GEOTECHNICAL STUDY

PHOTOVOLTAIC POWERPLANT, ENCLOSURE AND CONNECTION TO NATIONAL ELECTRICITY GRID,

TURDA, CLUJ COUNTY, ROMANIA

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TURDA, CLUJ COUNTY, ROMANIA

SAMPLE NO. **: 1**

BENEFICIARY **: RES INVEST SOUTH EAST EUROPE S.R.L.**

LIST OF SIGNATURES

AUTHOR : CEZAR IACOB, PhD

2022

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A. WRITTEN ELEMENTS

B. GRAPHIC ELEMENTS

1. GENERAL INFORMATION

a) Project name and location

The name of the project is: **Photovoltaic powerplant, enclosure and connection to national electricity grid, Turda, Cluj County, Romania**.

Project location

The site is located in Turda City, Cluj County, Romania.

***b) Beneficiary*: RES INVEST SOUTH EAST EUROPE SRL**

***c) General designer:* E-RES REAL ESTATE & ENERGY SRL**

d) Names of the entities participating in the current study:

- ICS Business International SRL, geotechnics specialist, Bucharest, 31-35 Vulcan Județul Str., bl. B3A, sc. 2, ap. 63, Sector 3;
- INCD URBAN INCERC**,** geotechnical samples analyses laboratory**,** Bucharest, 266 Soseaua Pantelimon, Sector 2.

e) Technical information provided by the general designer:

- site plan;
- scope of work.

2. CHARACTERISTCS OF THE STUDIED PERIMETER

a) Data regarding the seismic regime

From seismic point of view, according to SR 11100-1/93 norm, the studied area is situated inside 6 isoline, on MSK scale, where the index “1” corresponds to a recovery period of 50 years (minimum) (Fig. 1).

According to the technical norm „Code for seismic design - Part I – Design considerations for buildings”, no. P 100 / 1 – 2013, the investigated site is located in the area with a peak ground acceleration of the terrain of a_g=0.10g, for earthquakes with average recurrent interval (IMR) of 225 years, with 20% probability of exceeding in 50 years (Fig. 2).

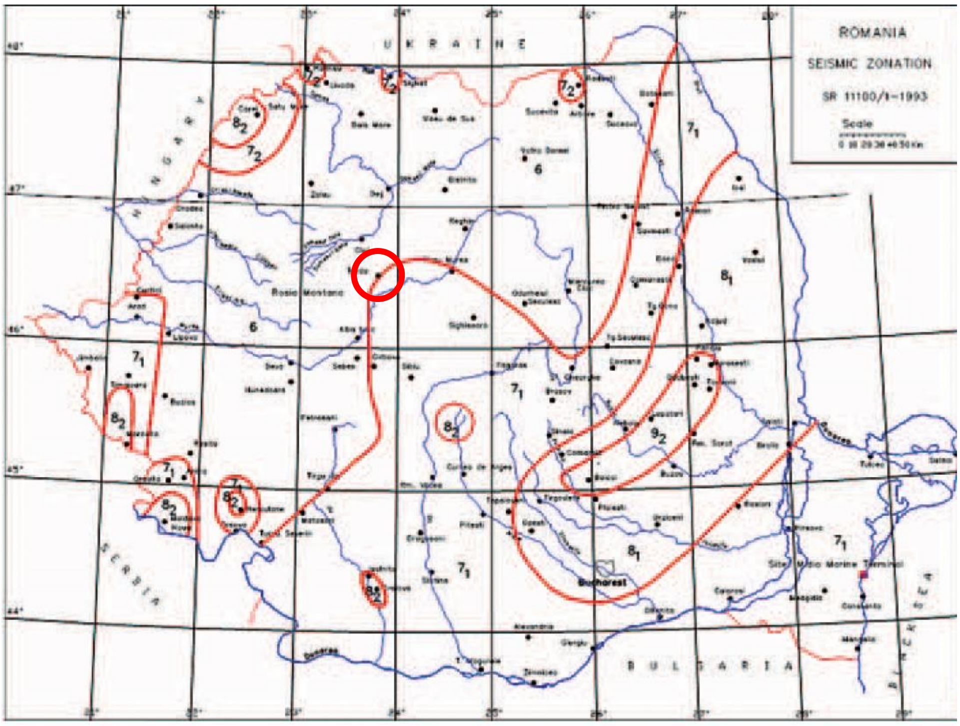

Fig. 2 – Romania – Seismic Zonation Map SR 11100/ 1-1993.

