CORRELATIVE ANALYSIS OF GEOLOGICAL EXPLORATION RESULTS FOR SOLAR POWER PLANTS AT MINE WASTE DUMPS

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Abstract: *Optimization of field geological, geotechnical exploration and laboratory tests in order to design solar power plants in areas larger than 10 ha and in anthropogenic environments (mine waste dumps or flotation waste dumps) is imposed as a primary goal for researchers, explorers and designers. How to cover with the required number of exploration and laboratory works, the exploration area for the construction of a solar power plant, which is in most cases heterogeneous, in terms of lithological composition, physical and mechanical properties and chemical characteristics?*

In these cases, geotechnical studies are very complex, with a multidisciplinary approach to the analysis of the subject site for construction, in compliance with the current legislation, regulations, norms and standards.

In order to optimize the designed methods in exploration areas intended for the construction of photovoltaic plants, and bearing in mind the fact that thermal conductivity depends on the type of soil, humidity and temperature, the obtained results of geophysical tests were correlated with the results of chemical analyses performed on soil samples from exploration boreholes (pH and SO_4^{2}-) performed at mining waste dumps.

The paper presents correlative analyses of the results of geophysical tests and chemical analyses from 5 locations of mine waste dumps in the vicinity of Bor and Majdanpek, which are intended for construction of solar power plants.

Key words: SOLAR POWER PLANT, OPTIMIZATION, GEOLOGICAL AND GEOTECHNICAL EXPLORATION, CORRELATIVE ANALYSIS, MINE WASTE DUMPS

INTRODUCTION

Analyses of the world's best practice prove that mine waste dumps can be turned into adequate land for construction of renewable and clean energy power plants. There are several advantages that characterize these locations: they have environmental conditions that are not acceptable for commercial or residential development, they are generally located near existing roads and energy transmission or distribution infrastructure, they can be adequately zoned for renewable energy sources, they can provide an opportunity for employment in urban communities and enable cleaner and more cost-effective energy technologies, they can reduce environmental impact of energy systems (e.g. reduce the emission of harmful gases) [1].

Solar power plants are usually built in large areas, which can lead to changes in geological and geotechnical conditions along the project site, so it is extremely important to design appropriate geological, geotechnical, geophysical and laboratory research work that reduces or limits geological uncertainty and determines the adequacy of the site for construction [6]. When selecting the type and method of funding of solar panels, for the purpose of determining the corrosiveness of the soil to the building materials that will be used for the construction of the solar power plant, it is necessary to be familiar with the physical and chemical characteristics of the soil: ph, moisture content, percentage of clay fractions, presence of metals: as, cd, cr, cu, ni, pb, zn, hg, mineral oils and hydrocarbons. Also, for the design of a photovoltaic plant, measurement data of electrical resistance and thermal conductivity of soil or rock mass are necessary [4].

For the purposes of correlative analysis, the results of geophysical tests and chemical analyses from 5 locations of mine waste dumps carried out for the purposes of the study on geotechnical conditions for the construction of solar power plants in the vicinity of Bor and Majdanpek were analyzed (Figures 1-5).

Figure 1, Schedule of exploration works - Site 1 (exploratory boreholes marked B1 and geophysical tests marked TM01)

Figure 2, Schedule of exploration works - Site 2 (exploratory boreholes marked B2 and geophysical tests marked TM02)

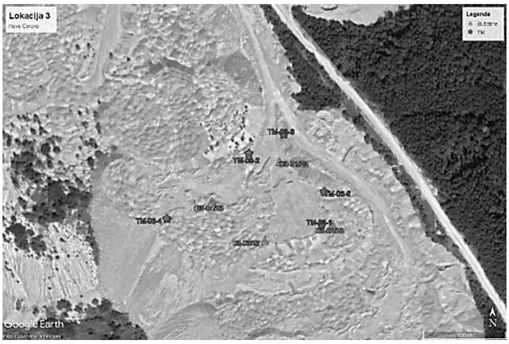

Figure 3, Schedule of exploration works - Site 3 (exploratory boreholes marked B3 and geophysical tests marked TM03)

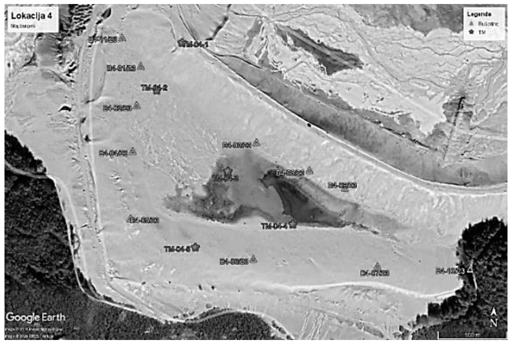

Figure 4, Schedule of exploration works - Site 4 (exploration boreholes marked B4 and geophysical tests marked TM04)

