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Modern geodetic methods for monitoring landslides – Case study "The approach road between Orşova municipality and Topleţ plateau, Dranic peak, Mehedinţi County"

Clara – Beatrice Vîlceanu[1], Sorin Ioan Herban[2], Cosmin Constantin Muşat[3]

Abstract: This paper's objective is to present the methodology, by means of modern geodetic techniques, of monitoring the behaviour in time of a landslide occurred in Mehedinţi County which affected the approach road to 2 wind-driven electrical power stations of 3 MW located on Dranic peak. The necessity of the study emerged from the requirement of reengineering works. The technology used and the final deliverable, materialized as the three dimensional model of the terrain, emphasises the importance and the applicability of geodesy in giving proactive solutions to engineering problems.
Keywords: landslide, geodesy, monitoring, three-dimensional model.

1. INTRODUCTION

The south-western region of Romania is confronted with instability phenomena (Fig. 1), requiring timely detection of slide prone areas present there, in order to establish prevention methods and drafting risk maps. Landslides are not characteristic to Mehedinţi County, but in recent years there have been many such phenomena due to heavy rainfall, massive deforestation and lack of banks and slopes along traffic arteries.

The case study detailed in this paper aims to describe the phenomenon of instability that affected the access road [1] to 2 wind-driven electrical power stations of 3 MW located on the Dranic peak in Mehedinţi County by an overview of the study area, which includes the soil stratification and also the topographic and geodetic measurements conducted.

Current works include the processing of the first session of topo-geodetic measurements, but other sessions of measurements will follow in order to determine the behaviour of the slope in time.

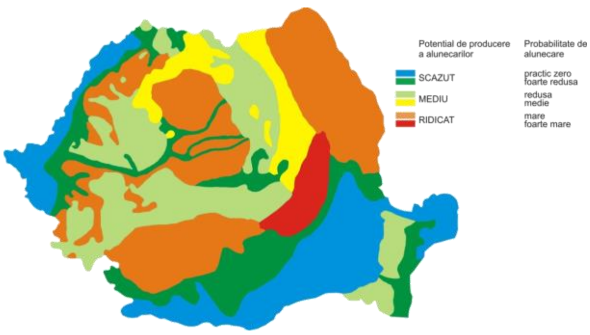

Figure 1. Romania – country with landslide potential [2]

2. DETERMINATION OF SPECIFIC GETECHNICAL PARAMETERS TO CHARACTERIZE THE BEHAVIOUR OF THE SLOPE – DRANIC PEAK

The investigated site is the road route linking the city of Orşova to Topleţ Plateau, located in Mehedinţi Plateau (Fig. 2).

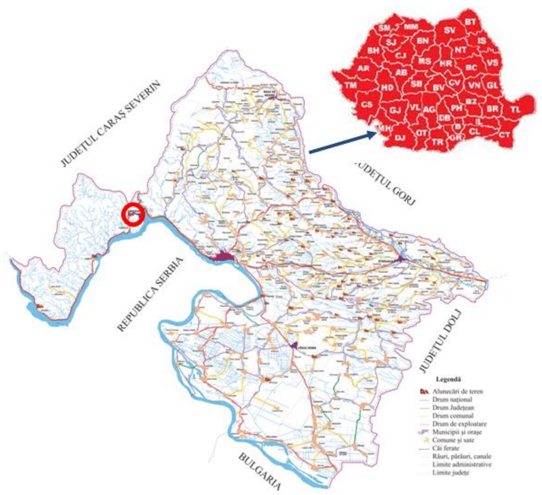

Figure 2. Location of Mehedinţi County on the map of Romania

[1,2,3] "Politehnica" University of Timişoara, Faculty of Civil Engineering, Department of Land Measurements and Cadastre, 2A Traian Lalescu str., 300223, Timişoara, Romania, PhD Student, beatrice.vilceanu@yahoo.com Ph.D. Lecturers[2,3], sorin.herban@ct.upt.ro, cosmin.musat@ct.upt.ro

Mehedinţi Plateau forms a lowered porch in eastern Mehedinţi Mountains and from physical-geographical point of view it can be distinguished as a well individualized region distinct from its neighbouring regions. It stretches over 50 km from north-east to south-west, 20 km wide, covering an area of approximately 1200 km^2. Although the general appearance of the landscape is smooth, the detailed landscape is highly fragmented and is crossed by numerous deep and narrow valleys with steep slopes, difficult to access (e.g. Topolnița valleys, Coşuştei and Bahnei). Crystalline rocks and limestones, acting variously with respect to natural factors, present a unique morphology with varied landscapes. [3] Crystalline rocks generate smooth forms, rounded, in contrast with limestones which generate a more spectacular relief consisting of steep rocky slopes, sinkholes, springs, natural bridges ("Bridge of God" (Fig. 3) - Ponoare), caves etc.

