Scientific Bulletin of Politehnica University of Timişoara

TRANSACTIONS on HIDROTECHNICS

Tom 64 (78), Issue 1, 2019

Monitoring and Analysis of Land Deformations and Construction Situated above Underground Golf

Dragomir Lucian[1] Eleş Gabriel[2] Bârliba Luminița Livia[1] Bârliba Costel[1]

Abstract – Significant contributions have been made to the development of new numerical monitoring and modeling techniques and predictions of land and building deformations located above the underground gaps, including the implementation of a telemetry monitoring system, the pioneering use of a Global Satellite Positioning System, a numerical method of deterministic modeling of land deformations and constructions located above the underground voids in crushed rocks and salt rocks, and the use of hydrographic elevations in offshore monitoring. Their applications are discussed in case studies of land deformation and construction deformations located above the underground voids in the Jiu Valley coal mines. It should be noted that Canada was one of the countries where monitoring was constantly evolving, with the evolution of activity in this area being significant for the whole history of the field.

Keywords: monitoring, mathematical modeling.

1. INTRODUCTION

Once in use, each structure is subject to evolutionary patterns of loading and other actions. Often, the intensity and type of request are very different from those taken into account during design and in many cases both nature and size can be unknown. The sum of these uncertainties created during design, construction and use is a great challenge for those involved and responsible for the safety, maintenance and operation of the structure. Structural status monitoring aims to provide much more solid information about the real status of a structure, to observe its evolution, and to detect new degradation. By installing a number of sensors or other motion sensitive elements, measuring relevant parameters for structural conditions and other important environmental parameters, it is possible to obtain an image of the state and evolution of the structure closer to its actual behavior.

Monitoring is a new safety and administration tool that perfectly complements traditional methods such as visual inspection, classic tracking methods, or visual modeling.

Monitoring of structures located above the underground gaps from operation is an older concern of specialists, but continuous monitoring has a very recent history of springs, especially in Australia, Canada, South Africa and China, but also in Romania, especially in the area mining and surface exploitations.

2. MATERIAL AND METHOD

The monitoring and analysis of land and building deformations located above the underground voids (subsidence, a term in the literature) began about 150 years ago in the mining regions of Central Europe. In the first half of the twentieth century in the Central Europe various empirical methods of modeling and predicting the deformations of the lands and structures above the underground gaps were applied.

Although they are still used in many parts of the world, including some variants adapted to mining conditions, these empirical methods are replaced by deterministic modeling based on numerical methods. Subsistence patterns contribute to the development of safer and more economical mining operations. New monitoring techniques contribute to verifying the deterministic patterns of rock behavior under various geological and mining conditions.

Since the 1860s, in Germany and other European countries, numerous scientific publications have appeared concerning the movement of land in mining regions and the mathematical formulation of predicting deformations of land and buildings located above the underground voids. Most of the first forecasting theories were made by mining topographers who had access to monitoring topographic data.

This tradition continues, and the International Society for Mine Surveying (ISM) is currently the most important international body dealing with such issues. Noteworthy that the ISM Organizing Committee meeting was held in Canada during the Second Canadian Minesweeper and Measurement of Roche Deformation Symposium, held at Queens University in

[1]Banat University of Agricultural Sciences and Veterinary Medicine, "Regele Mihai I al Romaniei", Timisoara, Calea Aradului 119, 300645, Romania, barlibacostel@yahoo.com

[2] Politehnica University of Timisoara, George Enescu Street, no. 1/A, 300022, Romania, gabriel.eles@upt.ro

1974. Also 14 countries established ISM in 1976, in Leoben, Austria. International Society of Rock Mechanics (ISRM), International Association of Hydrological Sciences (IAHS) and Commission 6 of the International Federation of Surveyors (FIG) are three other international bodies involved in subsistence studies. This suggests that a century and a half of research and development has not been enough to solve all the problems of modeling and predicting the deformations of the lands and buildings located above the underground voids. On the other hand, over the past fifty years, mining operators have realized that the new sophisticated numerical modeling and modeling techniques of land and building deformations located above ground pitfalls are useful not only for situations of legal responsibility or environmental control, but allow for a better understanding of rock deformation mechanisms, leading to the development of safer and more economic exploitation methods. Until the early 1960s, the methods of monitoring and predicting the deformations of land and buildings above the underground voids were approximate, so nearly 100 years ago the evolution of research in the field was slow. Towards the end of the 1960s, important improvements have been made, and this work continues today.

