Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. VII, 2018
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

# GEOTECHNICAL AND HYDROGEOLOGICAL STUDIES THAT UNDERLIE THE STABILITY OF THE LAND ON WHICH THE ROVINARI THERMAL POWER PLANT IS LOCATED

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***Abstract***

*The Rovinari Thermal Power Plant is one of the electricity suppliers of Oltenia (together with Turceni Thermal Power Plant, Craiova Thermal Power Plant) covering one third of the national electricity production.*
*The aim of this paper is to determine practically, by drilling, the physical and mechanical characteristics of the soil in the area of Rovinari Thermal Power Plant. The paper is intended to be an introduction to a broader study on the influence of mining lignite quarries in the Rovinari mining basin on the stability of the buildings in the Rovinari thermal power plant and its coal and slag-ash deposits. This stability depends on the safe functioning of the thermal power plant throughout its lifetime.*

***Key words****: Rovinari mining basin, Rovinari thermal power plant, lands features, safety, land stability.*

## INTRODUCTION

In the Rovinari basin, the influence of day-to-day operations and of the watering works performed on the aquifer system can be clearly seen over very large distances and in the adjacent quarries.
The Rovinari Thermal Power Plant is located at 3 km from the former Garla quarry and near the Rogojelu perimeter (Figure 1) where, a few years ago, there was a landslide caused by the sinking and consolidation of the aquifer with fine grain size but not exceeding 10-15 cm, which had no negative consequences on this very important industrial objective of Romania.
The safely exploitation of lignite deposits, through quarries in the meadow area of the Rovinari basin, required the descent of the groundwater piezometric level by 50-100 m, resulting the formation of a large depression funnel that was extended beyond the boundaries of the quarries.
Intense operations of dewatering and discharge of groundwater can lead severe and even the subsistence phenomena, with breaks and sudden bursts of clay-marl formations in the roof of aquifer layers and horizons.

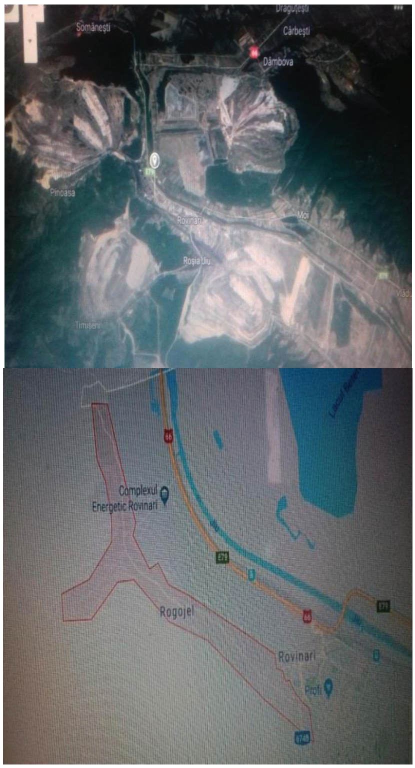


Figure 1. The location of the Rovinari Thermal Power Plant in the Rovinari mining basin (satellite image)

The inconveniences generated by the phenomena of compaction and subsidence could be avoided if the industrial activity is preceded by geotechnical and hydrogeological studies carried out very carefully at regional level, and if the appropriate measures of planning and management of the activities are taken on the basis of the obtained results from these studies.

This study was performed to determine the physico-mechanical properties of soils/rocks from the site power plant Rovinari.

These properties will form the basis of calculations of load capacity and of the land stability for the constructions made or to be performed on the Rovinari site: buildings, coal deposits, slag and ash deposits etc.

## GENERAL CHARACTERISTICS OF THE STUDY AREA

From a morphological point of view, the perimeter under consideration is a plateau located in the Jiu river meadow, on its right bank.

Geological composition of the area includes fine albedo-to-grown quaternary alluvial deposits.

Quaternary deposits are represented by clay, sandy clay, sand, gravel and boulders that are in various stages of consistency.

From a tectonic point of view, the area is part of the Getic depression, in the axis of the anticline Rovinari.