Fig. 1. Macroseismic zonation according to SR 11100-1/ 93

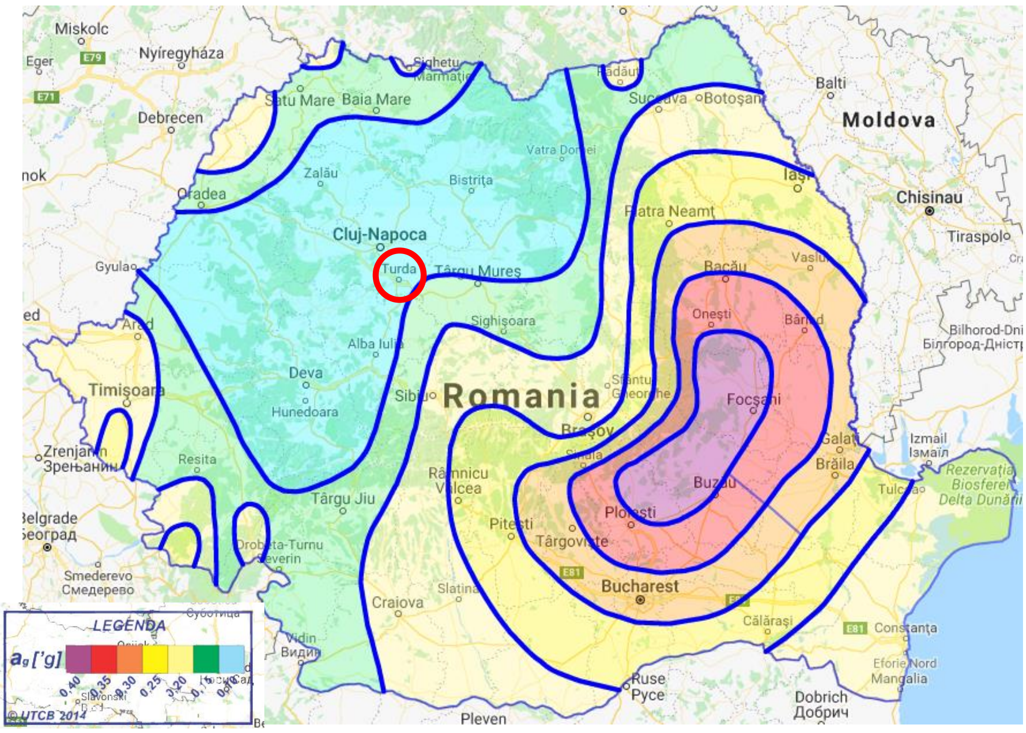

Fig. 2. Zonation of the terrain peak acceleration values a_g=0.10g with IMR=225 years and 20% probability of exceeding in 50 ani

According to the zonation of the Romanian territory in terms of corner (control) period of response spectrum, the investigated perimeter has a coefficient of Tc=0.7 sec.

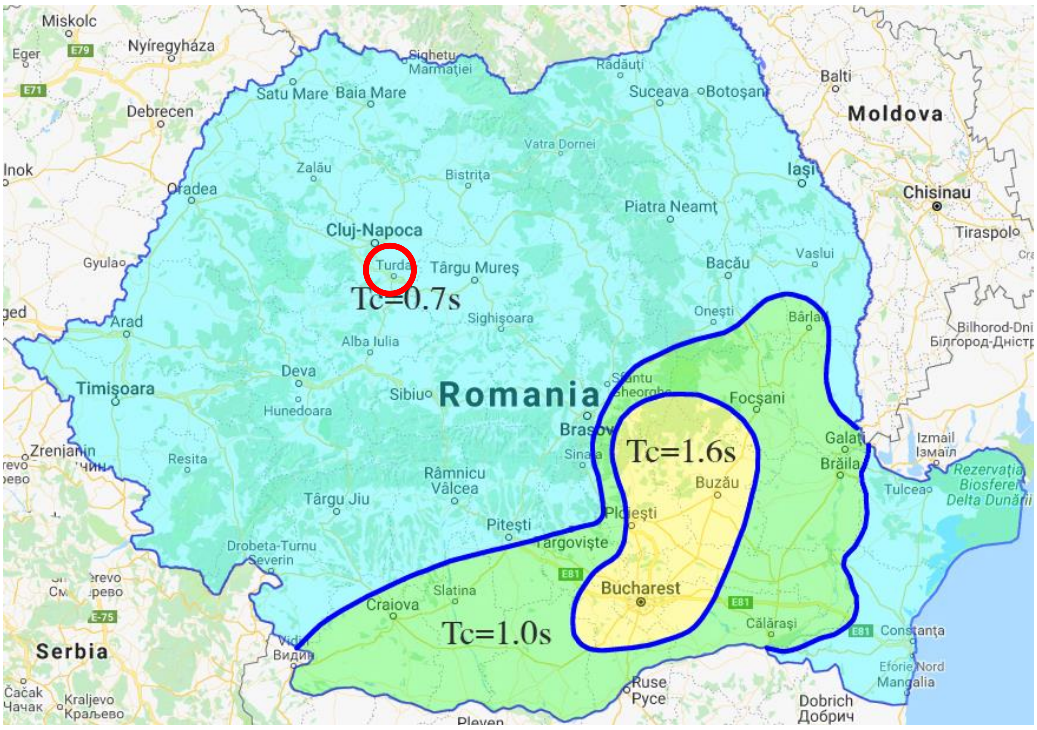

Fig. 3. Corner period of response spectrum Tc = 0.7 sec

b) General geological data

From geologic point of view, the subsoil in the studied area is occupied by Quaternary formations, belonging to Holocene and Upper Pleistocene ages. The Holocene is made of gravels and sands, while the Upper Pleistocene is made of gravel, boulders and sandy clays.

