ASPECTS REGARDING THE SUBSIDENCE PARAMETERS MONITORING IN CONDITIONS OF SALT DEPOSITS

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Abstract: *The paper aims to determine the parameters of subsidence areas under the conditions of salt deposits from Ocna Mures. The paper seeks the stability of the carriageway of Nicolae Iorga and Mihai Eminescu streets after creating the cone of subsidence in the area of Plus shop, due to the collapse of the ceiling of resistance of some old mine workings.*

Keywords: *cone of subsidence, monitoring, salt deposit.*

1. Introduction

The phenomenon of subsidence is defined as a process of lowering the soil surface due to underground voids created in the exploitation of minerals.

Under the action of gravitational forces, the gaps created after the excavation of minerals tend to be occupied by the covering layers and thus creates a movement process from the mined area to the surface, where it forms a trough dipping (in the case of coal deposits) or a cone of subsidence in the case of mineral and salt deposits.

In the case of coal deposits, the subsidence phenomenon spreads quickly because of the consistency of lithological strata and in the case of mineral and salt deposits due to the strength and compaction of the rocks, the subsidence phenomena propagates in a long time.

The exploitation of salt deposits is carried by dry methods, through underground mining operations, or by dissolution using deep probes.

In the case of salt deposits exploited by underground mining, the thickness of the slab resistance is 30-50 m, and when the slab reaches a thickness whose compressive strength is less than the pressure of the lithostatic column and the objectives from the surface, the resistance ceiling collapses creating the subsidence cones.

The thickness of the resistance ceiling shrinks by dissolving the salt under the action of water and peeling, which under the influence of gravitational forces drawn from the ceiling.

In the case of salt deposits from Ocna Mures, the first collapses of the ceiling occurred in 1979, in the exploitation perimeter, after which they formed lakes at the surface (Fig. 1).

The methods for determining the parameters of subsidence can be found in the scientific literature of various authors (Bräuner, 1973; Kratzsch, 1974; Ogloblin, 1972; Ortelecan *et al*., 1999; Peng and Chen, 1981).

The phenomenon of subsidence in the case of the salt deposits from Ocna Mures was monitoried by the Salt Mining Company and the Institute of Mining Research and Project Cluj-Napoca, which has placed a tracking station at the surface of the exploitation perimeter, consisting of marks placed on the probes foundation, on buildings and on adjacent streets.

Since the placement of the marks has not complied with their distribution on transverse and directional alignments face the deposit, due to local conditions, to represent the phenomenon of subsidence were used the isolines of diving (Fig. 2).

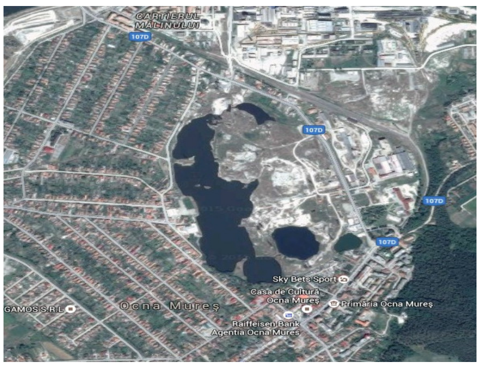


Fig.1 The lakes formed over the exploitation perimeter Ocna Mure

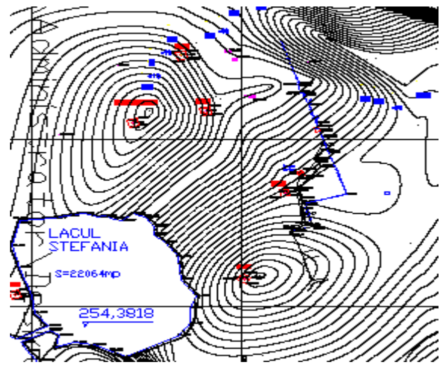


Fig.2 Isolines of sinking from the SE area of the mining perimeter

Fig.3 Plus shop after collapse

Fig.4 The formed lake with the remainings from the shop

Fig.5 Mihai Eminescu street

Fig.6 Mihai Eminescu street

In figure 2 is observed that in the east of the lake Ştefania, there is a sinking area of around 100 mm. In that area on 22.12.2010 was a collapse of the surface due to some old mining works unidentified on topographic plans, which resulted in the total destruction of the store "Plus" (fig.3-4) and damage of the adjacent streets Mihai Eminescu (fig.5-6) and Nicolae Iorga.