Figure 3. Bridge of God, Mehedinți County

By its position in the south-west of the country, Mehedinţi County has a temperate continental climate, with Mediterranean influences. Throughout the year, but especially in winter, above the county, invasions of wet and warm air masses with Mediterranean and Oceanic origin occur. From the point of view of communication channels in the area, the normative STAS 1709/1-90 located the site in the climatic type II. [4]

Direction of air masses in the county is influenced by the orientation and layout of relief units, prevailing winds are western, north-western and north-eastern. In the Danube Gorge and Mehedinţi Plateau, the predominant winds are the western and north-western ones. Average wind speed can reach [6, 7] m/s in mountain and canyon regions and lower values in Mehedinţi Plateau and Motru Piedmont. In contrast, annual maximum speeds reach up to 20 m/s in the Danube Gorge, where the wind is channelling on the Danube corridor.

Frost depth in the studied area is between [70, 80] centimeters, according to STAS 6054-77. [5]

According to the seismic design Code P 100-2006, ground acceleration for design (horizontal component of ground motion) is ag = 0.16 g, corner period is Tc = 0.70 sec, and β0 = 2.75, placing the studied site in an area with moderate seismic risk. [6]

In February 2011, at km 1+ 642 located in the curve of the road, a landslide, with the width of about 40 m and a length of about 70 m down the slope, occurred. For preparing the geotechnical study and determining the causes that led to the instability phenomenon of the natural slope and road part situated in the curve, 2 geotechnical drillings, F1, F2, were conducted in the foundation soil to a depth of -8.60 m, respectively - 6.50 m.

Foundation soil stratification revealed by drilling F1 is:

- [-0.00, -0.20] m – Humus;
- [-0.20, -0.90] m – Compacted silty brown yellowish clay;
- [-0.90, -2.00] m – Compacted yellowish gray sandy clay with gravel;
- [-2.00, -3.10] m – Compacted yellowish gray sandy clay with small gravel and ferruginous inclusions;
- [-3.10, -4.00] m – Compacted yellowish gray sandy clay with small grave and ferruginous inclusions;
- [-4.00, -5.30] m – Gray-ash sandy clay with small gravel and ferruginous inclusions and compacted at the base;
- [-5.30, -5.50] m – Compacted silty gray-ash clay;
- [-5.50, -6.40] m – Hard silty-sandy yellowish gray clay;
- [-6.40, -6.80] m – Hard silty greenish-gray clay;
- [-6.80, -7.50] m – Hard silty-sandy greenish gray clay;
- [-7.50, -8.20] m – Hard sandy clayish blueish-gray silt;
- [-8.20, -8.60] m – Hard silty sandy blueish-gray clay;
- [-8.60, downwards] m – The layer continues.

F2 drilling was done in the stable gabions area and it revealed the following stratification:

- [- 0.00, -0.10] m – Humus;
- [-0.10, -1.00] m – Hard silty sandy gray brownish clay;
- [-1.00, -1.70] m – Medium and large gray brownish sand;
- [-1.70, -2.20] m – Hard silty sandy ash gray clay;
- [-2.20, -2.90] m – Hard gray brownish loam sand ;
- [-2.90, -3.20] m – Medium and large gray brownish sand;
- [-3.20, -4.30] m – Hard silty marn blueish ash gray clay;
- [-4.30, -6.50] m – Hard silty sandy marn blueish ash gray clay;
- [-6.50, downwards] m – The layer continues.

The area at km 1 + 642 is an area where 2 natural slopes meet, their geomorphology being partially modified by the construction of the new access road. The main factor that caused instability of the road body is the natural slope's downstream failure up to the torrential valley situated at the base of the slope, due to excessive moisture this area. Accumulated stormwater from adjacent slopes and temporary flow of water from the valley produced excessive wetting of the soil massif situated between the mountain and the gabion valley. Under these conditions the instability phenomenon in this region has propagated toward the road body producing wall slip phenomena for gabions and body road volume of embankments.

3. TOPO-GEODETIC MEASUREMENTS

The configuration of the terrain affected by landslides gives the incontestable basis for the considerations of topographical and geodetic monitoring. [7]

The total station Leica TCRA 1205 + which has a sensitivity of 5^{cc} angle and distance of 2 ppm was used in order to perform the measurements of the described landslide, under favourable conditions of temperature and environment. The temperature during the measurements was +20 º C in the morning and +30 º C at noon.

The processing of the field measurements was performed with the help of a software specialized in automatic data processing providing accurate results, Leica Geo Office Combined (Fig. 4).

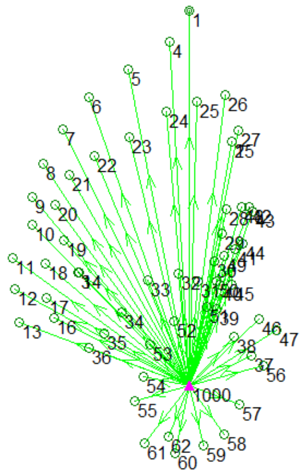

Figure 4. Sketch of tracking network for the landslide

Surface modeling is the process of plotting a natural or artificial surface through one or more mathematical equations. Land surface modeling is therefore a special case of modeling surfaces in which specific issues related to the representation of the Earth, or parts of the Earth, need to be taken into consideration. [8]

Creating the digital terrain model through planimetrical and altimetric precise measurements is of high importance because it can also be used for the calculus of:

- thickness and volume of the landslide body;
- length and width of the landslide body;
- partitioning surface area by establishing directions of slip;
- determining the longitudinal and transverse sections etc. [9]

For the making of land digital models, measurements must have a three-dimensional character. The measurements and the first iterations resulted in a data file with planimetrical coordinates and absolute rates of measured points. Then, the file was imported into a CAD program, in our case the Golden Surfer 8 program.