3. REZULTS AND DISCUSSION

Observing the deformations of the lands and buildings located above the underground voids in the Jiu Valley, HUNEDOARA

The Jiu Valley Carpathian Basin, also known as Petroşani Basin, is situated in the southwestern part of Romania, in the county of Hunedoara, between the northern latitude 45 ° 17 '- 45 ° 22' and the eastern longitude 23 ° 13 '- 23 ° 33'. It is surrounded by the Retezat, Parâng and Vulcan Mountains and crossed by the two large tributaries of Jiu: West Jiu and the Eastern Jiu. It has a surface of 163 km2 with a length of 45 km and a width of 2 km to the west, 9 km to the east, and it presents itself in the form of a triangular depression, being approximately NNE-SSV (Pop, 1993).

In the developed regions, the mining subsidence caused the destruction of surface construction, and as claims for damages for mining subsidence began to appear, companies began measuring and surveying surface damage. This is the Slatinioara area of Petrosani, where there have been a series of landslides due to underground voids, the Valea de Brazi Valley after the Uricani town, and the Matasari area in Gorj County, sludges from the exploitation of the JILT coal .

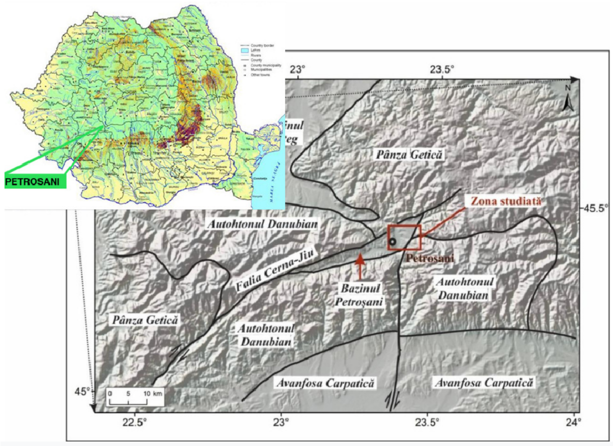

Figure 1. The position of the Mining Basin in the Jiu Valley towards Romania, as well as the study area Maleia - Petrosani (auxiliary building 2 for Livezeni Mining Exploitation)

The current monitoring of the behavior of the underground works is a follow-up activity of these works, which consists mainly in observing and recording aspects, phenomena and parameters that can indicate changes in the capacity of underground works to meet the required resistance, stability and durability requirements . The current tracking of underground work is carried out by direct visual examinations and, where appropriate, current or temporary means of measurement will be used.

Underground mining can have effects on the land surface through the subsidence phenomenon (Figure 2).

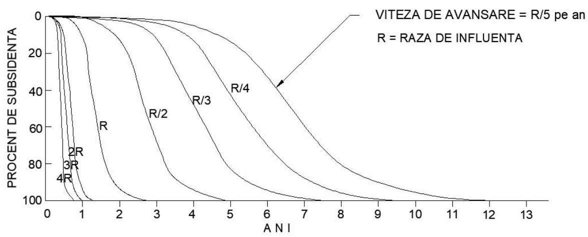

Figure 2. Manifestation of the phenomenon of subsidy

Mining subsoil is the phenomenon of land plunge as a result of the creation of underground voids. Due to the gaps caused by the construction of the underground workshop, it is possible to create overflows or dislocations of the cover rock masses, which in some cases can reach the surface. Depending on the nature of the covering rocks, dislocation can be done:

- by leaving the luggage package soft;
- by cracking, tearing and breaking the strings.