From geologic point of view, the area is covered by formations belonging to Sarmatian (Buglovian and Volhynian-Lower Bessarabian) and Quaternary ages (upper Pleistocene and Holocene).

The Buglovian (bg) is represented by the formations between two volcanic tuff layers: Hadareni tuff and Ghiris tuff. The deposits are mainly represented by dark-grey to dark violet clays and marls, with local tuff levels and thin interbedding of sands and sandstones, with higher frequency towards the top of the succession.

The Volhynian – Lower Bessarabian (vh – bs1) occupies a large area throughout the Transylvanian Plain. These formations are placed between two landmark volcanic tuff layers: Ghiris tuff and Bazna tuff. The Ghiris tuff occurs sparsely in the anticlines' axes. On top of this horizon, hard clays and marls are laying, in alternances with sands with concretions and sandstones. Towards the top of the succession, the sands become more frequent and, sometimes, include interbeddings of conglomerates and volcanic tuffs.

The Upper Pleistocene (qp3) occurs on the upper terrace of the right side of Aries River and is made of thick alluvial deposits with gravel, sands and boulders.

The Holocene formations are represented by the alluvial deposits in the lower Aries river bed, and are made of gravels with sands, sometimes covered with sandy silts.

c) Geomorphological, hydrographic and hydrogeologic settings

From geomorphologic point of view, the studied area is located in the right side of Aries River valley, being part of the greater relief unit called Transylvanian Plains.

From hydrographic point of view, the area belongs to the Mures hydrographic basin.

From hydrogeological point of view, the water table is found in the Quaternary formations, at depths of 2.9-4.0 m.

d) Climate

From climate point of view, the studied area belongs to the moderate-continental sector and is characterized by warm summers, with relatively frequent precipitations, and by cold winters, with stable snow layer and an average yearly temperature of 8.5°C.

The monthly minimum and maximum mean temperatures are -4ºC (January) and, respectively +19ºC (July).

The yearly average precipitation level is at 600 mm.

Hoars are frequent during springtime in April and possible in the first half of May as well. In the autumn, hoars occur in the second half of September, being frequent in October. The yearly mean hoar occurrence is at 32.5 days.

The maximum frost depth is h = 80-90 cm (STAS 6054/89) (Fig. 4).

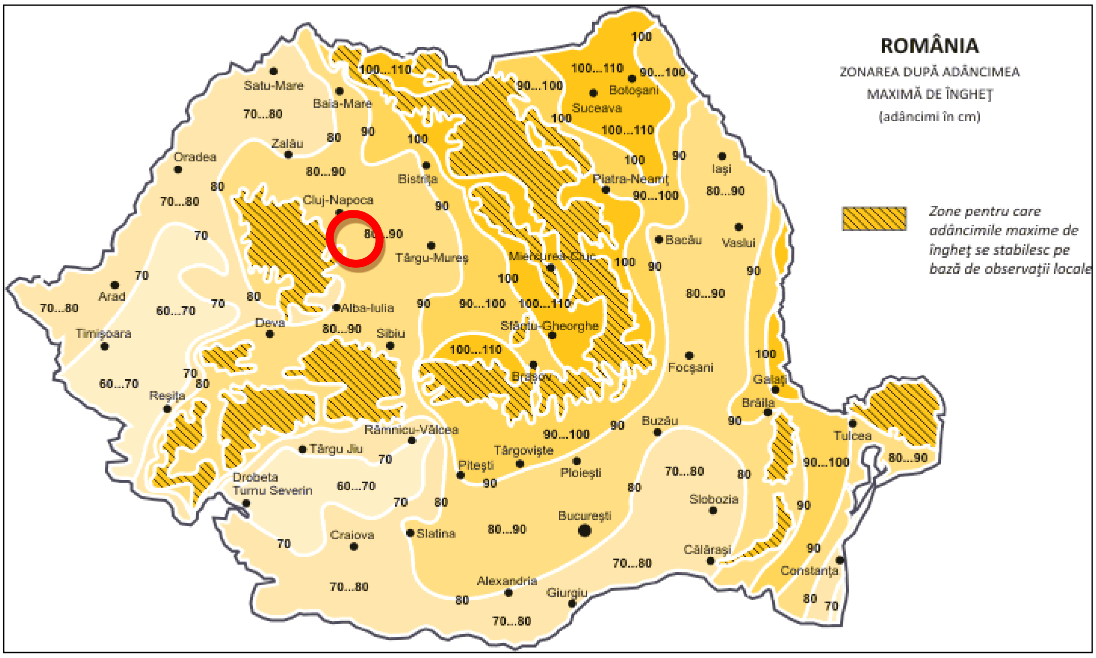

Fig. 4. The maximum frost depth map (STAS 6054/77)

