SURFACE SUBSIDENCE PROGNOSIS USING THE INFLUENCE FUNCTION METHOD IN THE CASE OF LIVEZENI MINE

Dacian-Paul MARIAN, Ilie ONICA**,*
*Ramona-Rafila MARIAN***, Dacian-Andrei FLOAREA****

Livezeni Mine is located in the eastern part of the mining basin of the Jiu Valley (Romania), having as the field of activity the pit coal exploitation. In the area of influence of the underground exploitation of the coal deposits there is also the access road to touristic areas of the Parâng Mountains among other civilian objectives. For the prognosis of the surface deformation as a result of the underground exploitation, the method of influence functions was used in this study. The results obtained are compared to the measurements carried out in the observing station of the surface deformation located on the surface in the area of the studied objective.

Keywords: *prognosis, influence function, subsidence, horizontal displacement.*

1. GENERALITIES

The coal basin of Petroșani, under the management of the National Coal Company Petroșani, contains the most important coal deposit in Romania, with a supply of balance of nearly one billion tons. This deposit has been known and extracted since 1788, the time of the Austro-Hungarian Empire [1]. However, intensive extraction of this deposit began with the industrialization of Romania after the Second World War, and reaching a capacity of production exceeding 9-10 million tons per year after 1980 [1].

Because of the restructuring of the Romanian industry after 1990 in accordance with the new requirements of the market economy, the production in this basin has reached approximately 3.5 million tonnes per year, of which 0.5 million are derived from the mining field of Livezeni.

In this area a number of 18 seams was identified by the geological research works, of which the greatest importance economically is the seam number 3 (48%) and 5 (12%).

The object of this study is to analyse the influence of the underground mining of four panels (panel (3-4), panel 5, panel 5A and panel 6) located on seam 3 block VI A, on the road to the tourist areas of the Parâng Mountains. For this study the influence functions method was used. Seam 3 (Fig.1) relating to those panels has been operated in the tilt slices (approx. 2.5 m thick) with mechanized long fronts (SMA P2H mechanical support, combines and armoured personnel carrier 2K52 MY-TR-7) and directing the pressure through total collapse of the rock from the roof [2].

The sizes of the coal-mining excavations resulted through the underground mining in these four panels are summarized in Table 1.

Table 1. *The average size of the extracted panels, seam 3, block VI A*

Panel	Number of slices	Total extracted thickness, (m)	Length of the coal face (m)	Extent of the coal face field, (m)
Panel (3-4)	4	10	119	346
Panel 5	5	12,5	87	440
Panel 5A	2	5	57	385
Panel 6	1	2,5	137	362

2. GEO-MECHANICAL CHARACTERISATION

Since the genesis of the deposit is sedimentary, the most common rocks in the basin are limestone, marl, clay, sandstone and clay shale, conglomerate, etc., whose strength is between 15 to 16 MPa, and even more than 50-60 MPa [3]. Mainly, the rocks have relatively low stability [3], [7].

** Lect Ph.D eng., University of Petroșani*
*** Prof. Ph.D eng., University of Petroșani*
**** Ph.D stud. eng., University of Petroșani*

Fig. 1. *Monitoring station of the ground movement and deformation at Livezeni Mine*

The main factors that contribute to the state of the tension and deformations developed around excavations generated by the underground mining with the collapse of rocks of the coal seams in the Jiu Valley are: the sizes of the underground excavation, the inclination of the deposit, the depth of location of the deposit, the characteristics of the support of face, the speed of advancing front coal face, and the distance from the adjacent coal face and the other extracted seams, the geo-mechanical characteristics of the surrounding rock, etc. [4], [5], [9]. As a result of the observations carried out on the ground surface under the influence of the underground mining, in order to design optimal sizes of the main pillars of safety, the limit angles of subsidence for different mining fields in the Jiu Valley have been established [9], [10].

The limit angle values of influence (β, γ and δ), depending on the operating depth *H* (m) for the mining area Livezeni, in accordance with the instructions drawn up by ICPMC Petroșani are expressed by the following relations:

$$\beta = 0{,}0309 \cdot H + 56{,}8$$
$$\gamma = 0{,}0261 \cdot H + 56{,}133$$
$$\delta = 0{,}146 \cdot H + 51{,}867$$

Also, in the same conditions, the average breaking angles recommended by ICPMC are [9]:

$\beta_{rupere} = 45 \div 55^{o}$; $\gamma_{rupere} = 55 \div 60^{o}$; $\delta_{rupere} = 75^{o}$ [9].

