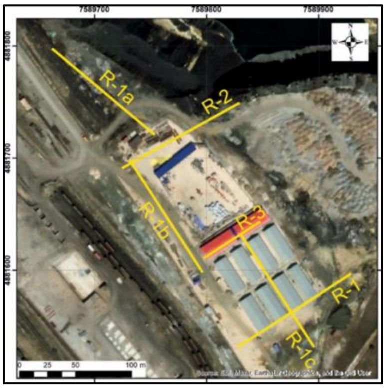

Figure 2. *Satellite image of the researched field with the position of seismic refraction test routes*

Figure 3. *Presentation of seismic refraction measurements in the field*

Seismic refraction tests with measurement of p and s wave propagation velocities, were performed along a range of 24 geophone locations (Figure 3). Tests measuring the speed of p-wave propagation along the routes of profiles R-1c, R-1 and R-2 were performed with an excitation with 6 points of impact, and along the routes of profiles R-1a and R-1b with 7 points of impact. Tests along the route of the R-3 profile, 60 m long, were performed with a range of 12 geophone locations and 5 impact points.

Tests by measuring the propagation speed of s-waves along the routes of all profiles were performed with excitation from 3 impact points. The distances between the geophones in all profiles were 5 m. A hammer weighing 6 kg was used as a source of excitation the elastic waves. The excitation was done by hitting the stump with a hammer, which was placed on the beaten earth. Registration of the p-wave arrival time was performed using a geophone with a vertical moving mechanism. Then, along the same profiles, the arrival time of the s-wave was recorded with geophones with a horizontal moving mechanism, placed in the same places as in registering the p-waves. Registration of the arrival time of p-waves was performed using a geophone with a frequency of 4.5 Hz, and s-waves using a geophone with a frequency of 10 Hz.

The results of seismic refraction measurements (arrival times of elastic waves to the individual receivers, distances between individual receivers, as well as distances between the excitation points of elastic waves) were determined using the program "ReflexW" version 7.5.5 [2], as well as the program "REFRACT". This program defines a two-dimensional model and then calculates the arrival times from the excitation points of elastic waves to the individual receivers (geophones). Times calculated in this way are compared with those measured in the field.

If the differences between the calculated and measured ones are not in the given range (program), the program generates another model, until this condition is met. The basic method used to create the mathematical model is a modified method of calculating the delay time and ray tracing method [3]. The speed of the first layer is determined as the mean value of quotient of the distance between the ignition point and geophone and corresponding wave arrival time. The speed of the layer is the inverse value of the slope of line, obtained by fitting the points of the hodochron, namely those points that have been corrected to the reduction plane and belong to the rays refracted from the corresponding boundary planes. The specified regression lines were obtained by the method of least squares.

3. RESULTS AND DISCUSSION

As a result of realized measurements, the seismic cross-sections were obtained according to the parameter of propagation speed of the p and s-waves (Figure 4).

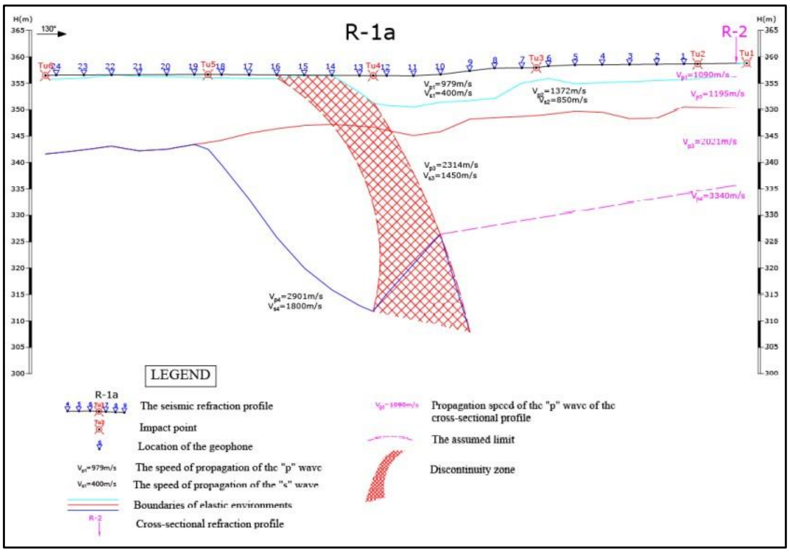

Figure 4. *Refraction seismic profile R-1a*

Based on the measurement results of the propagation speeds of p and s-waves, the Poisson's coefficients were calculated, as well as the dynamic and static modulus of elasticity and deformation modulus for the corresponding media. Considering that here is a bulk material and smelter slag, which correspond to the sedimentary rocks on the surface and in shallower parts of the profile, as well as the igneous rocks (andesites) at greater depths, the appropriate empirical relations were used for calculations [4].

A summary of the elastic properties of all 6 seismic refraction profiles is shown in Table 1.

4. CONCLUSION

In order to define the physical and mechanical parameters of rock mass, the geophysical seismic refraction tests were performed along 6 profile routes. On the basis of performed the seismic refraction tests using the profile method, the data were obtained on the physical and mechanical properties of the lithological media (technological formations) that make up the tested field. The static and dynamic elastic moduli were obtained, as well as the deformation moduli in representative environments. The obtained results were used in determining the position of geotechnical media, zones with increased cracking (fracture zones) within the smelter slag deposits were defined. Based on these, the conclusions and recommendations were made on the field suitability for construction the designed facilities.

Table 1. *Summary overview of the elastic properties of seismic refraction profiles*

MEDIUM	Poured heterogeneous material	Vs (m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
1	average	353	1029	0.43	2.00	1.6	721	99	21
	min	295	840	0.40	1.97	0.7	512	62	12
	max	415	1130	0.46	2.02	2.7	990	149	33
MEDIUM	Loose smelter slag	Vs(m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
2	average	593	1218	0.34	2.04	5.1	1929	361	98
	min	520	1170	0.29	2.03	2.7	1524	264	66
	max	650	1370	0.39	2.06	7.7	2360	470	134
MEDIUM	More compact smelter slag	Vs(m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
3	average	851	1561	0.28	2.09	6.5	3882	907	297
	min	835	1372	0.19	2.06	4.4	3541	803	256
	max	870	1780	0.34	2.13	8.5	4331	1047	353
MEDIUM	Consolidated smelter slag	Vs(m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
4	average	1193	2134	0.26	2.19	11.6	7975	2391	980
	min	935	1940	0.18	2.16	5.6	5175	1325	470
	max	1450	2314	0.36	2.22	19.8	10980	3578	1567
MEDIUM	Paleorelief - Degraded andesite	Vs(m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
5	average	1783	2921	0.20	2.32	∞	17728	5802	2180
	min	1765	2901	0.19	2.32	∞	17635	5753	2156
	max	1800	2940	0.22	2.32	∞	17821	5851	2204
MEDIUM	Paleorelief - andesite	Vs(m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
6	average	1748	3470	0.32	2.41	∞	19370	6702	2635
	min	1670	3180	0.21	2.36	∞	17775	5827	2192
	max	1933	3680	0.37	2.45	∞	21317	7797	3202
MEDIUM	Compact andesite	Vs(m/s)	Vp(m/s)	υ	P (g/cm^3)	h (m)	Edyn(MPa)	Ee(MPa)	D (MPa)
7	average	2205	3615	0.20	2.44		28615	12578	6001
	min	2100	3420	0.20	2.40		25381	10314	4607
	max	2310	3809	0.21	2.47		31849	14841	7395

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