The subsidence phenomena can be observed after a certain amount of time depending on the depth of the underground works:

- up to 100 m 0 - 1 year;
- between 100-200 m 1 - 2 years;
- between 200-300 m 2 - 3 years;
- over 300 m 3 years.

Determination of the value of the parameters defining the deformation and displacement of the terrain is done by direct and indirect measurements, by applying geodetic, topographic, photogrammetric, G.P.S. for measuring the measured quantities.

All the notions pertaining to each type of specific procedure are presented and defined in the documentation.

Analysis of the stability of formations around the holes formed by exploitation

Underground mining operations may cause negative effects on the implicit surface of buildings located in the area. Thus, undesirable, unfavorable phenomena can occur in the structures, and measures are needed to protect the constructions and the population. In order to prevent this, the physico-mechanical and elastic properties of the rocks, which were the basis of the classification of rock stability in the deposit, are determined.

When choosing the exploitation methods for different ore bodies, consideration should be given to geo-mining conditions and to ensuring the stability of the surface, resulting in two situations:

Surface stability is tracked,the stability of the surface is not pursued.

When protecting the surface so that the effect of exploitation does not reach the surface, appropriate exploitation methods are proposed. If the stability of the surface is not followed, accepting the relocation of the village from the affected area are proposed methods of exploitation with subtraction in sub-layers for different heights and sub-floor thicknesses.

To predict the expansion of the rock movement around the underground excavations, several methods are known, such as: physical models;

Developing analytical relationships based on topographic surveys over time under similar geo-mining conditions; mathematical models.

Physical models are complex forces providing qualitative and quantitative information, but they are costly, it takes a long time to develop a model, and it can only form a relatively small scale on an acceptable scale.

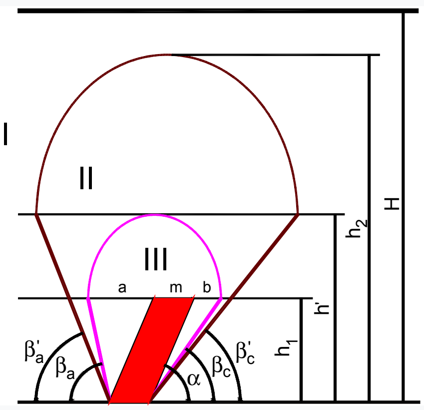

Figure 3 - Motion zones

Analysis of the movement phenomena around the underground mines

The prognosis of rock movements around the underground voids through the graf-analytical methodology follows from the following assumptions:

A. Around the underground voids if the amplitude dropping conditions are met, three zones are formed:

- zone I (low movements);
- zone II (intense movements);
- zone III (area of landing),

In the I-tier zone, the movements are in the order of millimeters and tens of millimeters, and they do not have a decisive effect on underground mining.

In the second-tier zone, movements are tens of centimeters, which contributes to the destruction of claims, mining works, and the appearance of significant tides (tens of centimeters). The effects of the movements disappear with the disappearance of the cause, respectively the movements are attenuated until disappearance, and in these areas it is possible to resume the activity.

In the area of the third degree creep, which is located in the immediate vicinity of the created void, the destruction of the mining works and of the ore bodies occurs and their subsequent recovery is impossible within this area. On the surface there will be pits, or chimneys of varying depths.

B. In any cross-section the extent of the movement zones is delimited by:

- a parabola (above the created goal);
- a semi-lip (in the walls of the gap);

In view of the modest way of determining the extension of the movement areas in the walls for ease of calculation, they were assimilated with a straight in the cross-section (respectively a plane in space).

C. In cases where there are large differences in the strength of the ore body and the surrounding rocks, the movements extend to the weaker areas.