3. MONITORING OF SURFACE SUBSIDENCE AT LIVEZENI MINE

At present, the monitoring of the movement and deformation of the surface under the influence of the underground mining is achieved by means of a monitoring station from the Livezeni Mine is made up of 50 benchmarks. Their layout was carried out along the way which assured the access to the tourist areas of the Parâng Mountains [4], 5.

This monitoring station [8] provides information on the movement and deformation of the surface as a result of the underground mining of seam 3, block VI A, the panels (3-4), 5, 5A and 6.

Topographical observations have been performed every three months since 2001. Over time, most initial benchmarks that formed the original monitoring station disappeared being replaced with new ones. Due to this, the interpretation of the measurements made on this station is cumbersome and does not provide satisfactory results in terms of the size of the surface degradation in the area.

The measured subsidence trough (Fig. 2) is a composed trough, resulted from the underground mining of the 4 coal panels. The subsidence trough has an irregular shape (somewhat sinusoidal) due to the fact that the four individual subsidence troughs (of each extracted panel) intersect, and because the state of the station is located at the edge of the extracted areas (Fig. 1), an area in which the transverse deviations are at maximum.

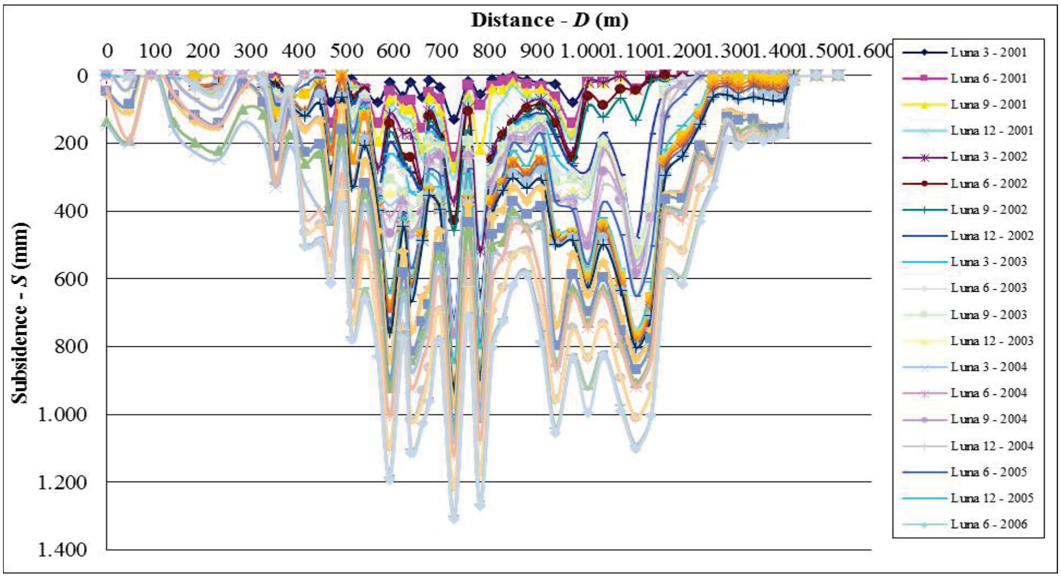

Fig. 2. *Subsidence profile measured in time at Livezeni Mine*

4. INFLUENCE FUNCTION METHOD

The influence functions methods are based on the prognosis of the subsidence trough with the help of the influence area theory around the point of extraction [4], [5], [10]. These methods can be applied to the extracted areas of different forms, but they are more difficult to calibrate and verify than the profile functions methods.

These are methods used to determine the influence exercised at the surface by the partial elements of the extracted area.

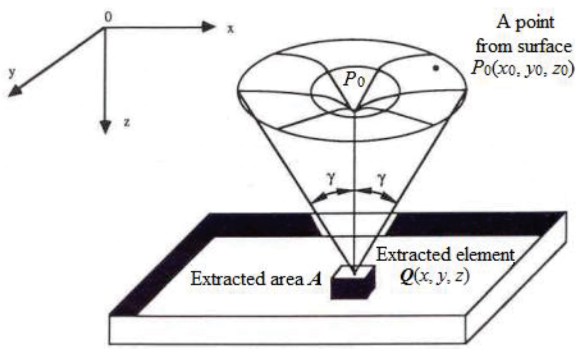

Fig. 3. *The influence of extracting the base element Q*

Different forms of influence functions were obtained by several researchers subsidence events including - Bals 1932 Bayer, 1945; Sann 1949 Knothe 1957 Kochamanski 1957 Ehrhardt and Sauer 1961; Brauner 1973; Zich 1993, etc. [5].

