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11th International Conference on Renewable Electrical Power Sources

PROCEEDINGS

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RAZVOJ APARATURE ZA IN SITU ISPITIVANJE ANKERA NOSACA SOLARNIH PANELA

DEVELOPMENT OF THE APPARATUS FOR IN SITU TESTING OF SOLAR PANEL RACKING ANCHORS

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Apstrakt

U izvesnim slučajevima se solarni paneli postavljaju na odgovarajuće konstrukcije koje su oslonjene na tlo, a to u okviru projekta konkretne konstrukcije obuhvata i odgovarajuće dimenzionisanje ankernih nosača, odnosno oslonačkih elemenata. Imajući u vidu velike varijacije u kvalitetu tla i različite ambijentalne uslove koji zavise od lokacije, razvili su se različiti načini dimenzionisanja, od iskustvenih, preko onih definisanih na osnovu uslova tla i teorijskih modela, do numeričkih koje karakteriše odgovarajući stepen tačnosti. U radu je prikazan princip in situ ispitivanja nosivosti probnih ankera pomoću posebno razvijene aparature, u cilju provere projektovanih uslova i eventualne korekcije ovog dela projekta konstrukcije.

Ključne reči: *solarni paneli; ankeri; pull-out metoda*

Abstract

In certain cases, solar panels are placed on suitable structures that are supported on the ground, and this includes the appropriate dimensioning of anchor supports, i.e. support elements, within the framework of the concrete construction project. Bearing in mind the great variations in soil quality and different ambient conditions that depend on the location, different ways of dimensioning have been developed, from experiential, through those defined based on soil conditions and theoretical models, and to numerical ones characterized by the appropriate degree of accuracy. The paper presents the principle of in situ testing of the load capacity of trial anchors using specially developed apparatus, in order to check the designed conditions and possible correction of this part of the construction project.

Keywords: *solar panells; anchorage; pull-out method*

1 Introduction

The solar panel industry represents a very dynamic area, with a wide range of places where solar panels can be mounted. Although the most common position of solar panels are the rooftops of residential and business objects, in some cases solar panels are placed directly on the ground. This is possible whenever there is a lot of space for their installation, and little possibility that they can be damaged by actions of nature or man, such as snow, leaves and branches, or vandalism.

Different electrical power sources have different foundation systems, according to their nature and application [1]. In such cases, when solar panels are positioned directly on the ground, a carrying structure (i.e. racking structure with several repeating sub structural groups) is calculated on the basis of different loads that are acting on the structure. These loads include: load of the structure itself, snow, compressive wind, tensile wind, and earthquake. These loads are usually combined through several loading conditions, in order to obtain the envelope of the load, leading to the proper design of the structure elements (columns, beams, tendons, primary and secondary trusses, etc.) and their connectors (screws, bolts, etc.), that can carry and transfer the load correctly. Besides the loads, possible limiting factors for the design of the structure elements are deflections in all three directions in the spatial model (one of the possible structure variants in deformed shape illustrated in Fig. 1) of the complete structure. These calculations, modeling, and designs are often made using commercial software that substantially improves the velocity and visualization of every step of the design process.