Figure 5, Schedule of exploration works - Site 5 (exploratory boreholes marked B5 and geophysical tests marked TM05)

TYPES AND VOLUME OF CONDUCTED EXPLORATION AND TESTS

The results of engineering geological and geotechnical exploration work should ensure obtaining the necessary data on the characteristics of the terrain for the appropriate level of design. For successful geotechnical design, it is necessary to collect and unify a series of adequate, multidisciplinary data required for assessing the adequacy of the location for the construction of a solar power plant [6]. In order to optimize the designed methods, the results of certain field and laboratory research work were analyzed in the paper:

- Measurement results of field geophysical works (electrical resistance of soil and measurement of thermal conductivity of soil) [2, 3, 4];
- Results of laboratory chemical tests of soil samples from exploratory boreholes (pH and SO_4^{2});
- Proving a correlative analysis.

PROVIDING A CORRELATIVE ANALYSIS

A correlative analysis of the obtained results of mutually measured parameters of geophysical tests with the results of chemical analyzes was carried out for the purpose of determining their correlation. Here, connection means that the value of one variable can be predicted with certain probability based on the knowledge of the value of another variable.

The relationship between two variables is represented graphically by means of a two-dimensional graph, the so-called dispersion diagram. The values of one variable are shown on the x-axis, and the other one on the y-axis of the diagram. The intersection points move around a certain direction, the regression line. The closer the points are to the direction, the higher the correlation, and the more dispersed the points are, the lower the correlation. Except in the case of "perfect" correlation, in practice it is very difficult to visually determine the degree of connection between variables. Depending on the relationship between the two variables between which there is a correlation, it can be linear or non-linear [8,9].

The values of physical and chemical parameters (electrical conductivity, thermal conductivity, pH, SO_4^{2-}) of the soil were analyzed with statistical software for their statistical description, correlation and regression. The coefficient of determination (R2) determines how well the regression line approximates the actual data points. In addition, Pearson's correlation (r) was also determined and indicates the strength and direction of the linear relation between the analyzed data.

The correlative analysis was done on the basis of the results obtained for the analyzed locations of the construction of solar power plants in the territory of Bor and Majdanpek.

EXPLORATION RESULTS AND DISCUSSIONS

Testing the terrain as a working environment, on which it is built and in which it is built, requires, due to its complexity, a versatile study thereof in terms of a large number of parameters [6]. Based on the exploration and testing results, a correlation was made between the obtained analyzed physical and chemical parameters. Knowledge of the mentioned parameters and their correlation enables a more reliable selection of parameters for design and with the aim of optimizing the designed methods on a wider research area.

Taking into account the size of the space intended for the construction of solar power plants and the medium slope of the terrain [6], at the locations in Bor and Majdanpek, 5 points of electrical resistance measurement and 5 points of thermal conductivity measurement were carried out, and the results of statistical analysis of the parameters of the results of geophysical tests and obtained pH values are shown in Table 1 [5].

Table 1, Results of statistical analysis of parameters obtained by geophysical field measurements and pH

Parameter	pH	Electric Conductivity σ [mS^{-1}]	Thermal Conductivity λ [W/m°K]
Number of measurements	19	17	19
Average	7,211	183,565	1,080
Minimum	2,110	39,600	0,556
Maxsimum	8,590	254,000	1,924
Range	6,480	214,400	1,368
St.dev.	1,829	54,084	0,366
Coefficient of variation [%]	25,37%	29,46%	33,85%

Figure 6 shows a graphic layout of the correlation between the pH value and electrical conductivity (mS^{-1}) with the coefficient of determination R2, while Figure 7 shows the correlation between pH and thermal conductivity (W/m°K) with coefficient of determination R2.