D.The inclination of the delimitation plane of the area of surplus to the area of the intense movement is determined by the perceptible limit angle (β^*) which can not be less than the minimal angle of chance (β) obtained by calculating the material needed to fill the void, or the area delimitation angle intense movements (β').

E. The maximum horizontal extension of the drop area is at the upper limit of the created void, and the intense movement area is at the upper limit of the drop area.

Factors of influence

Generally, the factors influencing the evolution of the rock movement can be divided into two large groups:

- natural factors;
- Factors related to in-service activity.

Natural factors refer to both the deposit and the surrounding rocks.

Those referring to the deposit are:

- shape and space position of the deposit;
- the distance between the deposit and the surface;
- the dimensions of the underground voids;
- he physical-mechanical and rheological properties of the covering rocks;
- tectonic and microtectonic of the same formations;

hydrogeological conditions;

the excavation process;

the level difference between the surface and the underground excavations.

the thickness of the deposit;
the height of the mineralized area;
inclination of the deposit;
the nature of the contact between the deposit and the surrounding rocks.

The main categories of stresses and the corresponding displacements (deformations) of the rocks subjected to such a process are compression - stretching, elongation, shearing - slipping and bending.

The shape of the deposit influences the mechanism of formation of the zones of influence and implicitly the area and the form of their extension (at the phononian deposits the drainage in most cases starts from the walls, the surrounding rocks being subjected to shearing, the horizontal lenticulars or the small inclinations the surge starts from the ceiling, the surrounding rocks being subject to bending, the drops in the walls are of lesser importance; in the case of the stock, the extension on the directional can have the same importance as the extension on the transverse, etc.).

The distance between the surfaces is decisive when calculating the efforts to which the surrounding rocks must resist (the bed, the roof, the ceiling). Also, the distance from the surface is decisive in shaping the shape of the influence zones. The thickness, height and slope of the deposit influences both the amount of effort that acts on the surrounding rocks and the magnitude of the expansion of the influence zones in different directions (bed, roof, surface).

The nature of the contact between the deposit and the surrounding rocks can decisively influence the direction of the landing zone (when we have a net contact separating areas with much different characteristics).

Existing hydrogeological conditions may influence the subsequent transformation of rocks.

The dimensions of the hollow created by exploitation is one of the most important factors, having the same influence on the expansion of the movements as those described in the influence of the dimensions of the ore body.

The influence of the void on the movement of the surrounding rocks is closely related to the applied method of exploitation, since its evolution and final volume depend on the applied method of exploitation.

In the case of application of the exploitation methods with the filling of the created void, the final volume of the voids is caused by:

- total empty void;
- primary compaction of backfill;
- secondary compaction of backfill.

Calculation of the extension of the influence zones

As for the calculation of the extension of the influence zones, the effect of the bridging mode will intervene in determining the mass resistance of the rock (σ_n C_n) through the cracking factor (cf).

The depth to which this influence is sensibly recorded is determined directly in situ, or if there is no such possibility, then with the help of the relationship:

$$R = 4 \cdot r_0 \sqrt[2]{\frac{2 \cdot \sigma_c \cdot K_d \cdot \mu}{\sigma_t \cdot K_d^{'} (1/\mu)}} \qquad (1.1)$$

where:

R - is the radius of influence of the holes;
r_0 - hole radius;
σ_c - compressive strength;
σ_t - tensile strength;
K_d; K'_d - coefficients that account for the mode of action of the explosive;
μ - its coefficient Poisson;
λ - coefficient of attenuation of seismic waves;

$$\lambda = 0{,}8 + \frac{5 \cdot 10^6}{(1+E) \cdot y} \qquad (1.2)$$

y - the heat of the explosion;
E - the energy transformation coefficient;

$$E = \frac{\rho_e \cdot D}{\rho \cdot V_e} \qquad (1.3)$$

ρ_e - density of the explosive;
V_e - velocity of propagation of longitudinal waves;
D - the detonation speed of the explosive;
ρ - density of the rock.