## GEOTECHNICAL STUDIES

Geotechnical works carried out in two steps in order to determine the physico-mechanical characteristics of the lands/rocks on the Rovinari site, properties that will be the basis of the load capacity calculations, implicitly stability of the foundation ground for the existing or further constructions.

They consisted of:

- direct observation (geological mapping);
- execution of seven geotechnical boreholes (F1 - F7) with FSC 2.5 drilling rig up to 15 m and 30 m depth, in the North-South and East-West directions on an almost flat and stable surface;
- sampling;
- soil/rock samples analysis in the laboratory.

The study was carried out in two stages: the first stage included the geotechnical investigation of the South-West part of the Rovinari thermal power plant's terrains, and the second, the North-East part.

The stages covered the geotechnical investigation works in order to provide the data needed to solve the following basic problems:

- stratification of the site;
- physical and mechanical characteristics of the soil / rocks encountered;
- hydrostatic level and chemical characteristics of groundwater.

The main factors that influence the land stability are:

- the shape of the land surface;
- the nature of the rocks and the groundwater and surface water regime;
- the physico-mechanical properties of rocks and base fields.

The positions of the boreholes were determined depending on the proposed location for the important building of the thermal power plant and the drilling depth was according to the development of these constructions both planar and vertical. Table 1 presents a synthesis of the mineral-petrographic composition of the material intercepted by drillings in the two stages.

The Table 2 presents the lithology of the formations encountered by the executed drilling works.

Table 1. Mineral-petrographic composition of intercepted material from geotechnical drilling works

| Intercepted material | STAGE I | | STAGE II | |
|---|---|---|---|---|
| | % | Nature of intercepted material | % | Nature of intercepted material |
| Clay rocks | 41 | clays, clayey slopes, sandy clays - soft to consistency and prickly with high compressibility to medium, high plasticity (weak clay) to very high (greasy clay), wet-very wet to saturated | 27 | clay, clayey slopes, sandy clays - are consistently prickly plastic with high compressibility to medium, high plasticity (weak clay) to very high (clayey), wet - very wet to saturated |
| Rocks of sandy nature | 59 | sand, clayey sands, silty sands-soft plastic to solid, high plasticity, wet to saturated | 66 | sand, clayey sands, silty sands- soft plastic to solid, high plasticity, wet to saturated |
| Rocks of a charcoal nature | - | - | 7 | Coal and coal clay |

Table 2. Lithology of the soil

| Directions / Stages | STAGE I | STAGE II |
|---|---|---|
| On direction North-South | - From the ground surface into the boreholes F1, F2, F5, had been intercepted by the formations preponderant 7-15 m sand, clay, gravel elements, the drilling F5 left to the bottom; further down to 15 m deep, drillings F1 and F2 crossed clay to sandy clay.<br>- The F7 broke from the surface to a depth of 1m deep dry clayey coal, then up to 5 m of silty sandy clay from 10 m, intercepting coarse sand with water to the bottom.<br>In the south, boreholes F3, F6 crossed a mixture of charcoal clay, sandy clay with coal fragments (filler) from the surface, and then they entered the sandy, sandy coarse sandy formation. Borehole F3 crossed a compact clay lens between 6 m and 9 m. From 15 m to 30 m deep, borehole F6 has intercepted clay on sandy clay. | - From the surface of the land in the F7 and F5 boreholes were intercepted up to 2-3 m of clayey coal, after which they entered predominantly sandy formations, sandy - clayey formations sometimes with small gravel elements.<br>- On the alignment of the F1, F2, F3 and F6 boreholes on the surface in the F2 and F3 boreholes, sandy clay was intercepted up to 6 m, after which a sandy clayey horizon crossed with rare elements of gravel, where F1 remained with the soleplate at 15 m deep. From 12 m, it went into clay in F2 and F3 to the soleplate. The F6 borehole starting 9m identified two charcoal states of 2-3 m thick, separated by a 1m thick sandy-clayey layer. Next, strong plastic silty clay was intercepted up to the drilling soleplate (30 m), with a sandy clay plastic consistent intersection in the range of 18-21 m. |
| On direction East-West | Boreholes F4 and F5 crossed a succession of clayey sands to rough gravel sands (F5). In the F4 borehole area of the 1 m thick surface, charcoal was found and between 8-9 m depth a soft-bodied silty clay lens with poor physical-mechanical characteristics. | The boreholes traversed a succession of clayey sands, silty sands in rough gravel sands (F5 and F7), and sandy clay with varying thicknesses. In the F5 and F7 boreholes area, clayey charcoal with a thickness of 1-3 m was encountered on the surface. In the deepest borehole F6 crossed from 15-21 m of strong clay to the sole. |