After reparing the streets, it started the monitoring of the area through topographic measurements on a tracking station formed of alignments transverse to the street Mihai Eminescu, alignments which were materialized through 39 metal marks (Fig. 7).

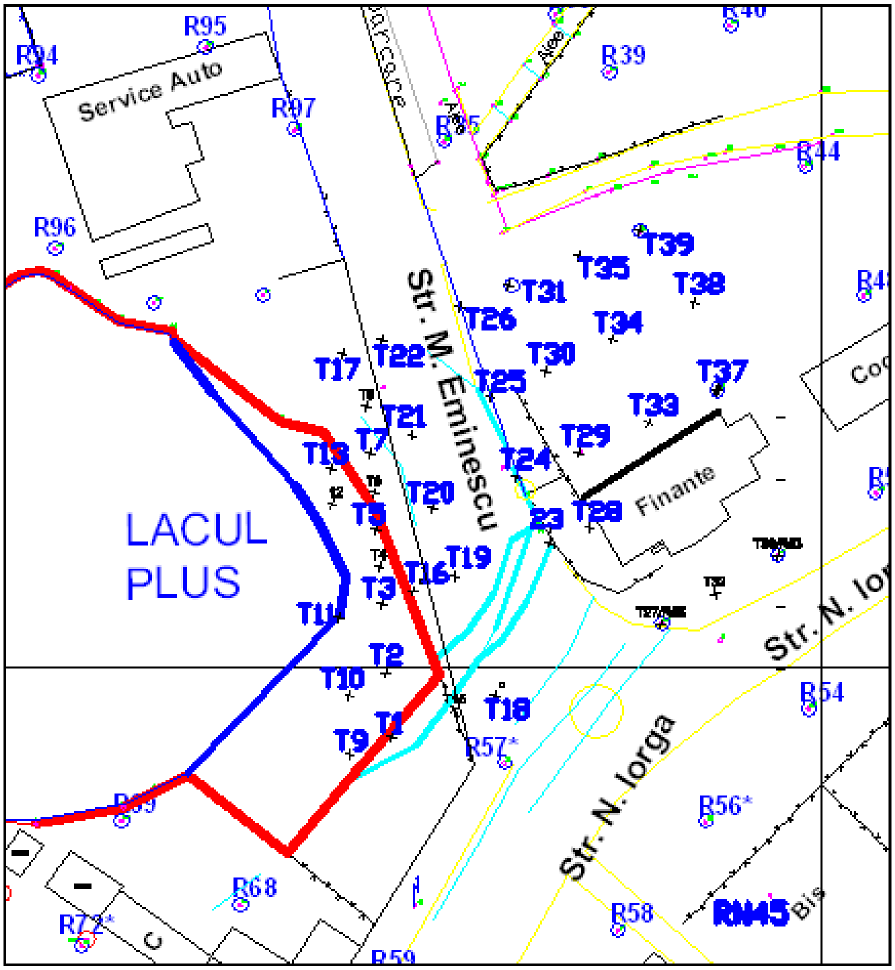


Fig. 7 The monitoring station from Mihai Eminescu street

2. Additions

For determining height of the tracking marks was used the level Ni 002 and the digital level Leica Sprinter 100.

The leveling mark RN1246, from which were transmitted the height through a geometric from the middle levelling polygonal route, in closed circuit, can be found outside the exploitation influence area, at CFR Unirea station.

The leveling transmission in the area of interes, every year, was made on the route RN1246 – RN2 (Mureş bridge) – RN1246, composed of 43 stationaries with a total length of 3.0 km. After processing the data was obtained an unclosure of 1.6 mm, which is acceptable from the point of view of the tolerance specific for the geodesic geometric from the middle levelling, of high precision. From the mark RN2 were acheived some routes in closed circuit in order to determine the height of the marks situated in the exploitation perimeter.

The positioning of the marks for tracking the stability of Mihai Eminescu street (fig.7), was acheived using a total station Leica TC 307, through a plannimetric polygonal route in closed circuit, starting from landmarks with known coordinates, placed outside the area of influence of the mining works.