The nature of the movement and deformation of the rock mass and the land surface

It has been established that the surface area of the day affected by the effects of the sinking due to the underground exploitation of the deposits in normal cases is greater than the area of the underground surface of the void over which it overlaps.

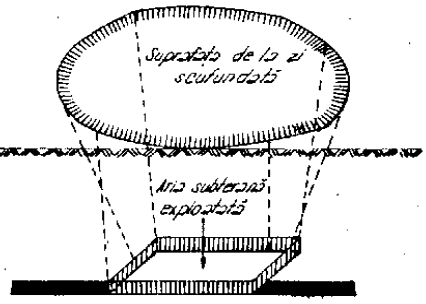

Figure 4. Area of the underground surface

The forces inside the rocks constitute, for as long as they remain undisturbed, a potential in equilibrium. When a gap is created, the forces become kinetic, and the actions are transmitted by pressure, the roof and the walls of the void. The process of rock movement usually starts with the bending of the formations above the abode and is usually accompanied by roof collapses. Further, the process evolves by successively dislodging the inner formations from the upper ones and by bending them after normal to the beam-like stratification or of the embedded plates on the contour. As movement progresses, the movement includes new portions of the undermined parquet and, in case of the large dimensions of the exploited package, spreads to the surface. Depending on the degree of disturbance of the rocks above the scattered space, three zones are distinguished (Figure 5):

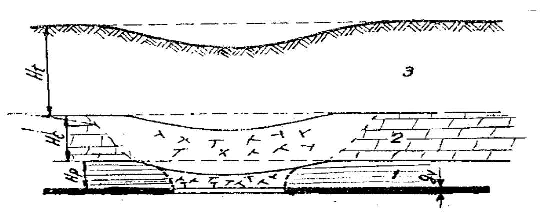

Figure 5. The way of movement and formation of the rock mass under the influence of underground exhaustion

Crash (1) - irregular drop area;
Bending with loss of continuity due to cracking or cracks (2) - the area of regular drifts;
Bold or transition bending (3) - the area of bridging the sterile layers after stratification.
Collapse area: Above the exploited area will appear a heavily crushed area. The height of the Hp collapse area varies depending on the nature of the rocks. The approximate height of this height is given by:
$5gv \leq Hp \leq 15gv$, where gv - the height of the exploited area
If the cover area is less than the height of the collapsing area, then tears appear on the surface.
In the case of the pressure guidance, there will not be any rupture at the surface.
Crack area - appears above the collapse area. The height of the crack area Hc - is in the range:
$15g_v \leq H_c \leq 50g_v$
If, from the surface, the exploited area is at a depth in the crack area, cracks and tears will appear at the surface.
Transition area - There is no rupture in this area with Ht height. Surface dips will be produced on the surface. The instability of the rock will influence this area, and the deformation will occur if:$H_t \geq 50g_v$
The COD (I) submerging area (total movements) occupies after moving a position parallel to the initial point displacement being oriented normal and substantially equal for the same formation. It is bounded by the angled planes with the total sublimation angles Ψ1 and Ψ2 drawn at the edges of the space but it does not extend to the vicinity of the extraction deposit; it also includes the collapsing area of the roof rocks.
The areas of pressure or rock compression pressure after normal stratification (IIIa and IIIb) appear between the LB and KJ boundaries of the exotics influences and EG and FH of the exploited space (III - a = LBEG and III = KJFH).
According to some opinions, the zones of the small deformations (VII - a and VII - b), with variable traction and compression sign, after normal stratification are located above the zones of the reayem pressure. The upper rocks move without distortion after normal (zones VIIIa and VIIIb).
The maximum bending zones of the rocks (II - a and II - b) develop between zones I and III, the bending causing the compression and traction deformations to occur in parallel with the stratification.
In the rocks of the reservoir there is a redistribution of the tensions, with the manifestation of the bearing pressure and the discharge of the tension. The support pressure attracts a strong compression of the rocks, while in the discharge areas the rocks are subjected to lifting phenomena towards the exploited space. Thus, in the couch it is distinguished:
The compaction zones of the rocks (IV a and IV b)
Non-uniform lifting zones (V a and V b)
Uniform lifting (unloading) zones (VI)
The ALBIJKM contour, encompassing all the areas listed above, delimits the field of influence of the exploitation at the considered stage; a similar contour can also be defined with respect to the longitudinal section through the baffle package.