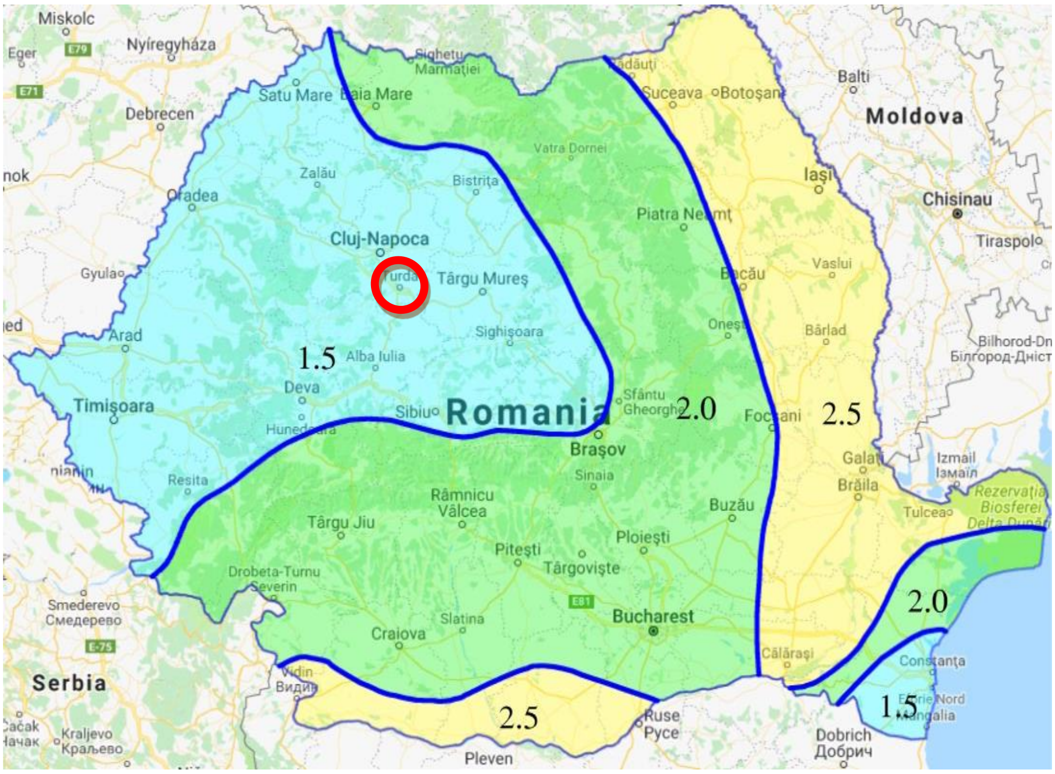

Fig. 5. The zonation map of the soil snow load according to CR – 1 – 1- 3/2012

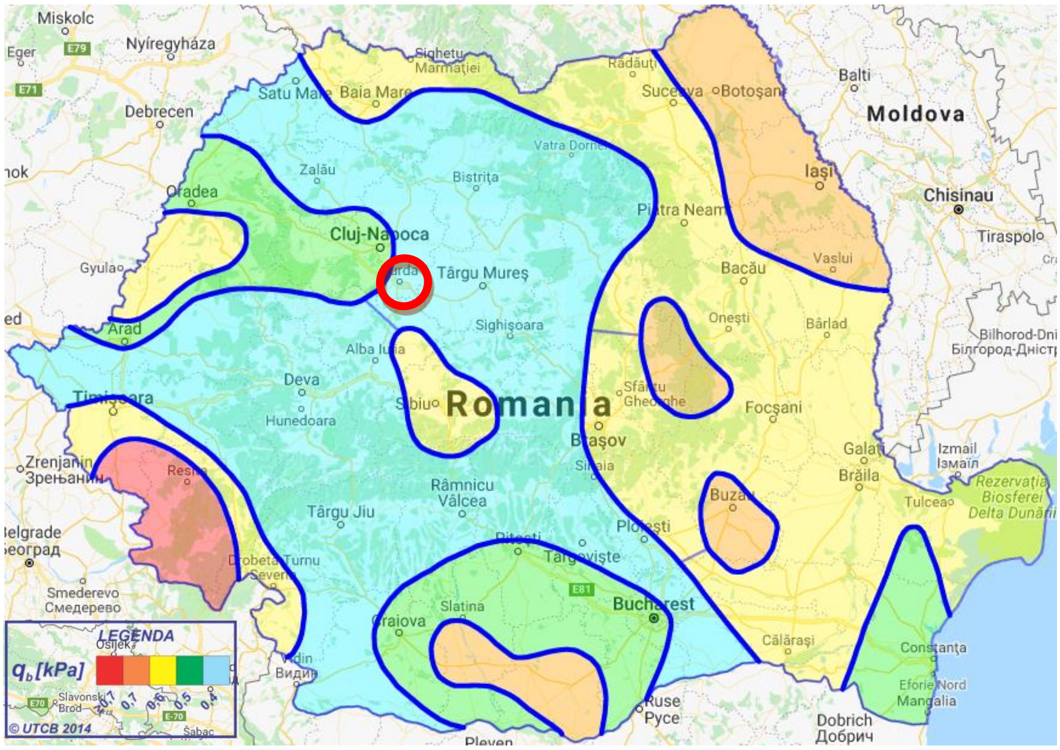

Fig. 6. Zonation map of the dynamic wind pressure according to CR – 1 – 1- 3/2012

According to the design code for evaluating the wind action on the constructions, Index CR-1-1-4/2012, the reference value of the dynamic wind pressure is q_b = 0.4 kPa with IMR = 50 years (Fig. 6). According to Table 2.1. from the code mentioned above, for the type III field category, the roughness length is z_0 = 0.3 and z_{min} = 5 m.

According to the design code for evaluating the action of snow on constructions, Index CR-1-1-3/2012, the characteristic value of the snow load on soil is s_k =1.5 kN/m^2 (Fig. 5).

e) Geotechnical general setting

From morphological point of view, the investigated site is placed on the right-side valley of Aries River, with a relatively flat terrain, stable, with no risk for landslides. The field is protected from floods by an embarkment built along the river.

From geological point of view, the outcrops in the area show gravel deposits belonging to upper Holocene.

The landscape in the area is poorly modeled by anthropic actions, being used in agriculture as pastures.

f) Site history and actual situation

The investigated site is part of the administrative territory of Turda City, outside the build-up area, being used as a pasture. The area is free of constructions.

Presently, the land is segmented by some light electrified fences for animals. In its central part, the site is crossed by a sewer pipe along a S-N direction.

g) Constrains with regard to vicinities

The investigated site is represented by an unenclosed land, neighboring an industrial park in E. The building area of Turda can be found in the S part and Aries River in N.