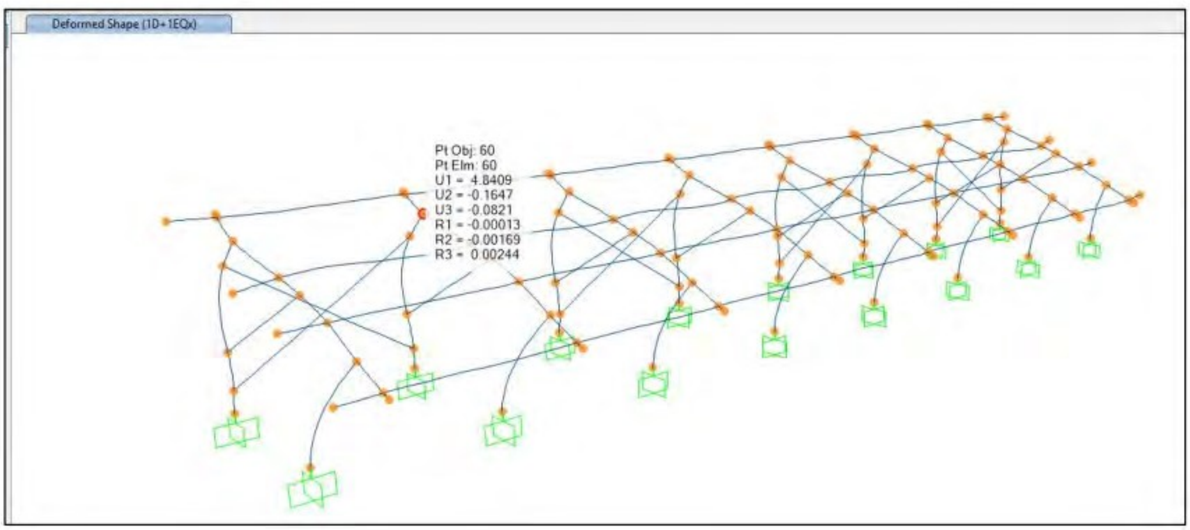


Figure 1: Illustration of the design interface of solar panel racking structure

As it can be observed from the illustration of the design interface of the solar panel racking structure, the structure ends with boundary conditions in the base of the structure, called supports that are of fixed type in all directions. Due to the nature of the soil, and according to the structure type and loads, supporting elements are materialized as anchors (piles). These piles can be of different dimensions and materials, and are usually calculated from the vertical and horizontal loads, with respect to momentum in all directions that come from the structure. This paper deals with possible solutions for the in situ testing of anchors for a solar panel racking structure, and offers one developed method for this estimation. At the end of the paper, the valorization of such a method will be shown, in the form of the case study.

2 Considerations related to the topic

The solar panel racking structure is considered to be a lightweight structure from the structural design point of view. Therefore, little consideration is given to the design of their supporting, or anchorage system. The anchors used in such structures are usually vertically driven to the soil and dominantly loaded by vertical loads, of which often tensile is of utmost importance. In most cases, the anchors are made of steel and they are approximately 1 m long, with different cross sections. Several possible anchors are shown in Figure 2.

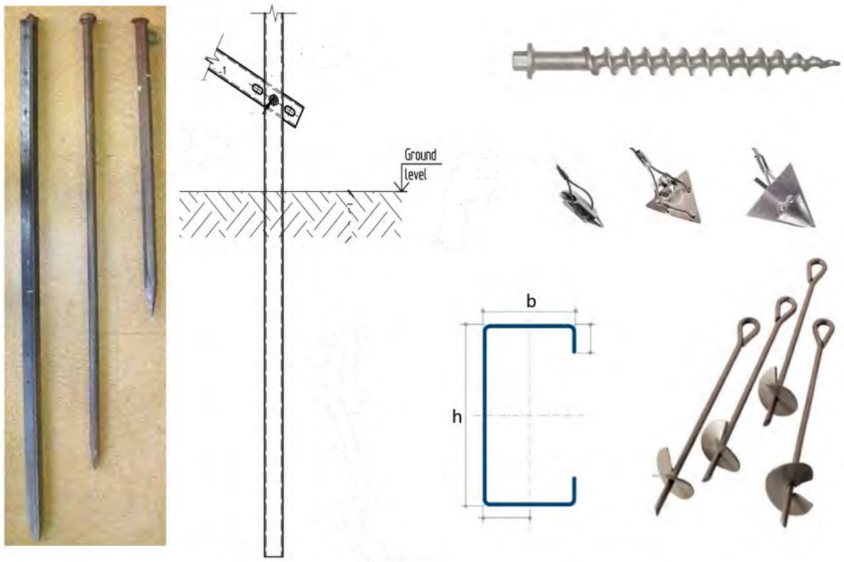


Figure 2: Several types of soil anchors for solar panel racking structures

The most important properties of steel anchors are connected to their chemical composition, mechanical and geometrical properties, etc. [2,3,4,5,6]. Besides the loads from the racking structure, these anchors are chosen based on the type of soil (for instance according to [7,8]) and following the specifications and guidelines, if present.

Due to the fact that the in situ conditions are different for every structure, carefully conducted testing improves the chances for proper design and building of the structures. The tests are usually made on site (or in situ), in order to take into account the effects of soil properties, ambient conditions, properties of the structure and connections with the upper part of the structure. Of course, the tests are made on the installed pilot anchors or control anchors, depending on the building phase, but always rooted and loaded the same way that the carrying anchors will be. Standards to be followed in such conditions are [9] or [10].

