Modern Means and Techniques for the Research upon the Analyse of the Subsidence Phenomenon

Maricel Palamariu, Ioan Voina

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Abstract

This paper presents the monitoring methodology during the terrestrial surfaces dislocation as a result of the subterranean exploitation, using the most recent means and techniques.

The technologies are top innovations in the domain of modern methods in the engineering topography, with the purpose of rigorously monitor the risk and hazard phenomena, presenting a complex specific analyse for the process specific information are obtained, in an efficient and precise manner, from a quantitative, also from a qualitative point of view.

The means and techniques, the results, too, are described in a synthetic form, highlighting the importance and the applicability of the engineering topography to obtain the optimal solutions for solving engineering topography problems in correlation with the durable development strategy.

Keywords: interferometry, LIDAR, terrestrial laser scanning, subsidence

[1.] Prof. univ. dr. ing. ec. Maricel Palamariu
"Universitatea 1 Decembrie 1918" Alba Iulia,
Facultatea de Științe Exacte si Ingineresti,
Catedra de Topografie si Cadastru,
e-mail: mpalamariu@gmail.com

[2.]Student doctorand ing. Ioan Voina
Universitatea Tehnica de Construcţii Bucuresti
Facultatea de Geodezie,
Catedra de Topografie si Cadastru,
e-mail: nutu_rc@yahoo.com

1. General aspects

The measuring and representation in plan for the form and the relief of Earth is one of the oldest preoccupations of the humans. The terrestrial measurements gained importance in several domains of the human activities once the knowledge amplified and the society developed.

The preoccupations of topography as fundamental science of terrestrial measuring results from its etymology, two Greek words brought together: "topos"= place and "graphein"= description. Topography resolves the problems from the terrestrial measuring science connected with other connected disciplines sharing instruments and methods. 7]

The progress from the last years in geodesy and topography, with the implementation of modern measuring technologies, left rapidly its mark on all the topographic – geodesic activities, with a high degree of applicability in research upon: special topographic elevations, topographic enginery, mining topography, the creation of the digital model of the field, time monitoring for land movement and constructions deformations etc.

2. Problem study

The coal basin from Valea Jiului registered in the last four decades an excessive input of population with different traditions and behaviour, reflecting mostly the social and economic situation of the county, numbering three municipalities: Petroşani, Vulcan, Lupeni, 3 towns (Petrila, Aninoasa, and Uricani) and a single village, Băniţa, compounded of three small villages (fig. 1).

Inside a context of durable development of the coal basin in Valea Jiului and of Petroşani municipality, several aspects are to be considered.

One of the most important factors influencing the process of durable development is the subsidence phenomenon, manifested inside the area with a high touristic potential and inside other areas of the Coal Basin Valea Jiului [4].

From a tectonic point of view, Petroşani basin has the form of a strongly fractured synclinal, especially on the limbs.

A system of major breaks oriented along the basin (west – east direction) delimitates the synclinal so the basin looks like whiter. A second breaks system compartments the sedimentary feeling of the basin in various blocks unhooked one over others, on vertical and horizontal plane

As a result of the subterranean exploitation of mineral substance (coal) a movement of rocks is produced from the roof, affecting the integrity of the surface.

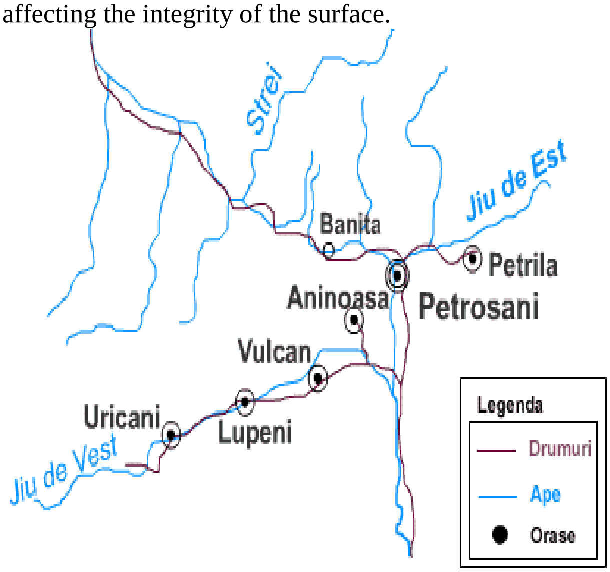

Diagram 1 the geographical placement of Coal Basin Valea Jiului

The blanks created as a result of the exploitation affects the surface above the bigger they are, through processes of sinking, movement, and deformation.