In the case of this paper, for the surface deformation prognosis due to the underground mining, was applied the influence function method developed by Knothe (also known as Knothe-Budryk method).

This method is based on Gaussian distribution of the probabilities. In this method, the math function is:

$$k_z = \frac{1}{R^2}\left[e^{-\left(\frac{\pi x^2}{R^2}\right)}\right]$$

5. THE PROGNOSIS OF SURFACE DEFORMATION AT LIVEZENI MINE

By applying the influence functions method in the case of Livezeni mine, for the four extracted panels taken into account and combining the subsidence beds generated by the extraction of each panel, has resulted a common subsidence trough. Its configuration in the studied route (road makes access to tourist areas to the Parâng Mountains) is shown in Figure 4.

The maximum subsidence expected has a value of 5150mm, a value that exceeds the value measured by in the monitoring station of 1309mm. This difference between the measured and expected subsidence is due to the fact that the predicted subsidence bed is considered to be final, the phenomenon of subsidence is still in the active phase, but also because the initial benchmarks that made up the topographical monitoring station have been replaced with others (due to modernization works of the road).

Similarly, the horizontal displacements of the surface have been obtained on the two directions (X and Y, Fig. 5 and Fig. 6), and the total maximum horizontal displacement (Fig.a7).

The horizontal movement on the axis X, considered approximately transversely on the direction of the road, has a maximum value predicted of 550mm (Fig. 5) and the axis Y, considered somehow on the direction of the road, takes values between -2230mm and +2140mm (Fig. 6).