The construction works will be executed at legal distances from the property limits.

h) Site classification as ”Risk zone”

According to law 575/2001 – Law regarding the approval of the National Land Use Plan – Section V, natural risk zones, published in the Official Monitor no. 726/2001, for the site located in Turda City, risks can be associated with earthquakes, the area being situated in a 6 MSK intensity susceptibility zone.

There are no risks with regard to floods or landslides.

According to norm 125:2010, soils sensitive to moisture are not likely to be found in the area.

According to norm 126:2010, soils with contractions and swells can be found in the area.

3. GEOTECHNICAL INVESTIGATIONS AND RESULTS

a) Types of investigations realized

For identifying the geotechnical characteristics and the founding terrain lithology, a high detail geological-geotechnical mapping has been performed in the area, the scientific bibliography mentioning this area has been consulted, and a number of various field investigations had been executed: ten geotechnical wells, four cone penetration tests and two geoelectrical profiles.

The field positioning of the geotechnical works executed is according to the site plan (Annex 3).

b) Methods and equipment used

The geotechnical wells have been realized using a mechanized drilling unit Titan Pride 120 with a coring bit of 13.1 cm diameter.

The static cone penetration works have been implemented using a Pagani equipment.

c) Calendar dates of the field works

The geotechnical field works have been executed in June-July 2022. The period can be considered dry from the amount of precipitation point of view, when comparing to the annual average.

d) Stratigraphy emphasized by the geotechnical wells

The stratigraphy identified in the geotechnical wells is presented below in tables 3.1-3.10.