Many researchers offered prediction models for the performance of anchors with respect to their pullout capacity, concluding that the most important parameters for this process include: equivalent anchor diameter, embedment depth, average cone resistance along the embedment depth, and average soil adhesion along the shaft depth [11]. In summary, and as expected, the measured pullout capacities were greater for soils of higher skin friction, as the width or diameter of the anchor increased, as the embedment depth of the anchor increased, and for static rather than dynamic installation [12]. The paper estimated various researchers' predictions in terms of overrating or underrating the capacity of anchors. Some valuable insights have been achieved through the fiber optic measurements along the anchors, with the aid of numerical simulations [13], but the most effective results are those of in situ tests. Here the modified Pull-out test will be shown, which was initially intended for the assessment of the pull out strength of the reinforcement bars in the concrete, and therefore intended for the assessment of the concrete properties.

3 Case study of the in situ testing of anchor

Due to the real need of the solar energy power plant building in a specific location, the in situ procedure of investigation of anchors was conducted. The anchors were designed to have a total depth of 1.5 m. The maximum tensile force in the carrying anchors was calculated to be 8.7 kN, on the basis of the statical design report of the structure. For this endeavor, the pull out apparatus according to the standard SRPS EN 12504-3 was modified in order to provide valuable data on the ultimate load bearing of the test anchors with respect to their head vertical displacements (longitudinal to the anchor).

The testing was conducted with the pull out test apparatus C376N of the producer Matest S.p.A. and the specially made extension kit, designed and made in the workplace ELNOS GROUP Banjaluka, as shown in Figure 3. The kit consists of the simple structure, made of a rigid rectangular frame as a stable ground support and a thick steel plate with openings matching the anchorage cap and four threaded steel bar connectors of ground support and steel plate. Through the lead of the instrument the load is applied on the head of the anchors, and gradually increased with the aid of a hydraulic press, equipped with a force measuring gauge. The loading was ended either when the ultimate load was reached, or when the deflection reached 50 mm, according to the D. S. Lau and J. V. Simmons criteria [14].

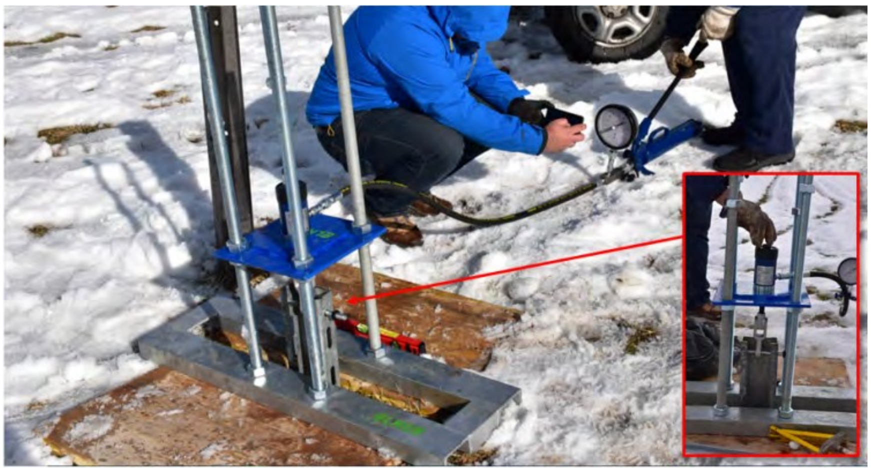
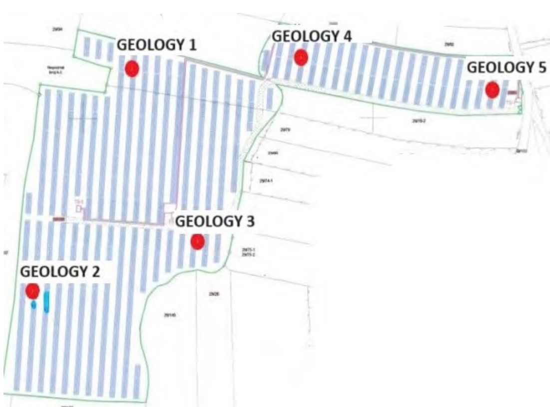


Figure 3: Modified extension kit for pull out tester

The testing anchors were driven to the soil after the properties of the soil were recorded, based on several test drills. The illustration of the test drill and properties of the soil is shown in Figure 4.