Following the laboratory analysis carried out on the soil/rocks collected from the cores, the physical (Table 3) and mechanical (Table 4) properties were resulted.

Table 3. Physical characteristics of the analysed material

| Intermediate material | PHYSICAL CHARACTERISTICS | |
|---|---|---|
| | STAGE I | STAGE II |
| Clayey type rocks | • Specific weight $\gamma_s$ = 24.6 ÷27.0 kN/m$^3$<br>• Apparent volumetric weight $\gamma_a$ = 18.0÷20.4 kN/m$^3$<br>• Natural humidity W = 20.2÷40.5%<br>• Consistency index $I_c$ = 0.45÷0.71 ($I_c$ = 0.25 dusty clay $F_4$)<br>• Plasticity index $I_p$ = 26.6÷37.2<br>• Humidity degree $S_r$ = 0.90÷1.10<br>• Granulometric composition: Sand 4-44%; Silt 27-50%; Clay 30-60% | • Specific weight $\gamma_s$ = 23.6÷26.9 kN/m$^3$<br>• Apparent volumetric weight $\gamma_a$ = 19.0-20.4 kN/m$^3$<br>• Natural humidity W = 19-29%<br>• Consistency index $I_c$ = 0.64÷0.77 ($I_c$ = 0.25 silty clay $F_4$)<br>• Plasticity index $I_p$ = 29.7-38.8<br>• Humidity degree $S_r$ = 0.78-1.07<br>• Granulometric composition: Gravel 5%; Sand 13-39%; Silt 25-45%; Clay 31-42% |
| Sandy type rocks | • Specific weight $\gamma_s$ = 25.0÷26.8 kN/m$^3$<br>• Apparent volumetric weight $\gamma_a$ = 18.8÷22.0 kN/m$^3$<br>• Natural humidity W = 10.2÷29.55<br>• Consistency index $I_c$ = 0.30÷0.56<br>• Plasticity index $I_p$ = 9.2÷18.0<br>• Humidity degree $S_r$ = 0.8÷1.04<br>• Granulometric composition: Gravel 4-94%; Sand 6-95%; Silt 4-33%; Clay 5-24% | • Specific weight $\gamma_s$ = 25.0÷27.5kN/m$^3$<br>• Apparent volumetric weight $\gamma_a$ = 18.5÷21.5 kN/m$^3$<br>• Natural humidity W = 12.2÷34.2<br>• Consistency index $I_c$ = 0.46÷0.77<br>• Plasticity index $I_p$ = 13.5÷19.6<br>• Humidity degree $S_r$ = 0.79÷1.05<br>• Granulometric composition: Gravel 2-24%; Sand 31-80%; Silt 10-50%; Clay 6-40% |
| Coal type rocks | - | • Specific weight $\gamma_s$ = 20.7÷23.3kN/m$^3$<br>• Apparent volumetric weight $\gamma_a$ = 12÷15 kN/m$^3$<br>• Natural humidity W = 29.2÷49.4<br>• Humidity degree $S_r$ = 0.8÷1.04 |