F1 well - 563402.32 (N), 410908.46 (E), Altitude – 309.1 m *Table 3.1*

0,00 – 0,30 m	Soil
0,30 – 3,00 m	Gravel and sand, dense, with clayish binder
3,00 – 10,00 m	Dark grey clay, hard, with very high plasticity

F2 well - 563493.80 (N), 410929.80 (E), Altitude – 310.3 m *Table 3.2*

0.00 – 4.20 m	Fillings and gavel with sand
4.20 – 10.00 m	Dark grey clay, hard, with very high plasticity

F3 well - 563737.39 (N), 410908.01 (E), Altitude – 309.1 m *Table 3.3*

0,00 – 0,20 m	Soil
0,20 – 3,80 m	Gravel with sand and clayish binder
3,80 – 10,00 m	Dark grey clay, hard, with very high plasticity

F4 well - 563321.68 (N), 411211.77 (E), Altitude – 309.3 m *Table 3.4*

0,00 – 0,20 m	Soil
0,20 – 3,20 m	Sand with gravel, with clayish binder
3,20 – 10,00 m	Dark grey clay, hard, with very high plasticity

F5 well - 563550.97 (N), 411198.52 (E), Altitude – 308.9 m *Table 3.5*

0,00 – 0,30 m	Soil
0,30 – 4,00 m	Grave land sand, with clayish binder
4,00 – 10,00 m	Dark grey clay, hard, with very high plasticity

F6 well - 563701.08 (N), 411369.06 (E), Altitude – 308.6 m *Table 3.6*

0,00 – 0,10 m	Soil
0,10 – 4,40 m	Sand with gravel, with clayish binder
4,40 – 10,00 m	Dark grey clay, hard, with very high plasticity

F7 well - 563520.59 (N), 411460.23 (E), Altitude – 308.7 m *Table 3.7*

0,00 – 0,20 m	Soil
0,20 – 4,60 m	Gravel with sand, with clayish binder
4,60 – 10,00 m	Dark grey clay, hard, with very high plasticity

F8 well - 563521.33 (N), 411742.00 (E), Altitude – 307.6 m *Table 3.8*

0,00 – 0,20 m	Soil
0,20 – 4,50 m	Gravel with sand
4,50 – 10,00 m	Dark grey clay, hard, with very high plasticity

F9 well - 563294.27 (N), 411672.66 (E), Altitude – 307.2 m *Table 3.9*

0,00 – 0,20 m	Soil
0,20 – 4,20 m	Gravel with sand
4,20 – 10,00 m	Dark grey clay, hard, with very high plasticity

F10 well - 563309.34 (N), 412096.26 (E), Altitude – 307.0 m *Table 3.10*

0,00 – 0,30 m	Sandy soil
0,30 – 4,70 m	Gravel with sand, with clayish binder
4,70 – 10,00 m	Dark grey clay, hard, with very high plasticity

Fig.7. F1 well – meters 0-6

Fig.8. F1 well – meters 6-10

Fig. 9. F8 well – meters 0-6

Fig. 10. F8 well – meters 6-10

Fig.11. F10 well – meters 0-6

Fig.12. F10 well – meters 6-10

e) Underground water level and aquifer characteristics

In the executed wells, the water level was encountered at depths between 2.90 – 4.00 m. The laboratory analyses realized on the water sample collected from F10 well reveal the fact that the water in the aquifer shows **a lower sulphatic aggression to concrete** and is **slightly corrosive to metals**.

4. GEOTECHNICAL DATA PROCESSING AND ASSESSMENT

a) Ranking the project in a certain geotechnical category

A project's ranking in a geotechnical category is made according to NP 074/2014: "Norm regarding the principles, requirements and geotechnical investigation methods of the foundation terrain".

The geotechnical category indicates the geotechnical risk for constructing a building. The geotechnical risk depends on two groups of factors:

- Factors related to the terrain: terrain reliability, underground water and seismic area;
- Factors related to the importance level of the building and the relationship with the vicinities.

According to NP 074/2014, annex A, table A.1.2, the geological formation being a foundation layer is classified as good foundation terrain.

The water level has been encountered in the executed wells at depths of 2.90-4.00 m.

Geotechnical risk

The risk evaluation and the geotechnical ranking has been realized according to the elements in the following table:

Considered factors	Categories	Points
Terrain reliability	Good terrains	2-3
Underground water	No sumps	1
Building importance	Low	1
Vicinities	No risk	1
Seismic characteristics	$a_g = 0.10$ g	1
TOTAL points		7-8

The geotechnical category resulted after summing the elements in the table above is 1, corresponding to a **reduced** geotechnical risk.

b) Field and laboratory data analysis and interpretation

The project site is located in the Transylvanian Plain morphological unit.

Throughout the field investigations, sand and gravel deposits have been identified at the surface.