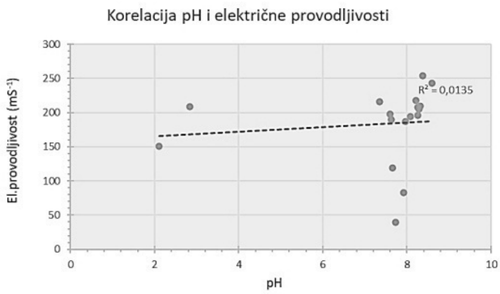

Figure 6, Correlations of pH values and electrical conductivity (mS^{-1}), r = 0.116

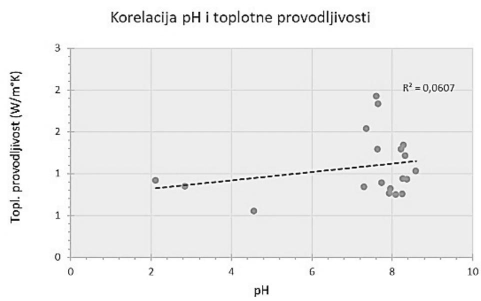

Figure 7. Correlations of Ph value and thermal conductivity (W/m°K), r = 0.246

Based on the obtained results, it can be concluded that the correlation coefficient between the obtained physical and chemical parameters is very small to small, and the correlations are positive.

Table 2 shows the statistical parameters of the results of geophysical tests and the obtained values of sulphate ion concentrations (SO_4^{2-})

A graphic layout of the correlation between the concentration of sulphate ion SO_4^{2-} and electrical conductivity (mS^{-1}) with the obtained coefficient of determination R2 is shown in Figure 8. In Figure 9, a graphic layout of the correlation between the concentration of sulphate ion $SO_4^{2-}$and thermal conductivity (W/m °K).

Table 2, Results of statistical analysis of parameters obtained by geophysical measurements in the field and SO_4^{2-}

Parameter	SO_4^{2-} (mg/kg)	Electric Conductivity σ [mS^{-1}]	Thermal Conductivity λ [W/m°K]
Number of measurements	19	17	19
Average	3821,761	183,565	1,080
Minimum	8,190	39,600	0,556
Maxsimum	30967,370	254,000	1,924
Range	30959,180	214,400	1,368
St.dev.	7924,865	54,084	0,366
Coefficient of variation [%]	207,36%	29,46%	33,85%

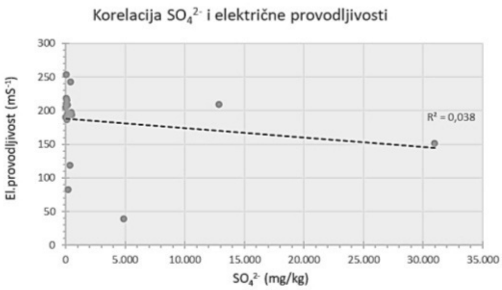

Figure 8, Correlations of SO_4^{2-} sulphate ion concentrations and electrical conductivity (mS^{-1}), r = -0.195

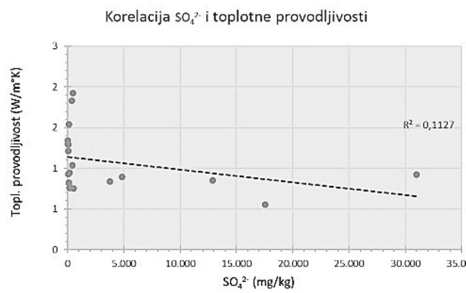

Figure 9, Correlations of SO_4^{2-} sulphate ion concentrations and thermal conductivity (W/m°K), r = - 0.336

Based on the obtained results, it can be concluded that the correlation coefficient between the obtained physical and chemical parameters is very small to small, and the correlations are negative (Figures 8 and 9).

CONCLUSION

Assessing the adequacy of the location of the mining waste dump in terms of sustainability is a difficult task that should be solved comprehensively [7]. A good geological-geotechnical study is always necessary when assessing the adequacy for the construction of a photovoltaic plant, providing valid data for design based on the optimal number of exploration field and laboratory works, thereby reducing risks and long-term problems during the operation of the facility.

Based on the results of a relatively small number of obtained physical and chemical parameters, a statistical analysis was performed for their statistical description. The obtained values of Pearson's correlation (r) indicated the strength and direction of linear relations between the analyzed parameters.

Through the statistical analysis presented in the paper, it can be concluded that the correlation coefficient between the obtained physical and chemical parameters at the examined locations of the mining waste dump is very small to small, and the correlations are positive (in the case of correlative analyses of the obtained pH values and geophysical parameters of the soil) and negative (in the case of correlative analyses of obtained values of sulphate ion concentration $SO_4^{2-}$and soil geophysical parameters), which can be interpreted by differences in the lithological composition of the disposed mining waste and the small number of analyzed pairs (tables 1 and 2).

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