PULL-OUT TESTS REPORT

TURDA 1 PHOTOVOLTAIC POWERPLANT

TURDA, CLUJ COUNTY, ROMANIA

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SAMPLE NO. **: 1**

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

LIST OF SIGNATURES

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A. WRITTEN ELEMENTS

B. GRAPHIC ELEMENTS

1. GENERAL INFORMATION

a) Project name and location

The pull-out tests have been executed for the project entitled: **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) Contractor: **ICS BUSINESS INTERNATIONAL SRL**

d) Site description

The area of interest lies between the inhabited areas of Turda municipality and the flood protection dam of Aries River. The perimeter is free of constructions and is currently used in agricultural interests, as pasture. The topography is relatively flat, but local variations are present, caused either by natural or anthropic interference.

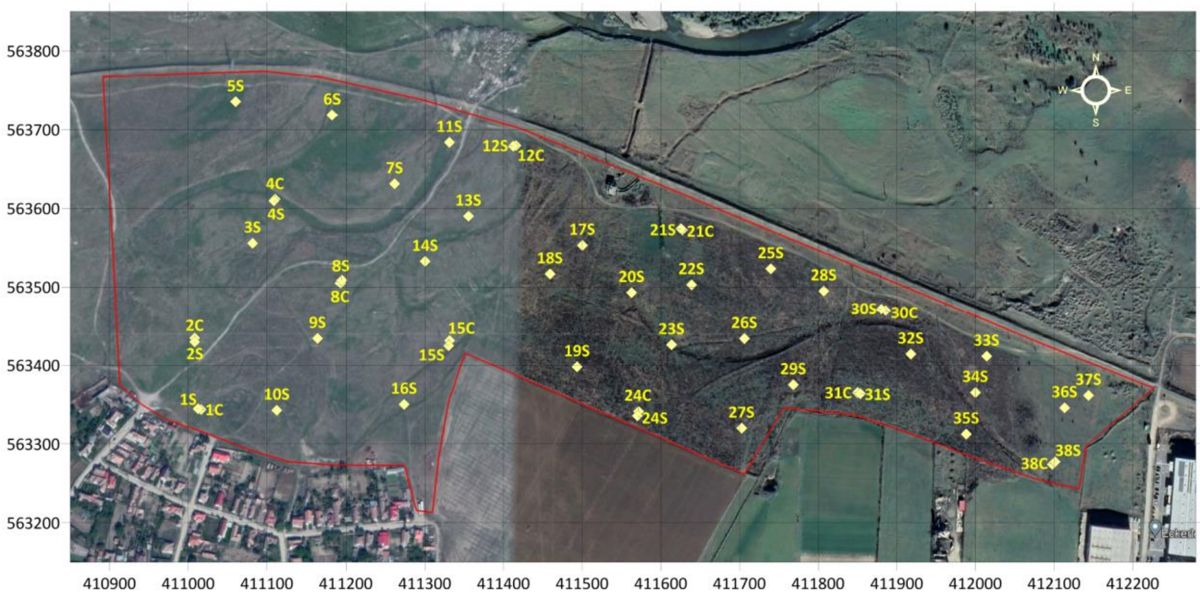

Fig. 1. Site plan of Turda 1

2. SITE PREPARATION FOR PULL-OUT TESTS

a) Metallic profiles

For the pull-out test in Turda 1 perimeter, two types of profiles have been used:

- Sigma type metallic profile – made of steel (quality index S350), with Zinc coating (Z275), 3.5 mm in thickness. The profiles had lengths of 4 m and the main dimensions of the section were 70 x 200 mm.

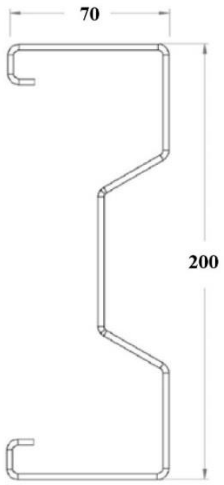

Fig. 2. Section of Sigma type metallic profile

- C type profile: made of steel (quality index S350), with Zinc coating (Z275), 3.5 mm in thickness. The profiles had lengths of 4 m and the main dimensions of the section were 70 x 140 mm.