ENGINEERING AND GEOLOGY DATA*

	BUILDING DEPTH (m)	LAYER THICKNESS (m)	UNDER-GROUND WATER LEVEL (m)	LITHOLOGICAL COLIMN PROFILE	LITHOLOGICAL DESCRIPTION OF THE MATERIAL	DEPTH (m)
	0,50	0,50		1	HUMUS/HUMUS CLAY	0,3 0,6
	1,70	1,20		2	UNBOUND LIMESTONE COARSE GROUND	0,9 1,2 1,5 1,8

*SAME GEOLOGY DATA OBTAINED AT ALL 5 GEOLOGY TESTING LOCATIONS

Figure 4: Properties of the soil at the specific location

The anchors were driven three days prior to the testing. Ambient conditions at the location, at the time of testing, were as follows: temperature of 3.5-4°C. Snow layer was present in the area at the time of testing. Relative humidity at the time of testing was 50-58% (Figure 5). The low air temperature could indicate a possible frost of the soil, which can result in higher pull-out readings.

Figure 5: Ambient conditions at the in situ testing

As an illustration, the appearance of the profile before and after the testing, measured pull out heights before and after the testing and force readings on the gauges are shown in Figs 6 – 12.

Figure 6: The appearance of the anchor POS 1 before testing

Figure 7: The appearance of the anchor POS 1 after testing

Figure 8: Initial height POS 1

Figure 9: Height after the I displacement POS 1

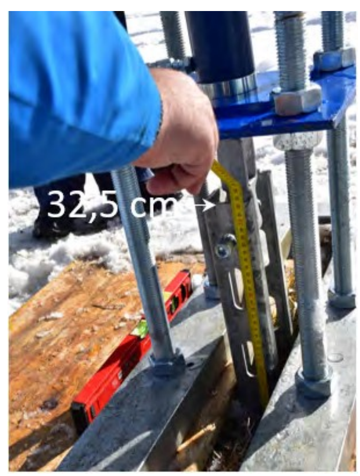


Figure 10: Height after the II displacement POS 1

Figure 11: Reading after the first displacement POS 1

Figure 12: Reading after the second displacement POS 1

Finally, results of the tests, pull-out ultimate load forces and longitudinal displacement values on five locations are given in Table 1. As can be observed, the dissipation of the results is very high, but the results hold a valuable interpretation of the exact field conditions, which is of high importance for the design check and serves as a good base for the start of construction work.

Table 1: Results of the tests conducted in situ on five locations

Designation of the field test position	Displacement (mm)	Force measurement (kN)
POS 1	53	11.0
POS 2	59	10.5
POS 3	57	5.0
POS 4	95	11.5
POS 5	59	10.5

4 Conclusions

The developed field extension kit for the pull out apparatus for solar panel racking structure anchorage is presented in the paper. There are a number of conclusions that can be made on this topic:

- the ultimate loads corresponding to 50 mm displacements of anchors were in a wide range between 5.0 kN and 11.5 kN, with only one below the design value of 8.7 kN (stated as the lowest value according to the design project);
- The variation in the test results is the consequence of different soil properties at the exact location, and to a small extend the consequence of the different approaches and possitionings of the equipment;
- The final suggestion based on the test was to increase the anchorage depth by 0.5 m, to the total depth of 2.0 m.

Besides the stated specific conclusions, the overal conclusion was reached that it is possible to use the developed and addopted test method even in the harsh ambient conditions, but freezing of the soil at time of tests should also be taken into account. Namely, the obtained results are most probably somewhat higher then expected, due to such improvement of the soil properties at freezing conditions. Consequently, special care must be taken with respect to the change of the measurement with regard to the ambient conditions.

This test represents only a short illustration of the segment whenever building of the solar panel racking structure takes place on an area with little or no population, directly on the ground. It shows the significance of the field tests and the possibility of alternation of the common methods in order to answer the needs of sustainable electrical energy power sources in this phase of its construction.

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