The movement of the surface is the result of redistribution of the tensions in the rocks, under the influence of subterranean excavations created by mining or as effect of the ascension of the aquafer formation. [4].

The sinking of the surface from above provokes: the loss of the reserves of potable water, the loss of stability of some protection blocks, the drift of acclivities due to the change of tensions in the block etc.

The problem of protecting the constructions and the fields on the surface are current, especially for the coal basin in Valea Jiului, where the number of objectives at the surface is very big.

The phenomenon that appears due to the movement of the surface is called subsidence.

Subsidence phenomenon are causes mostly due to the closing of subterranean blanks remained from the subterranean extraction of useful mineral substance and / or due to the alteration of hydrogeological conditions, as a result of applying a forced and very intense dewatering of the aquafer system in the area.

The parameters of the surface movement and deformation are graphically represented through: the sinking bed, the components of the absolute movement and of the differential movement, the sinking angles and the influence area.

The parameters of the movement process are obtained through topographic measurement of level and distances between the bench-marks of the alignments on the surface.

In most of the cases, the subterranean exploitation has repercussions upon the surface, manifested through sinking that may reach the amplitude of dozens of meters.

The movement of the surface as a result of the subterranean exploitation has a capital importance when the total exploitation of coal is involved, respectively the thick layers or a suit of close layers. Thus, in the civil and industrial constructions area, may appear blanks and cracks, menacing the safety; the agrarian area may present eyeholes where the rain water gathers; inside the infrastructure of communication and water or gas networks may present cracks etc. Very often, the sinking may be instantaneously produced and the braking of the equilibrium of strata may lead to catastrophes.

The moment the subterraneous excavations or the coal faces are higher than the critical dimensions from the point of view of the stability of the rocks around and any actions for the sustenance and the eliminations of blanks were taken, the decline of rocks is produced, leading to complex phenomena, named subsidence effects, that may reach the entire depth of the covering rocks, until the surface.

In Romania, subsidence phenome took place in much subterranean exploitation for coal and other minerals, e.g. the surface destruction followed by constant sinking in the coal mines in Motru, Petroşani and in the minerals mines in Ghelar, Muncelu, Deva, Baia Mare etc. (diagram 2).

The fractured instable surfaces affected several rural households and, in some cases, necessitate the evacuation and the demolition of some blocks in Petrila, or even the demolition of an entire micro district of houses in Lupeni.

The safety of a normal, without danger exploitation may be obtains only through experimental control (monitoring) upon the surface behaviour and a systematic observance in time of the existent movement at the surface level.

Studying the influence of subterranean exploitation upon the surface is necessary for highlighting the movement phenomenon and protecting the objective at the surface and the surface itself.

Because the difficulty in prevent the movement process of the surface persists, appeared the necessity of identifying procedures for abstract or analytic calculation, easy to apply for the movement of the surface, without using mechanical models (on equivalent materials).

It is more and more obvious that the classic topographic systems of observing the surfaces in the coal basins respond with difficulty to nowadays necessities due to the manifestation and resolving period of this phenomenon.

3. Modern methods and techniques

Prognoses calculations for subsidence and the dimensioning of the protection blocks may not be realises without knowing the value of sinking limit angles and maximum sinking angles.

From a graphic point of view, the size of the area affected by the movement of the entire rock massif in comparison with the size of the working space is delimited by planes which together with the horizontal plane form a number of angles named sinking angles (βs, γs, δs) and breaking angles (βr, γr, δr)[8], depending on the depth of working, on the nature and mechanical characteristics of the rocks (diagram 3). Cracks appear in places where the breaking lines defined by the breaking angles cut to the surface.

Diagram 2.Subsidence phenomenon in Petrosani coal basin

The prognosis for the deformation and movement of the terrestrial surface is based on the values of sinking angles, in the interval of 60^0-70^0.

From the observations upon the sinking result that both the rocks massif and the surface suffer movements and deformations, giving birth to compressions and tractions efforts.

The most important factors that influence the process of deformation and movement of the surface are:

- The physical and mechanical characteristics of the covering rocks;
- The tectonic of the field and of the rock massif;
- The hydrogeological conditions;
- The depth and the inclinations of the exploited strata;
- The exploitation method;
- The pressure guiding method of the surrounding rocks;
- The dimensions of the exploited space;
- The exploitation depth [4].