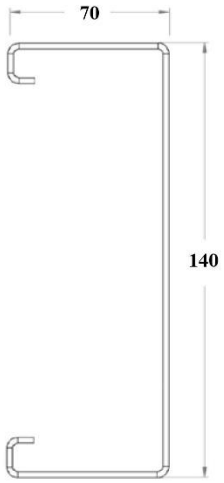

Fig. 3. Section of C type metallic profile

The metallic profiles have been acquired from TeraSteel factory (Bistrița County). The purchased quantities were: 40 Sigma profiles and 12 C profiles. The package was transported from the factory to the field site, where the profiles were distributed in the field to the planned ramming positions.

Fig. 4. Transportation of metallic profiles to the field site

A set of six metallic plates, 4 mm in thickness, 1 m length and 30 cm in width, have been acquired. Four metallic profiles (two C profiles and two Sigma profiles) have been equipped with reinforcement wings. The wings have been mounted on the short lateral of the profiles, so that, after the ramming process with a depth of 2 m, the plates should be completely buried, covering the depth interval 0.00-1.00 m.

b) Ground conditions

According to the geotechnical study executed in the area of interest, the typical lithological succession characterizing the ground conditions is made of:

- 0.00 – 1.00 – soil and sand with gravel, loose of medium dense;
- 0.80 – 3.00 – gravel with sand with clayish binder, medium dense and dense.

In the South-Western part of the perimeter, thick layers of fillings can be found, made of fine sediments and municipal wastes for the depth interval 0.00-1.00 m. Below 1.00 m, according to information collected from locals, there are big blocks of concrete resulted from building demolitions processes and abandoned out in the field.

Locally, elongated depressionary areas can be observed, with channel shape, being old erosional valleys associated to Aries River.

c) Ramming

The profiles' ramming was executed using a hydraulic vibrating plate mounted on a Sunward SWE90UF excavator.

Fig. 5. The ramming process of the metallic profiles

A network of 38 locations had been selected for performing the tests. Sigma type profiles have been installed in all these locations. In 11 locations, close to the Sigma profile (around 10 m), also a C type profile was installed, for efficiency comparison tests.

The ramming depth targeted for most of the locations has been 2.00 m. In some cases, a deeper depth was targeted, reaching to at most 2.50 m. However, there were a series of locations where the ramming could not be executed down to 2.00 m due to boulders or concrete fillings encountered. In all the locations where both Sigma and C profiles were installed, the ramming depths were similar, emphasizing that the ramming depth limitations are not due to unique local conditions, but they characterize the surrounding area.