With the help of the coordinates file, created by extracting coordinates X, Y, Z of all points obtained from measurements, a grid, contour lines (Fig. 5), and a schematic view of the 3D object's shape and structure were performed (Fig. 6).

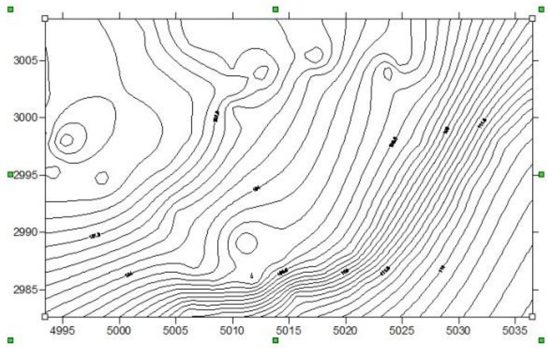

Figure 5. Contour lines for measured surface

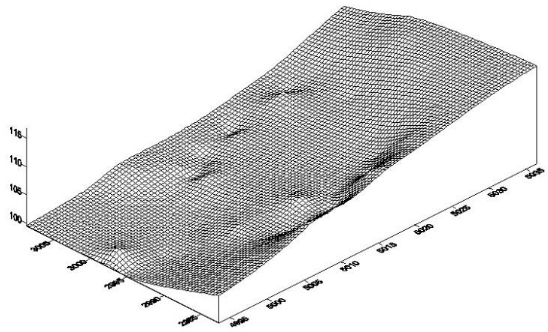

Figure 6. Schematic view of the shape and structure of the 3D object created (wireframe)

Final results of morphological analysis of the relief and those obtained for modeling geomorphological processes, directly dependent on the quality of digital terrain model (Fig. 7).

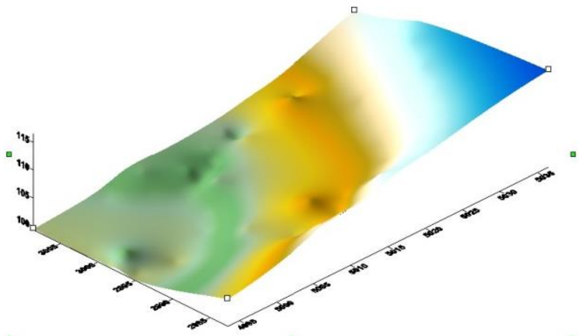

Figure 7. 3D model as a result of modeling

4. CONCLUSION

In recent years, more and more engineers worldwide have approached this relatively new field, the three-dimensional modeling, preferring 3D design systems instead of the traditional 2D drawing.

A 3D model is composed of objects, materials, layers forming a complex structure. In it we can visualize certain parts separately or all the elements together. Objects and materials have easy to highlight properties, called visual properties such as colour, light reflection, contrast. As a final product we can obtain the facade of buildings, their roofs or 3D terrain models.

The three dimensional model offers multiple possibilities for working: correction rates, connecting elements that are part of the creation of a new product starting from the basic elements. Easy handling and complexity of information provided facilitates the design process. Finally, the data can be integrated and exported to other programs specialized in a particular field, such as: design, urban planning, tourism, real estates, police and security etc. Dimensional models can be, in turn, very helpful in specific analysis, but can also be sources for the implementation of another product.

The program used in this paper for obtaining the 3D model from measurements taken with the total station is Golden Surfer 8.

By analyzing all data from the geotechnical studies as well as topo-geodetic measurements, it was concluded that the stabilization of the access road to wind aggregates can only be achieved through a complex work of embankments which necessarily must include:

- water drainage ditches at the intersection of two natural slopes that meet in the curve at km 1+ 642 having the purpose of discharging storm water and water from snow melting in the torrential valley at the base of the slope;
- compacting works of the earth massif at the base of the natural slope having the area between the layout line of the gabions and the torrential valley at the base of the slope. In carrying out this work crushed stone of large dimensions will be used for wedging of land in the area as well as layers of geogrid, for reinforcement of the massif, of a minimum thickness of 2.00 m;
- compacting works of the earth massif of the former alignment of the gabion structure that will be reinforced with geogrid layers to a depth of about 1.20 m;
- restoration of road embankment concurrently with the execution of gabions using layers of geogrid for soil fillings reinforcement up to the road structure;
- restoration of the gabion structure on the old alignment;

Future research will focus on the calculation of deformations and displacements for gauges placed on the sliding body that will result in future measurement instalments, thus further emphasizing the importance of collaboration of specialists from different fields in order to find pro-active solutions to engineering problems.

5. ACKNOWLEDGEMENT

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