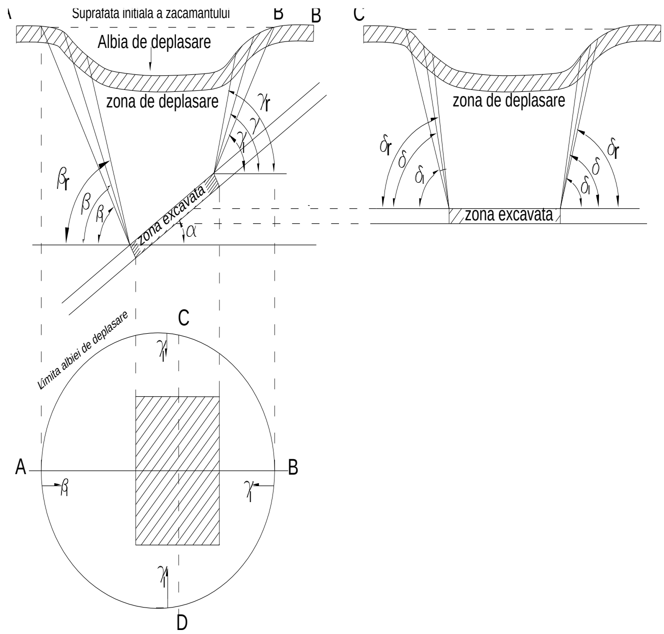

Diagram 3. Sinking angles.

While the technology is on an ascendant trend, we may say that, in the majority of technical domains, the activity of topographic insurance is mandatory for tracing, technological montage of equipment and subassemblies, the representation of objects in space, also for the insurance and the quality control of the finite products obtained after special measuring [3].

The evolution and the fundamental transformation of techniques necessary for the engineering topography projects is characterised by a continuous development and adaptation to the need for higher precision [3].

We may state that the last decade opened a new field of action through new notions as: automation, quality safety and control, leading to precise and rapid determination of objects in space inside the terrestrial measuring.

In time, a series of methods for lifting the spatial point were elaborated, starting with the classic methods to the tachometric methods, where the lifting was realised point by point with separate attributes, until the mass of points was lifted through photogrammetric and LASER scanning. [3]

The scanning technologies are based on RaDAR/LiDAR (Radio Detection And Ranging / Light Detection and Ranging) detection and localisation systems, which permit the determination of distances, orientation and relative movement speed for fix or moving objects, with the help of electromagnetic waves.

3.1 RaDAR Scanning Technology

The terrestrial LASER scanning is a geodesic technical method that permits a complete and automatic measuring for the geometry of a structure, without the help of a reflecting environment, with high precision and speed, the result of the measuring being highlighted through a multitude of points, named points cloud.

LASER scanning technology is part of the most recent methods for collecting geo data. It has applicability especially in domains that use high precision 3D data.

The principle of LASER scanning is the following: a laser beam is sent and it measures the distance from the source to the surface or to the object.

It registers the direction in the same time. Information upon an object at the surface is obtained after the evaluation of the parameters.

The LASER dispositive may be put statically on the ground (terrestrial laser scanning) or in a plane or helicopter (aerial laser scanning). For special applications, the LASER may be put in a vehicle.

The main product of LASER scanning is a set of 3D coordinates of the reflected points – point cloud. With the help of automatic, semi-automatic and manual procedures, the points are classified through later processing. In some case, information for the intensity of the reflexion may be used, and even the real colour of each reflexion (for the simultaneous acquisition of digital images, the colouring of the cloud is possible with the help of the photography).

The final result of the data procession LASER scanned may be, e.g., a very detailed model of the field or of the surface under the form of triangles (triangulation) or a general 3D vector model (diagram 6).

The technique of LASER scanning may be classified as static or dynamic.

The static LASER scanning is defined when the scanner is installed in a fix position during the acquisition of data and presents the advantage of offering a high precision of data and a vast density of collected points. (Diagram 4).