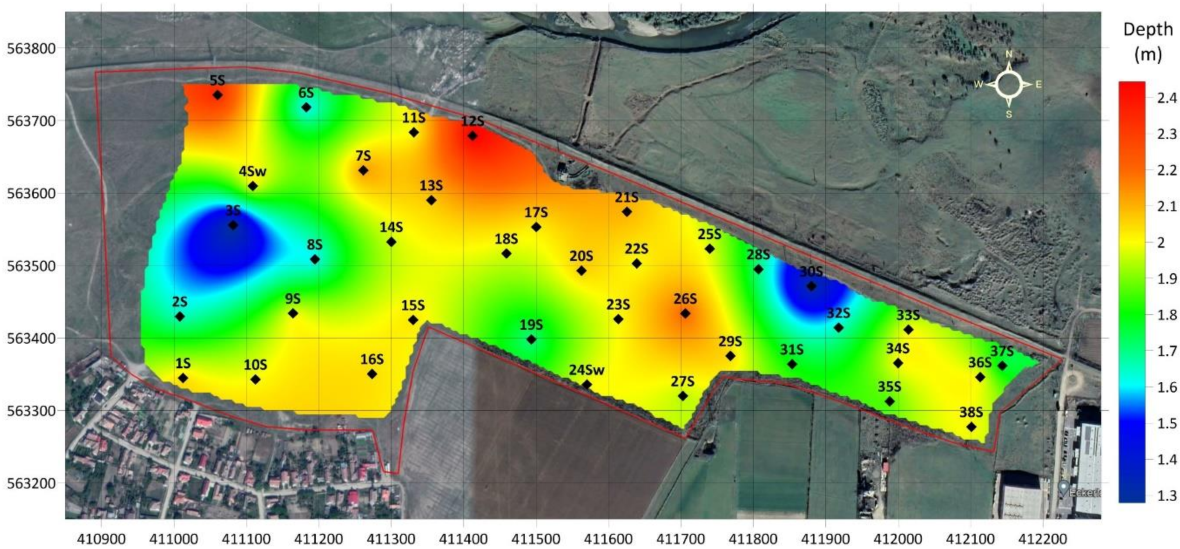

Fig. 6. Field distribution of the embedding depth

3. PULL-OUT TESTS EXECUTION

a) Measurement technology

The measuring equipment was composed of:

- AXIS FB50k Force Meter dynamometer. The device has external sensor and precisely measures extensional force up to 50 kN. The data is stored in its internal memory. The device has a performant internal clock.
- BerronTech EG1000 electronic tape measure. The device has a 1 mm precision. The data is transmitted in real time by Bluetooth to a smartphone where it's received and displayed by a mobile app. The data is recorded by the app and exported via email for data processing.

Fig. 7. The force sensor coupled vertically (left) and horizontally (right)

Fig. 8. The tape measured coupled horizontally (left) and the measurement recordings using the Axis receiver and the BerronTech phone app

For the horizontal tests, the necessary force was developed by the hydraulic propulsion system of the Titan Pride 120 drilling rig. This machine weights 5t and can develop a force of about 4t, proportional with its maximum ground coupling. The hydraulic force developed is easy to control, allowing a high discretion in terms of pulling force. The metallic profiles were tied to the drilling rig with 5t towing cables at 1 m distance from the ground. The force sensor was located in between two towing cables. The tape measure was installed at the base of the profiles, at 10 cm distance from the ground.

Fig. 9. Titan Pride 120 drilling rig tied to a Sigma metallic profile

For the vertical tests, the necessary force was developed by a Sunward SWE90UF excavator. A hole was drilled in the upper part of the profiles. The force sensor was located in between two metallic chains, one connected to the profile and the other one to the excavator arm.

Fig. 10. Metallic profile during vertical tests

b) Horizontal tests

The challenge for the horizontal tests is to identify the maximum load that can be applied to a profile without overpassing the displacement limits allowable. The limits used were:

- 25 mm displacement when the load is applied
- 10 mm displacement when the load is removed

The tests gave a large variation of results, emphasizing a significant heterogeneity of the founding terrain. The maximum loads supported by the profiles gave results between 0.5 – 20 kN. At 20 kN the Sigma profiles showed significant elastic bending, causing the field operator to stop the measurement so that the profile won't be destroyed. In one case, higher loads have been experienced. The profile suffered permanent shape modifications at 22 kN. All the following tests have been stopped at 20kN, if the displacement had remained up to that load within the allowable interval.

The maximum loads supported by the profiles have been defined as those load values that were the last ones before the test was considered to fail (displacement out of the allowable interval). A distribution map of the maximum loads has been realized, offering a good image of the site conditions from horizontal loads point of view. The map was only realized for the Sigma profiles. The C type profiles gave significantly poorer result.