Monitoring the subsidence phenomena is acheived through repeated geodesic measurements, which keep the same provisional heights in all measurement epochs. Analysing the vertical displacements is made after processing separately for each measurement epoch.

Solving the leveling polygonal routes and the acolated leveling networks are made easier using the conditioned measurements method than using the indirect measurements method, but has disadvantages on programming. Also the standard deviation of the most probable values are obtained on the basis of some functions established for each size.

In the case of using the conditioned measurements at solving the leveling routes (Dima *et al.*, 1999), the correction equation is presented as follows:

$$[a_i v_i] + W = 0; \quad weight\ P_i \tag{1}$$

where:

a_i – correction coefficients;

v_i – correction of the measured elements;

W – unclosure on heights.

Written in matrix form, equation (1) is presented as follows:

$$B^T V = W,\ weight\ P_i \tag{2}$$

The normal equation:

$$(B^T P^{-1} B)k - W = 0 \tag{3}$$

where:

$$B = \begin{pmatrix} a_1 & b_1 & \dots & r_1 \\ a_2 & b_2 & \dots & r_2 \\ \dots & \dots & \dots & \dots \\ a_n & b_n & \dots & r_n \end{pmatrix}, \quad B^T = \begin{pmatrix} a_1 & a_1 & \dots & a_n \\ b_1 & b_2 & \dots & b_n \\ \dots & \dots & \dots & \dots \\ r_1 & r_2 & \dots & r_n \end{pmatrix}, \quad P^{-1} = Q = \begin{pmatrix} \frac{1}{p_1} & 0 & \dots & 0 \\ 0 & \frac{1}{p_2} & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & \frac{1}{p_n} \end{pmatrix} \tag{4}$$

$$k = \begin{pmatrix} k_1 \\ k_2 \\ \\ k_r \end{pmatrix}, \qquad W = \begin{pmatrix} w_1 \\ w_2 \\ \\ w_r \end{pmatrix} \tag{5}$$

From the normal equation (3) result the corelates “k” which are used to calculate the corrections V:

$$k = (B^T Q B)^{-1} W \tag{6}$$

$$V = QB(B^T Q B)^{-1} W \tag{7}$$

The error of the weight unit is given by the relation:

$$S_0 = \pm\sqrt{\frac{V^T PV}{r}} \tag{8}$$

For the mean square error of a size obtained through conditioned measurements of different precision, is applied the following relation:

$$S_F = \pm S_0 \sqrt{Q_{FF}} \tag{9}$$

where:

$$Q_{FF} = f^T Qf - f^T QB(B^T QB)^{-1} B^T Qf = f^T Q_{ll} f \tag{10}$$

Given that the phenomenon of point displacement is continuous, including the timeframe in which the measurements are made, it can be considered that the vertical displacements are time functions (Ghiţău, 1983):

$$H_P = H_P(t) \tag{11}$$

$$\overline{H}_P = H_P^0 + x_P + \dot{\chi}_P \, \Delta t_{01} \tag{12}$$

$$(H_P^0) = H_P^0 + x_P \tag{13}$$

$$\dot{\chi} = (x / \Delta t)_P \tag{14}$$

$$\Delta t = t_i - T_0 \tag{15}$$

where:

$\overline{H}_P$ - the value of the height at the measuring moment t_i;

H_P^0 - the height provisional value of point P;

(H_P^0) - the height probable value of point P at the initial moment T_0;

x_P - corrections for the provisional coordinates;

T_0 - initial moment.

Taking into account relation (12), the correction equation of the leveling difference between two marks P and R, it can be written:

$$v_{PR} = -x_P + x_R + \dot{\chi}_P \, \Delta t_{0i} - \dot{\chi}_R \, \Delta t_{0i} + l_{PR}^i \tag{16}$$

where:

$$l_{PR}^i = H_R^0 - H_P^0 - h_{PR}^i \tag{17}$$

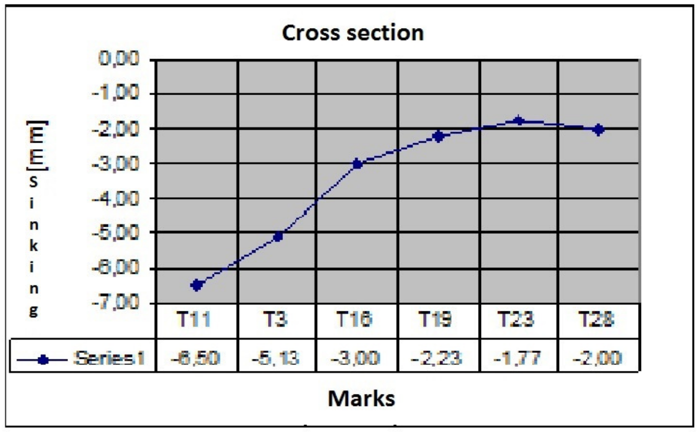
A general model of equation is obtained by introducing in the variation of the vertical displacement of the points of some elements of random nature $\widetilde{v}$, obtaining the relation:

$$v_{PR} = -x_P + x_R + \dot{\chi}_P \, \Delta t_{0i} - \dot{\chi}_R \, \Delta t_{0i} - \widetilde{v}_P + \widetilde{v}_P + l_{PR}^i \tag{18}$$

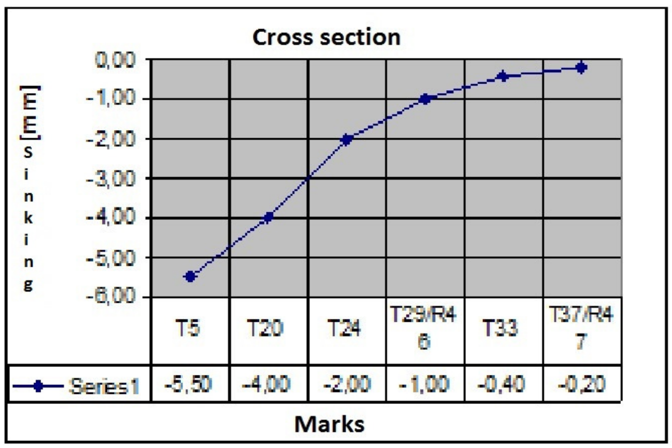
In this case, the processing is made by putting the following condition:

$$V^T PV + \widetilde{V}^T P \widetilde{V} \rightarrow \text{minimum} \tag{19}$$

After transmitting the heights from the mark RN2 (Mureş bridge) to the marks of the transversal alignments on Mihai Eminescu street, at the current epoch June 2013 were determined the vertical displacements from the basis measurement February 2013. The sinking values are presented in figure 8a-f.



a



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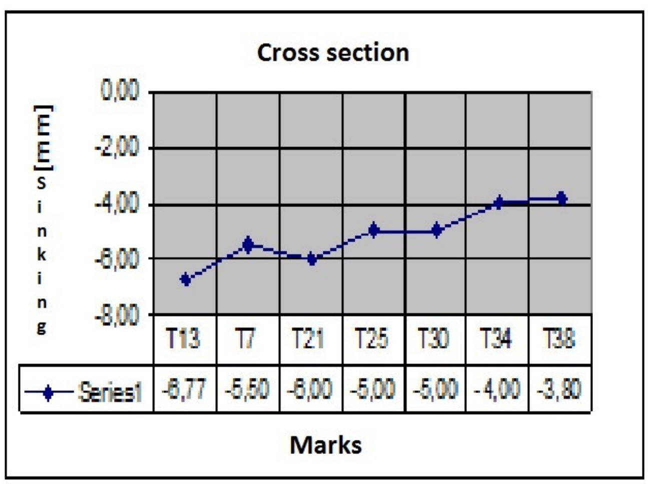

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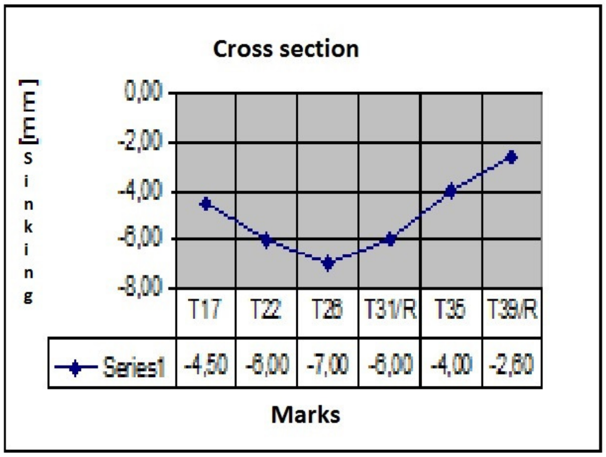