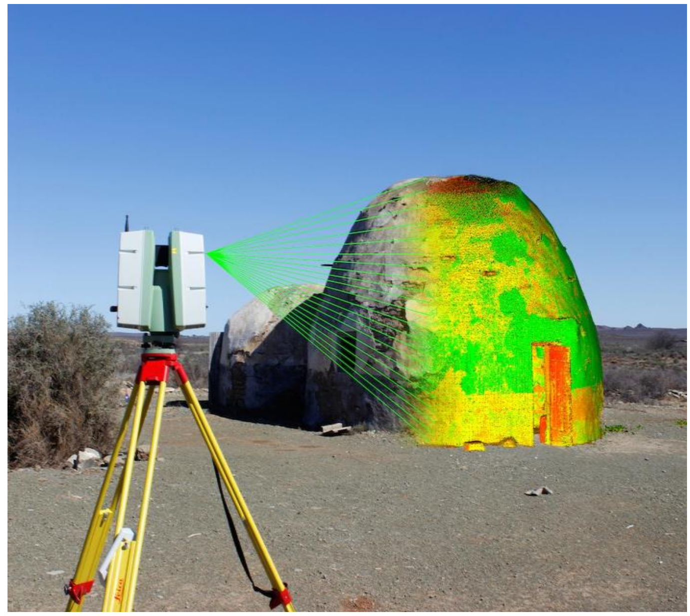

Diagram 4.Terrestrial laser scanning system.

Dynamic LASER scanning is the LASER scanning where the scanner is mounted on a mobile platform.

These systems are more complex and more expensive, because they are meant to work most of the time with additional positioning systems (diagram 5).

3.2 LiDAR Scanning Technology

LiDAR Technology (Light Detection and Ranging = detection of light and estimation of distances) represents an active technique of tele detection that helps to obtain high accuracy data upon the topography of the field, vegetation, buildings etc., being nowadays a very viable cartography technology.

It is an optical technology based on LASER impulses that measure the properties of dispersed light in order to determine the position and/ or other data upon an object in the distance.

Diagram5. Laser mobile scanning system.

Diagram 6 3D monitoring of an area, model realized with the help of RaDAR technology.

The applicability of LiDAR technology covers many domains: one of them, extremely important for the conservation of the natural resources and the protection of the human resources, is the management of emergency situations caused by hazard and, especially, the earth flows. Information upon the principles of LiDAR technology appeared even before the discovery of LASER.

The first attempt to measure the density of air in the superior part of the atmosphere dates since 1930.

LiDAR acronym was first introduced in 1953 by Middelton and Spilhaus.

In 1960, once the LASER was discovered (implemented by Hughes Aircraft Company) also a step in the direction of the use of modern LiDAR technology development is made, an evolution that continues in time.

Presenting concise the LiDAR technology, we may say that is linked to the use of a sensor, fixed with high precision in the carling of a special plane, adapted to this type of operations. The sensor transmits LASER pulses to the ground and receives them again with the help of a receptor.

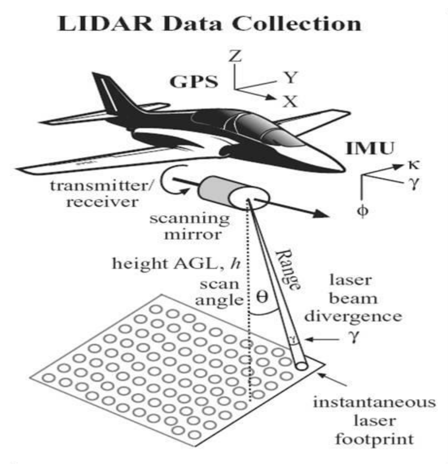

Diagram 7. LiDAR data collection.

The integrated processor determines the time interval in which the pulse leaves the plane, reaches the ground and comes back, correlating the precise position of the plane, the altitude, the movement speed, to calculate in the end the 3D position of the points from the ground (X,Y,Z), obtaining a "points cloud", compounded of hundreds of thousands or even millions of points (diagram 7). It permits a data collection with a precision up to 35 mm [9].

3.3 InSAR Technology

During the last decades, a multitude of experimental engineering works were developed using the applications of interferometry with the help of synthetic aperture radar (InSAR) with satellite sensors, starting from agrarian programmes to the monitoring of slopes movement and subsidence phenomena.

The technique uses for the satellite monitoring of terrestrial movement are called InSAR (Interferometric Synthetic Aperture Radar – interferometry with the help of synthetic aperture radar) and consists of a satellite equipped with an antenna aligned to the terrestrial surface, its inclination being called nadir angle. Starting from the first success in monitoring the movement of the slopes made by Freneau, which generated six interferograms in his attempt to monitor the slopes in La Clapiere, obtaining a movement of 30 mm per day and a model of the simple translational flow that explains the interferometric data till our days, SAR interferometry proved to be a technique that permanently tends to go in a well-defined direction to a large scale in the cartography of the terrestrial surface movement [1].