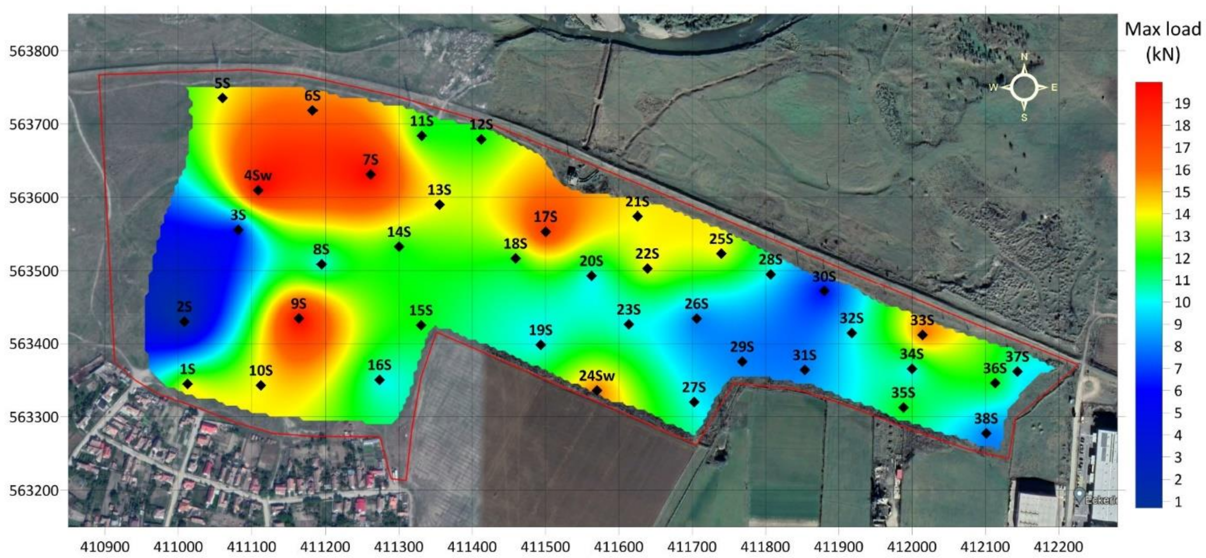

Fig. 11. Maximum loads in horizontal tests

The distribution of the results emphasizes areas with good geotechnical behavior of the ground and areas where enhancements need to be made in order to properly secure the foundation of the construction.

The tests have shown that most of the efforts of the lateral pull are taken by the formations in the depth interval 0.00-1.00 m. There is almost no correlation between the embedding depth and the horizontal pull-out results for the profiles rammed down to at least 1.50 m.

The areas colored in green, yellow and red in the map in Fig. 11 are in general area with acceptable geotechnical properties from lateral resistance point of view.

The areas with maximum loads between 6-10 kN are in general areas with poor lateral resistance. The profiles in this area are recommended to be optimized with reinforcement wings for the depth interval 0.00-1.00 m on the short lateral of the metallic profile.