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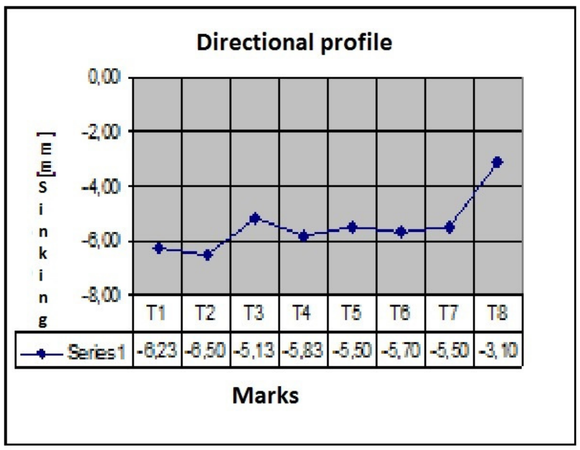

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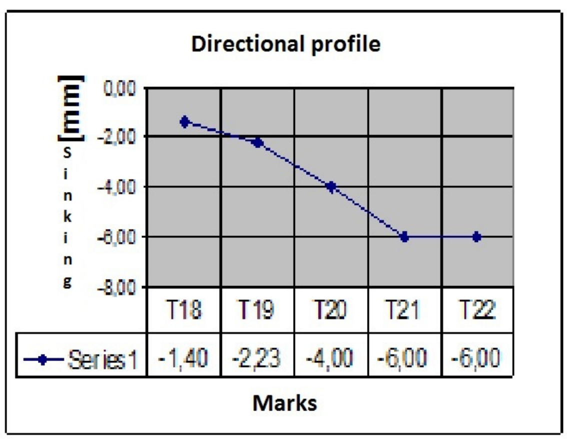

f

Fig. 8 Values of the sinking

In the cross sections it can be seen that the marks which are placed close to the cone of subsidence have higher sinking than the marks which are place far from the cone, fact which is confirmed also at the directional alignments.

The dives from the cross section (fig. 8d) are also confirmed by the sinking allure presented in figure 6.

3. Conclusions

As a consequence of the exploitation of salt, either by dry methods or by kinetic dissolution, it can be said that the pillars and the safety floors may not prevent the occurrence of some sinking beds or subsidence cones.

In order to get a better accuracy of the phenomena of subsidence, at representing of the sinking isolines of the terrain, should be removed the marks with positive values, marks which are placed on the fundation of the probes.

When planting some new marks, due to the destruction or disappearance of some marks, in order to have values more close to the reality, at the absolute values of the sinkings should be also added the sinkings of the destroyed marks.

4. References

1. Bräuner, G. - Subsidence due to Underground Mining. 1.Theory and practices in predicting surface deformaiton.Bureau of Mines Information Circular, 1973;
2. Dima, N., Herbei O., Vereş I. - The theory of errors and least squares method, Universitas Publishing House, Petroşani, 1999;
3. Dragomir, V., Ghiţău, D., Mihăilescu, M., Rotaru, M. – Earth figure theory, Tehnică Publishing House, Bucharest, 1977;
4. Ghiţău, D. - Geodesy and geodesic gravimetry, Didactic and Pedagogic Publishing House, Bucharest, 1983;
5. Kratzsch, H. – Bergschadekunde, Berlin,1974;
6. Ogloblin, D. - Markşeiderskoe delo. NEDRA,Mackba,1972;
7. Ortelecan, M., Palamariu, M., Jurca, T. - Plotting the mining workings, Infomin Publishing House, Deva, 1999;
8. Peng, S., S., Chen, D., W. - Analysis of Surface Subsidence Parameters Due to Underground Londwall Mining in the Northern Appalaghian Coalfield, Department of Mining Engineering, West Virginia University, 1981.