The principle of interferometry is using the phase of the radar signal through the comparison of two complex radar images simultaneously or to a time interval processed.

Interferometry produces two types of information: information upon the altimetry of the field and information upon the planimetric and altimetry movement of the topographic surface. In the first case the technique is named conventional interferometry and just interferometry (InSAR) in the second case. Its product is the altimetry digital model of the field (MDA).

In the second case, the final product is the map of movement for the topographic surface. The technology is called differential interferometry (DInSAR) (diagram 8).

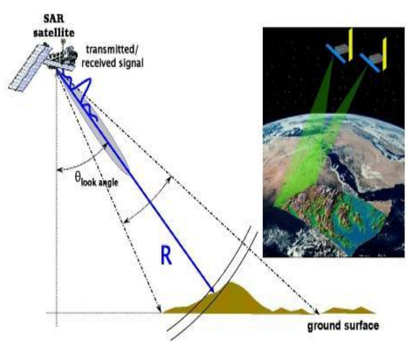

Diagram 8. Data acquisition using DInSAR technology.

This method makes possible the detection of differential changes of "gamma" distances between the sensor and the radar targets due to the movement of the target itself, in our case the movement of the terrestrial surface (fig. 9).

Starting from the considerate that brought to a concrete stage the presented theoretical aspects, we may deduce that the results obtained using modern methods and techniques described above offer a special advantage in the case of subsidence phenomenon, through efficiency, a vast volume of information and the quality of data resulted after the determinations.

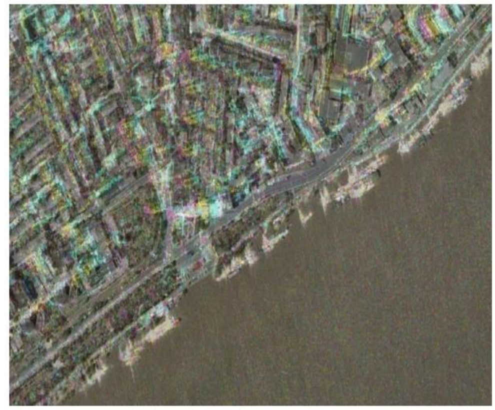

Diagram 9 Interferogram obtained on the base of four satellite scenes.

4. Conclusions

The technology of measuring and process data developed so much during the last years, reaching today to the stage when monitoring the deformations and the movement of the surface can be made in real time, helping to avoid disasters.

Based on aspects presented in our study, we may conclude that the modern methods described for the monitoring of the subsidence offer efficiency, precision and a special quality, compared to the old methods.

The results obtained in Romania and abroad sustain the idea that these methods and techniques may be applied in the engineering practice, especially for areas that are necessary to me monitored and are large enough to justify the costs, while the area are is hardly accessible.

Among the advantages of these methods for analysing the subsidence phenomenon, the following are described as follows:

a) The Advantages of RaDAR Technology

One of the superior advantages of this technology is the high density of points, differentiating this technology from the rest of classic instruments of engineering topographic measuring, not only as precision, also as quality of details obtained in a short time.

b) The Advantages of LiDAR Technology

The advantage of LiDAR is given by the fact that the LASER beam may penetrate the terrestrial surface till the exploited subterranean area and the answer may be multiple and linked to the number of obstacles the beam meets in its way.

The number of answers may vary from 1 to 5 and may return 0 when it meets the surface of water.

The resulted data are compound of points with the following attributes: registering time, intensity, height, classification.

Using recorded GPS data and raw LiDAR data, the time is transformed into x, y, z coordinates.

LiDAR folders are obtained and they contain a "cloud" of points in coordinates that are characterized by intensity, height, response and classification.

These folders may be LAS format or ASCII format.

The system offers in the same time to the user the possibility of realising analyses on models extracted from the cloud of points and to a reduces cost inside an efficient time.

c) The Advantages of DInSAR Technology

Monitors the earthquakes, earth flows, volcanoes eruptions and subsidence phenomenon, using radar sensors with synthetic aperture (SAR).

Offers a high precision with the help of electromagnetic waves until ±3 cm in case TerraSAR-X satellite.

Permits the covering of large areas, with a very big density of measuring points and with a penetration possibility until the area of subterranean exploitation in case of the research upon the subsidence phenomenon.

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