The identification and characterization of the soils has been realized by analyzing the undisturbed and altered samples collected from the geotechnical wells, resulting the following parameters:

- Granulometric composition
- Plasticity limits (Atterberg limits)
- Natural moisture
- Free swell
- Natural density
- Oedometric modulus
- Direct shear resistance

c) Determination of the geotechnical parameters

According to the geotechnical laboratory analyses on the undisturbed sample P13 and the disturbed samples P12, P64, P91 and P103, the identification and characterization physical parameters for the dark grey shales, have the following values:

- granulometric fraction distribution:
    - clay: 50-56 %
    - silt: 40-45 %
    - sand: 4-6 %
- natural moisture: w = 15,97 – 19,03 %
- lower Atterberg plasticity limit: w_P = 21,11 – 22,63 %
- upper Atterberg plasticity limit: w_L = 51,87 – 60,74 %
- plasticity index: I_P = 30,76 – 38,11 %
- consistency index: I_C = 1,072 – 1,175
- natural density: ρ_n= 2,01 g/cm^3
- dry density: ρ_d= 1,71 g/cm^3
- porosity: n = 36,61 %
- pores index: e= 0.58
- moisture degree: Sr= 0.800
- Oedometric modulus: $M_{200\text{-}300\ natural}$= 25000 kPa

- undrained consolidated cohesion: c_{cu}= 77,56 – 90,27 kPa
- undrained consolidated internal friction angle: ϕ_{cu}= 14,45 – 14,57 °
- Free swell: Free Swell = 170 – 338.33 %
- pH = 8,70
- Chlorine: Cl = 53 mg/kg
- Soluble sulphates: SO_4 = 156 mg/kg

The values above classify the formation as cohesive soils, with very high plasticity, hard consistency, with reduced compressibility and high resistance at direct shear. According to NP 126-2010, the formation is very active regarding its swelling and contracting behavior.

According to the geotechnical laboratory analyses on the disturbed samples P11, P61, P63, P101 and P102, the identification and characterization physical parameters for the gravel with sand have the following values:

- granulometric fraction distribution:
    - clay: 0 – 11 %
    - silt: 0 – 14 %
    - sand: 31 – 79 %
    - gravel: 22 – 52 %
- pH = 8,15 – 8,81
- Chlorine: Cl = 11 – 25 mg/kg
- Soluble sulphates: SO_4 = <50 – 436 mg/kg

The values above classify the formation as non-cohesive soils, with heterogenous granulometry.

The **static cone penetration tests (CPT-E)** have encountered significant problems at equipment anchoring in the soil. Since the first layer is non-cohesive and contains boulders down to at least 3 m, the consistence did not allow the equipment to anchor itself with the ground for three of the investigation points. This operation is needed in order to develop the necessary pull-down force with the cone. For each of the three points, a number of 8 – 10 anchoring attempts had been made.

In the case of **CPT3** survey point, placed in the vicinity of F6 well, the anchoring could be realized, allowing a static penetration down to a depth of 2.17

m, where the investigation was stopped due to a penetration refuse, caused probably by a layer of bounders. After processing the data and integrating the results with the well data and laboratory analyses, values for the following parameters have been obtained:

Layer	Depth (m)	Nspt	Type	Compaction degree	Cone resistance Qc (MPa)	Sleeve friction fs (MPa)	Friction ratio Rf (%)	Internal friction angle ϕ (°)
1	0.8	26	Non-cohesive	Medium dense	12.61	0.18693	1.59	47
2	1.6	10	Non-cohesive	Loose	4.22	0.04258	0.99	38
3	2.17	25	Non-cohesive	Medium dense	12.65	0.08143	0.68	41