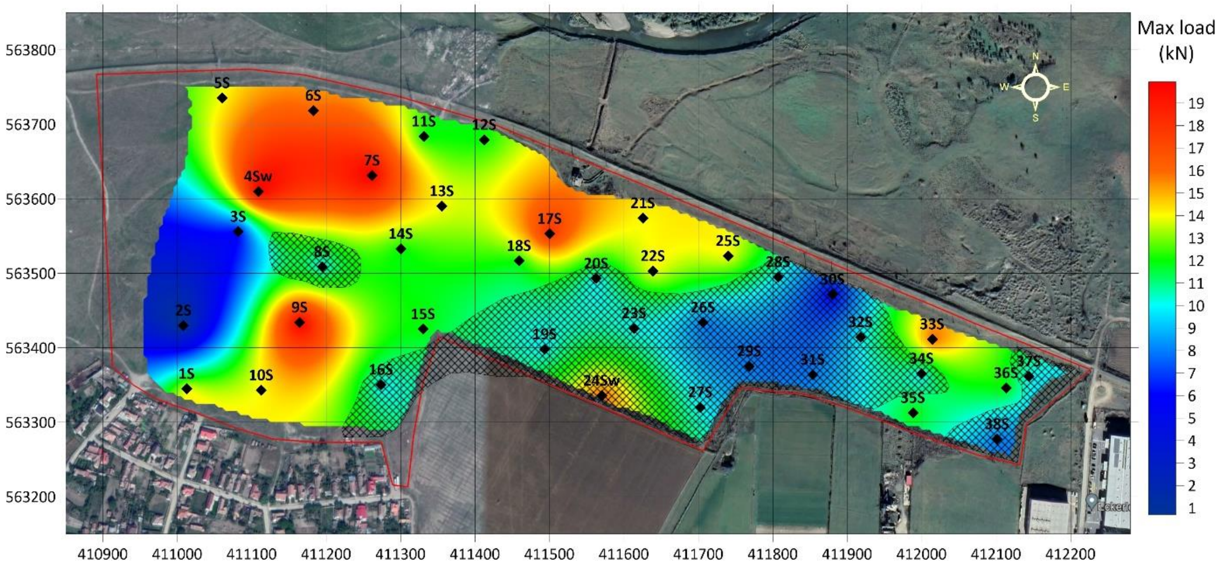

Fig. 12. Poor areas from lateral resistance point of view

The marked areas in fig. 12 also contain the point 24Sw. The profile in that point was optimized with a reinforcement wing, thin being the main cause of the good result. The test in this point offers also a relevant image of the efficiency of reinforcing the metallic profiles with 1.00 x 0.30 m wings.

The area colored in deep blue located in the SW of the perimeter is dominated by fillings on the depth interval 0.00-2.50 m. The ramming was also problematic in this area. We evaluate that, in this area, reinforcing the profiles will not work.

c) Vertical tests

The vertical tests have been executed with a step of 1 kN, starting from 0.5 kN. The maximum load applied was 30 kN. The maximum allowable displacement on the vertical was 20 mm. The moment a displacement overpassed this limit, the test was stopped.

The maximum loads supported by the profiles have been defined as those load values that were the last ones before the test was considered to fail (displacement out of the allowable interval). A distribution map of the maximum loads has been realized, offering a good image of the site conditions from vertical loads point of view. The map was only realized for the Sigma profiles.