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 4. Mechanical characteristics of the analysed material

| Intermediate material | CHARACTERISTICS | STAGE I | STAGE II |
|---|---|---|---|
| Clayey type rocks | Compressibility in oedometer | Compressibility module<br>$M_{2-3} = 60\div118$daN/cm$^2$<br>($M_{2-3} = 38$daN/cm$^2$ silty clay $F_4$)<br>Specific subsidence<br>$e_p = 1.95\div5.1$cm/m<br>($e_p = 7.6$ cm/m silty clay $F_4$) | Compressibility module<br>$M_{2-3} = 65\div181$daN/cm$^2$<br>Specific subsidence<br>$e_p = 1.19\div4.3$cm/m<br>($e_p = 7.6$ cm/m silty clay $F_4$) |
| | Resistance to direct shear | Internal friction angle $\Phi = 12\div18^o$<br>Cohesion<br>$C = 0.13\div0.20$daN/cm$^2$ | Internal friction angle<br>$\Phi = 16\div19^o$<br>Cohesion<br>$C = 0.14\div0.28$daN/cm$^2$ |
| Sandy type rocks | Compressibility in oedometer | Compressibility module<br>$M_{2-3} = 50\div86$daN/cm$^2$<br>Specific subsidence<br>$e_p = 3.95\div8.25$cm/m | Compressibility module<br>$M_{2-3} = 105\div200$daN/cm$^2$<br>Specific subsidence<br>$e_p = 2.15\div9.35$cm/m<br>($e_p = 7.6$ cm/m silty clay $F_4$) |
| | Resistance to direct shear | Internal friction angle<br>$\Phi = 22\div24^0$<br>Cohesion<br>$C = 0.07\div0.13$daN/cm$^2$ | Internal friction angle<br>$\Phi = 12\div18^o$<br>Cohesion<br>$C = 0.13\div0.20$daN/cm$^2$ |

**HYDROGEOLOGICAL STUDIES**

Hydrogeological tests were carried out in all 7 executed boreholes by intercepting the ground-water horizon determined by sandy quaternary deposits.

The hydrostatic stabilized level was at a depth of between 1.5 m (F2) and 12.5 m (F5), with an average of about 6 m. The spring was intercepted at depths between 5.7 m (F6) and 13.1 m (F5) in stage I, and in the second stage the hydrostatic level ranged from 5 m depth (F5) to 14.9 m (F1), with an average of 9.9 m.

The depths at which geotechnical drillings intercepted the aquifer horizon during the execution period and the level stabilized at the end of the period are presented in table 5.

It is noted that in periods of heavy rain the water level can raise more, the aquifer horizon generally having a weak ascent as it is opened by the excavation.

Laboratory analyses of the groundwater have made it possible to assess its aggressive character on building materials (concrete, metal), (Table 6).

Table 5. Depths at which drills intercepted the aquifer horizon and stabilized level

| Borehole number | Daily level (m a.s.l.) | | Source | | | | Hydrostatic level | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | | Elevation (m a.s.l.) | | Depth (m) | | Elevation (m a.s.l.) | |
| | Stage I | Stage II | Stage I | Stage II | Stage I | Stage II | Stage I | Stage II | Stage I | Stage II |
| $F_1$ | 161.5 | 161.4 | 5.75 | - | 155.7 | - | 5.50 | 14.9 | 156.0 | 146.5 |
| $F_2$ | 161.7 | 162.1 | 10.8 | 8.5 | 150.9 | 153.6 | 1.50 | 6.50 | 160.2 | 155.6 |
| $F_3$ | 163.2 | 163.2 | 10.6 | 14.9 | 152.0 | 148.3 | 4.60 | 14.7 | 158.6 | 148.5 |
| $F_4$ | 163.5 | 163.6 | 9.7 | 14.9 | 153.0 | 148.7 | 3.20 | 14.8 | 160.3 | 148.8 |
| $F_5$ | 163.4 | 163.6 | 13.1 | 14.0 | 150.0 | 149.6 | 12.5 | 5.0 | 150.9 | 158.6 |
| $F_6$ | 164.1 | 160.0 | 5.7 | 6.0 | 158.5 | 154.0 | 4.10 | 5.20 | 160.0 | 154.8 |
| $F_7$ | 163.2 | 163.0 | 12.1 | 9.1 | 151.0 | 153.9 | 11.80 | 8.40 | 151.4 | 154.6 |
| Average | 161.5 | 162.4 | 9.6 | 11.2 | 153.2 | 151.3 | 6.10 | 9.93 | 156.7 | 152.4 |