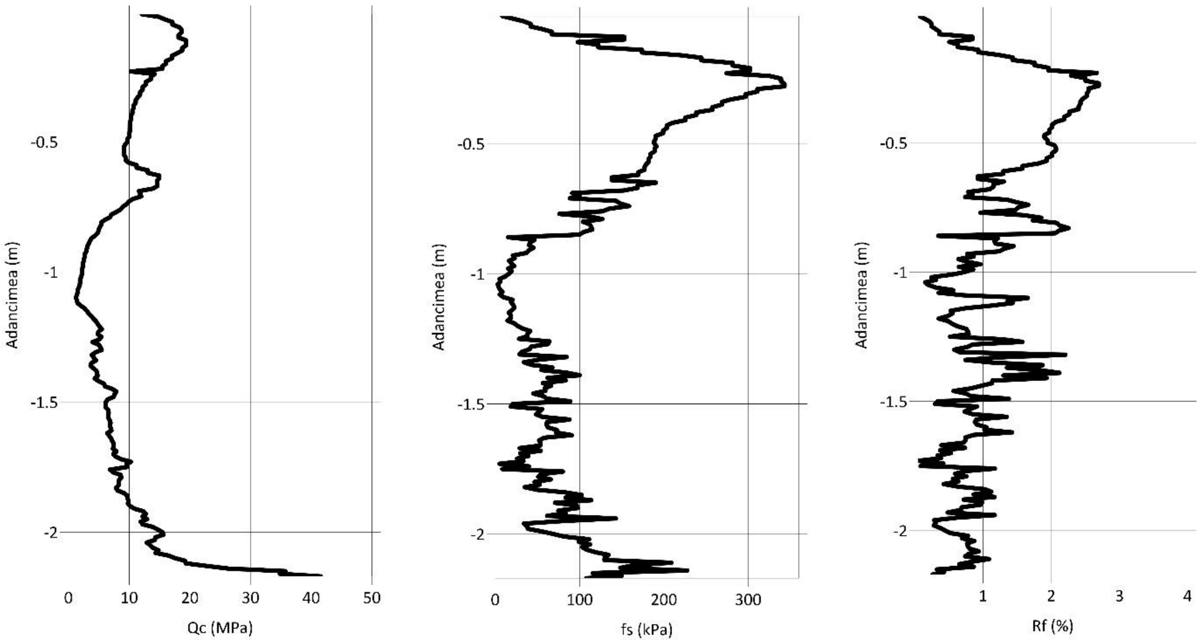

Fig. 13. Variation of Qc, fs and Rf factors with depth

The **geoelectric surveys** realized in the central part of the perimeter have aimed at identifying the burial depth of the sewer pipe that crosses the site on the NE-SW direction. After data processing and interpretation, depths of 2.40-2.60 m have been obtained for the depth of the top part of the sewer pipe.

The **geomorphological observations** made in the investigated site and the information collected from the locals have emphasized an area covered by an unofficial landfill, build in the area where F2 well was placed. The landfill was recently covered with a mixture of clay and gravel by the authorities. Initially, in this site a gravel exploitation was in place. After the exploitation stopped, the resulted holes were filled by locals with wastes from constructions or from house activities. The area can be seen as a positive relief zone, with up to 1 m higher than the surrounding field. The estimated geotechnical properties of this anthropic formation are similar with the gravel and sand formation that covers the rest of the perimeter.

d) General and local stability of the terrain

The investigated terrain does not show risks related to stability or flooding susceptibility caused by rivers.

e) Classifications of the soils forming the bed of the roads

According to STAS 1709/2-90, the formation encountered, that will represent a bed formation for the future roads, is classified as P1 – soils insensitive to frost.

f) Hydrologic conditions

The underground water has been encountered in the geotechnical wells at depths of 2.9-4.00 m. The terrain meets favorable hydrological conditions.

g) Climatic type

According to the Romanian zonation map established based on the Thornthwaite humidity index, the studied perimeter is found in the climatic type I, with I_m between -20 and 0.

The value of the frost index from the worst five winters in a period of 30 years, determined according to STAS 1709/1-90 for rigid road systems, is $I_{med}^{5/30} = 550\ ℃ * zile$.

h) Estimation of the dynamic modulus of elasticity

According to norm PD 177-2001, the estimated value of the dynamic modulus of elasticity of road foundation beds in the studied area is E_p=90 MPa.

i) Soil quality as embarkment construction material

Judging from construction quality point of view, the soils in the area have a good quality (index 2a-3a) as road foundation beds according to STAS 2914/84.

j) Recommended compaction grade

According to STAS 2914-84, for roads and platforms a compaction grade of 98% is recommended at depths of h ≤ 0.50 m from the road/platform surface, inside the embarkment body.

k) Classification of the soils according to Ts

According to the Ts indicator, table 1, the soils encountered in the geotechnical wells executed in the project are as follows:

No.	Soil type	Position	Cohesive properties	Loosening after excavation
3	Sand with gravel	17	Poorly cohesive	14 – 28 %
4	Clay	27	Very cohesive	24 – 30 %

l) Recommended foundation depth and system

The minimum *recommended footing depth* is $D_f = 1.10\ m$.

The *recommended footing geological layer* is made of gravel and sand, with clayish binder.

For structures, a direct footing system is recommended. Before pouring the leveling concrete, it is recommended that the base of the foundation holes will be compacted up to a 90% compaction degree.

m) Bearing capacity evaluation

The base allowable bearing pressure at depth of 2.00 m and a foundation width of B=1.00 m, according to NP 112/2014 annex D, is:

- q_a= 170 kPa for gravel with sand clayish binder, loose and medium dense.

5. **CONCLUSIONS**

From morphological point of view, the investigated perimeter is situated in the Transylvanian Plain. The area does not show risks regarding instability and landslides.

From geological point of view, quaternary deposits outcrop in the area, represented by gravels with sands and boulders.

From geotechnical point of view, the stratigraphy identified in the geotechnical wells executed is presented in **Chapter 3.d – *Identified stratigraphy*** and, together with the laboratory analyses, on the borehole log sheets – appendixes 4-13.

In the executed wells the water level has been encountered at depths of 2.90-4.00 m.

According to NP 074/2014, the geotechnical risk for the current project is **reduced**.

The present study is only valid for the project **”Photovoltaic powerplant, enclosure and connection to national electricity grid, Turda, Cluj County, Romania”.**

Using this study for other locations or for other studies exempts the geological engineer of any responsibility.

Author:

Cezar IACOB, PhD