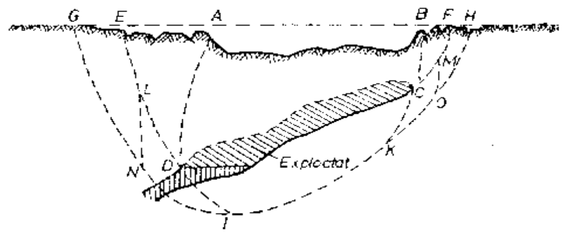

Figure 6. Areas of motion and influence in the case of ore deposits

The general notions of stratiform deposits are valid, with some differences and for other types of ore, including for ores. For example, the exploitation of an ore deposit can be distinguished:
ABCD - area of crashes;
ADLE and BCMF - motion zones with loss of rock continuity (cracking);
GNIDE and HOKCF - smooth motion zones;
LNID and MOKC - swing pressure zones;

5. CONCLUSIONS

As a conclusion, we can say that the chosen goal was achieved, namely to obtain high quality measurements of the horizontal and vertical movements caused by the mining activity of the Livezeni mine, the Maleia Puff, the Petroşani basin. It has been shown that results can be obtained after mini-short GPS campaigns made within one year. The results are conclusive and of good quality. It has been shown that the central part located near the old mining galleries is affected by the subsidence phenomenon, taking the form of a bowl with a diameter of approximately 500m. The maximum subsidence rate is 250 mm / year, while the marginal area has a slight lifting trend with a maximum rate of 40 mm / year. Also, quite high values of about 300 mm / year were obtained, of the displacement of the horizontal component in the central area. The direction of travel is constant, if the movement on the vertical component is also taken into account and it can be concluded that the area is affected by the sliding phenomenon.
It is very clear that these deformations of the surface may cause the hazard to occur in the area. Fortunately, the area is not populated or crossed by major infrastructure. We believe it is important for the area to be further monitored to follow developments cruise shifts through GPS measurements and even leveling measurements. It would also be useful to install a permanent GPS station in the central area to detect

possible temporal variations in surface movement. Since we did not have access to some information (groundwater level, abandoned gallery information, mining period), no modeling results were used.

REFERENCES

[1] Dragomir, L., 2007 R. Traceability of construction and deformations to their respective land.
[2] Ortelecan, 1997 M. tudy of the surface movement under the influence of the underground exploitation of the deposits in the Jiu Valley, eastern area. Thesis, Petroşani.
[3] Paunescu, C., Mocanu, V., Munteanu, L., Andrei, G., Muntean, A., Herebei, O., Veres I., Dima, N., Filip, L., 2008. Stability analysis of over-exploited mining areas by satellite geodesy, GEO 2008, The scientific meeting of the Faculty of Geology and Geophysics, University of Bucharest, Ed Vergiliu, 218-220, ISBN 978-973-7600-49-3.
[4] Păunescu, C., Dimitriu, S.G., Mocanu, V., 2011 The positioning system using satellites (GNSS).
[5] Pop, Emil, 1993. The Geological Monograph of the Petrosani Basin, Romanian Academy Publishing House, Bucharest, 300 p.
*[6]***, Valea Jiului Portal,* http://valeajiului.blogspot.ro
*[7]***,ICPM, Institute of Research and Mining Design SA Petroşani.* www.icpm.ro.
*[8]***,ITRF, International Terrestrial Reference Frame - The Earth Ground Reference International website. http://itrf.ensg.ign.fr/.*