Table 6. Characterization of intercepted waters in relation to aggressiveness

| Borehole number | The nature of the aggression | Registered value (mg/l) | Characterization |
|---|---|---|---|
| $F_2$ | Leaching $HCO_3^-$ | 109.50 | Weak aggressiveness |
| | Generally acid | 6.18 | Weak acid aggression |
| | Magnesium $Mg^{2+}$ | 18.20 | No aggression |
| | Sulphates $SO_4^{2-}$<br>$Cl^-$ | 139.40<br>17.70 | No sulphate aggression<br>No sulphate aggression |
| | Salinity | 367.20 | No aggression |
| $F_3$ | Leaching $HCO_3^-$ | 85.40 | Weak aggression |
| | Generally acid | 4.47 | Weak acid aggression |
| | Magnesium $Mg^{2+}$ | 39.50 | No aggression |
| | Sulphates $SO_4^{2-}$<br>$Cl^-$ | 331.40<br>85.10 | Weak sulphate aggression<br>Weak sulphate aggression |
| | Salinity | 693.50 | No aggression |
| $F_4$ | Leaching $HCO_3^-$ | 91.50 | Weak aggressiveness |
| | Generally acid | 5.72 | Weak acid aggression |
| | Magnesium $Mg^{2+}$ | 29.20 | No aggression |
| | Sulphates $SO_4^{2-}$<br>$Cl^-$ | 365.00<br>17.70 | Weak sulphate aggression<br>Weak sulphate aggression |
| | Salinity | 659.00 | No aggression |
| $F_5$ | Leaching $HCO_3^-$ | 79.30 | Weak acid aggression |
| | Generally acid | 4.86 | Weak acid aggression |
| | Magnesium $Mg^{2+}$ | 25.50 | Weak acid aggression |
| | Sulphates $SO_4^{2-}$<br>$Cl^-$ | 372.20<br>24.80 | Weak sulphate aggression<br>Weak sulphate aggression |
| | Salinity | 658.90 | No aggression |
| $F_6$ | Leaching $HCO_3^-$ | 103.70 | Weak acid aggression |
| | Generally acid | 6.61 | Weak acid aggression |
| | Magnesium $Mg^{2+}$ | 35.90 | No aggression |
| | Sulphates $SO_4^{2-}$<br>$Cl^-$ | 384.20<br>21.30 | Weak sulphate aggression<br>Weak sulphate aggression |
| | Salinity | 700.00 | No aggression |
| $F_7$ | Leaching $HCO_3^-$ | 109.80 | No aggression |
| | Generally acid | 6.48 | Weak acid aggression |
| | Magnesium $Mg^{2+}$ | 25.50 | Weak aggression |
| | Sulphates $SO_4^{2-}$<br>$Cl^-$ | 487.50<br>31.90 | Weak sulphate aggression<br>Weak sulphate aggression |
| | Salinity | 877.40 | No aggression |

## CONCLUSIONS

A thorough geotechnical and hydrogeological study of land on which anthropic targets are located is a sine qua non condition to establish their safety.

The paper is intended to be a stepping stone for building stability calculations (buildings, installations, deposits, etc.) that form the industrial objective of the Rovinari Thermal Power Plant.

Based on geotechnical and hydrogeological investigations carried out, the paper summarizes the entire approach of the authors in establish those physical, mechanical and chemical characteristics necessary for the stability studies of resistance structures from the area of the Rovinari Thermal Power Plant.

## REFERENCES

Bancila I., 1981, Geological Engineering, vol. I and II, Technical Publishing House, Bucharest.

Gaman S., 2016, Romanian Mining Strategy 2017-2035, preliminary draf for the Ministry of Economy - Ministry of Energy.

Rotunjanu, I., Lazar M., 2014. Hydrology and Mining Hydrogeology, Ed. Universitas, Petrosani.

xxx Geotechnical study for buildings and equipment related to Rovinari Thermal Power Plant, conducted by the Institute of Studies and Power Engineering S.A. Bucharest.