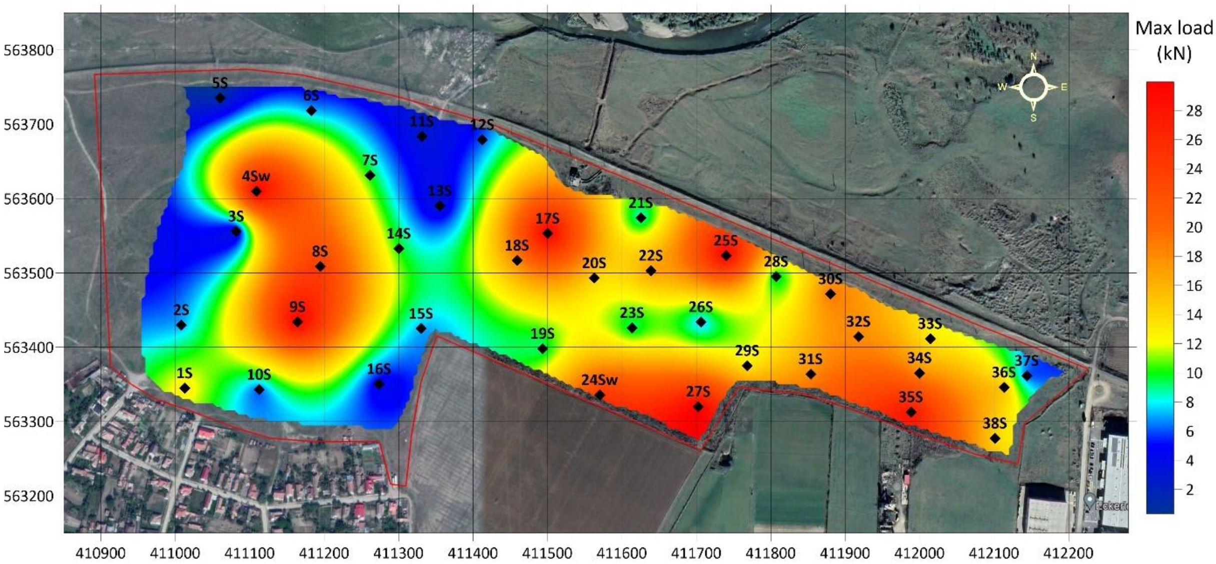

Fig. 13. Maximum loads in vertical pull-out tests

The tests showed almost no correlation with the embedding depth and a poor correlation with the horizontal tests. In general, the Western part of the perimeter gave poor results. The SW part of the studied area gave poor results for the vertical tests as well, confirming the bad ramming conditions identified so far.

The C profiles gave in general poorer results than the Sigma profiles. Where the C profiles were optimized with reinforcement wing, they gave better results than the Sigma profiles even on the vertical tests.

4. CONCLUSIONS

Horizontal and vertical pull-out tests have been realized on Turda 1 photovoltaic plant perimeter. In total, a number of 49 tests have been performed: 38 on Sigma profiles and 11 on C profiles. After analyzing all the data obtained, the following conclusions and recommendations are to be mentioned:

- Ramming is possible and recommended for about 90% of the studied area;
- In most of the areas, ramming can be safely executed down to 2.00 m;
- There are areas where ramming cannot be executed at 2.00 m, due to the presence of big boulders or of big concrete blocks deposited as fillings;
- The Sigma profiles used (70x200 mm in section) could be tested for horizontal resistance up to 20kN. The profiles break at 22 kN (permanent deformations).
- The terrain showed a high degree of heterogeneity from geotechnical point of view. A large variation of values characterizes both horizontal and vertical tests;
- Sigma profiles gave much better results than C profiles. The main reason is probably related to the bigger size of the Sigma piles (70x200 mm in section) compared to the C profiles (70x140 mm in section). It is recommended that the profiles used for the construction process should have the length of the section of at least 200 mm. Profiles with section width of 100 mm will show better resistance.
- Tests performed on profiles with reinforcement wings gave much better results on both horizontal and vertical tests.
- The profiles that supported horizontal maximum loads between 6-10 kN characterize area with poor lateral resistance for the depth interval 0.00-1.00. In these areas, it is recommended that the profiles should be enhanced with reinforcement wings for the depth interval 0.00-1.00.
- There is a poor correlation between the embedding depth, horizontal and vertical tests.
- The lateral resistance is defined by the compaction grade of the soil for the depth interval 0.00-1.00 m. Deeper ramming would not improve the horizontal resistance.
- The vertical resistance is defined by a large number of factors, cumulating granulometry, compaction grade and contact surface between the metallic profile and the soil. Even though the embedding depth increases the chances for better resistance, the tests showed poor correlation between the two. Reinforcement wings showed efficiency in increasing the vertical pulling resistance.

- The area in the SW of the perimeter is dominated by fillings, with loose sediments on the depth interval 0.00-1.00 and big concrete blocks between 1.00-2.50 m. The area is not suitable for ramming. A different foundation system should be used. A potential solution would be: drilling holes of 250 mm in diameter with pneumatic ground hog or with hydraulic percussion, fill them with concrete and install metallic profiles in the liquid concrete, before cementing. The depth of the holes should be between 2.00-2.50 m.
- There are areas with lower elevations in the perimeter, with channel shapes. Those areas should be filled with compacted fillings. It is recommended that the granulometry of the chosen material be as variable as possible. The gravel class should not contain rocks bigger than 50 mm.

The test sheets and the results centralizer are attached to the current report in Appendix 5.

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