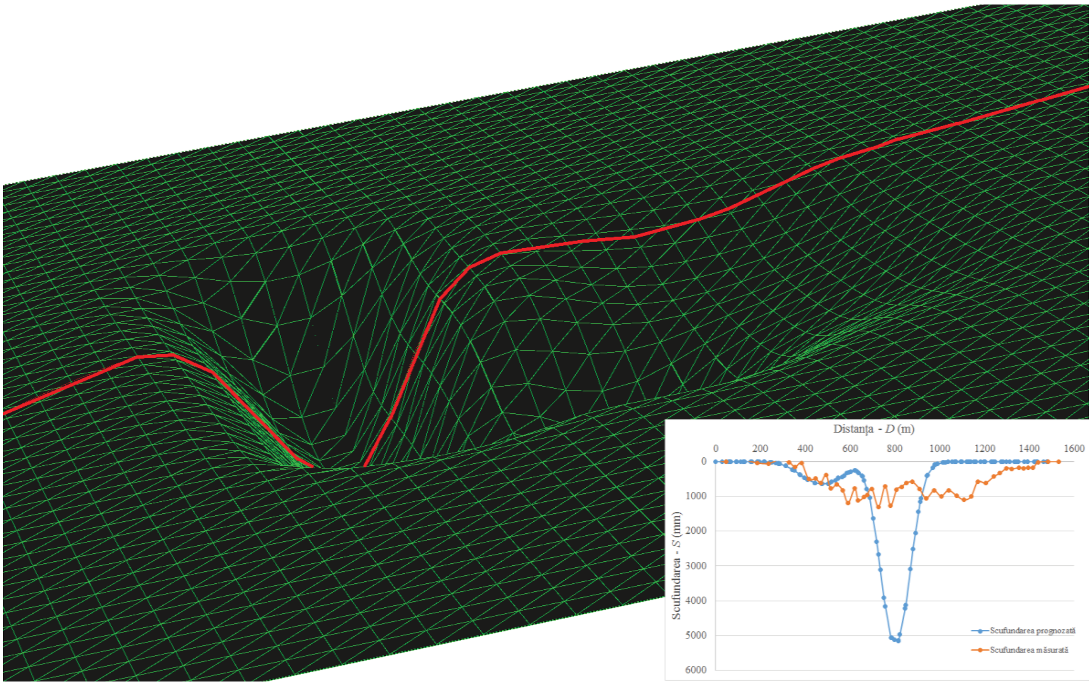

Fig.4. *The subsidence trough obtained using the influence function method*

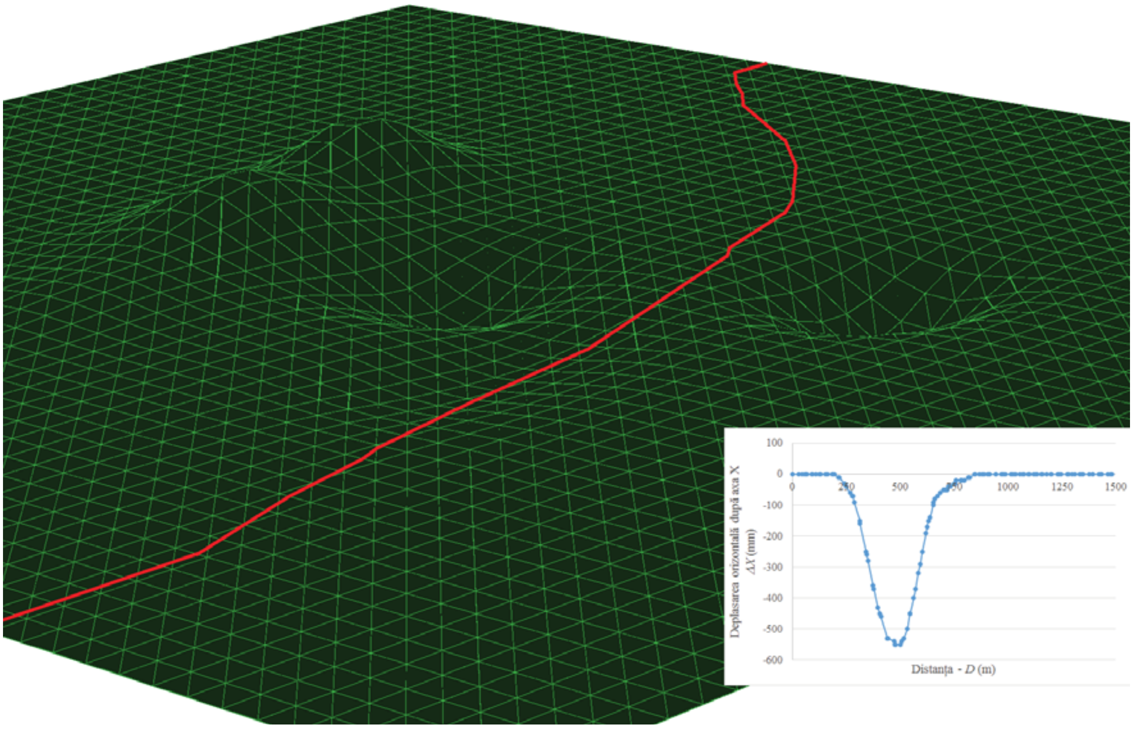

Fig.5. *Horizontal displacement after X axis*

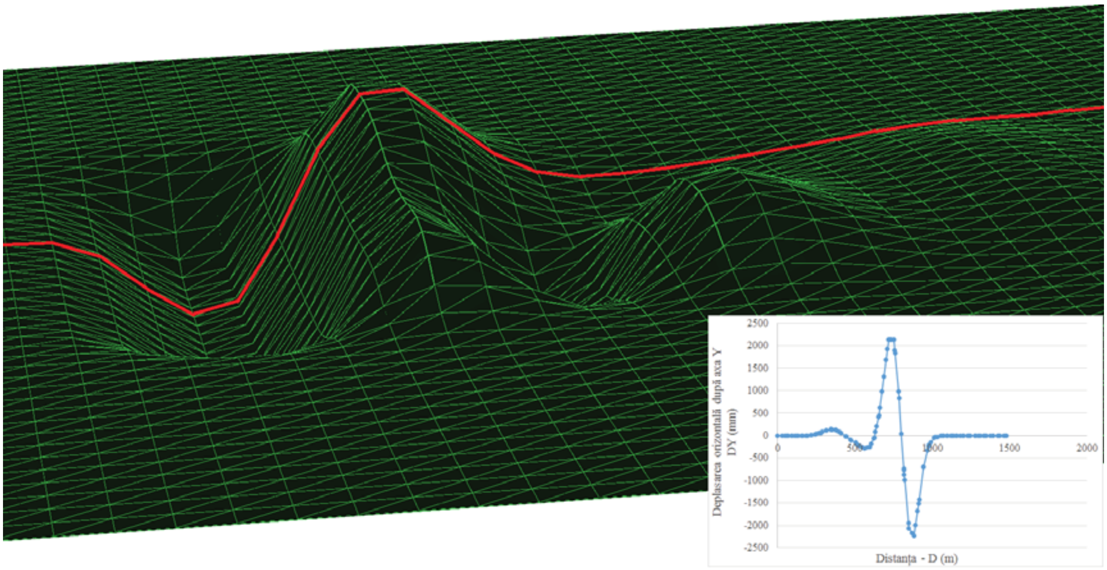

Fig.6. *Horizontal displacement after Y axis*

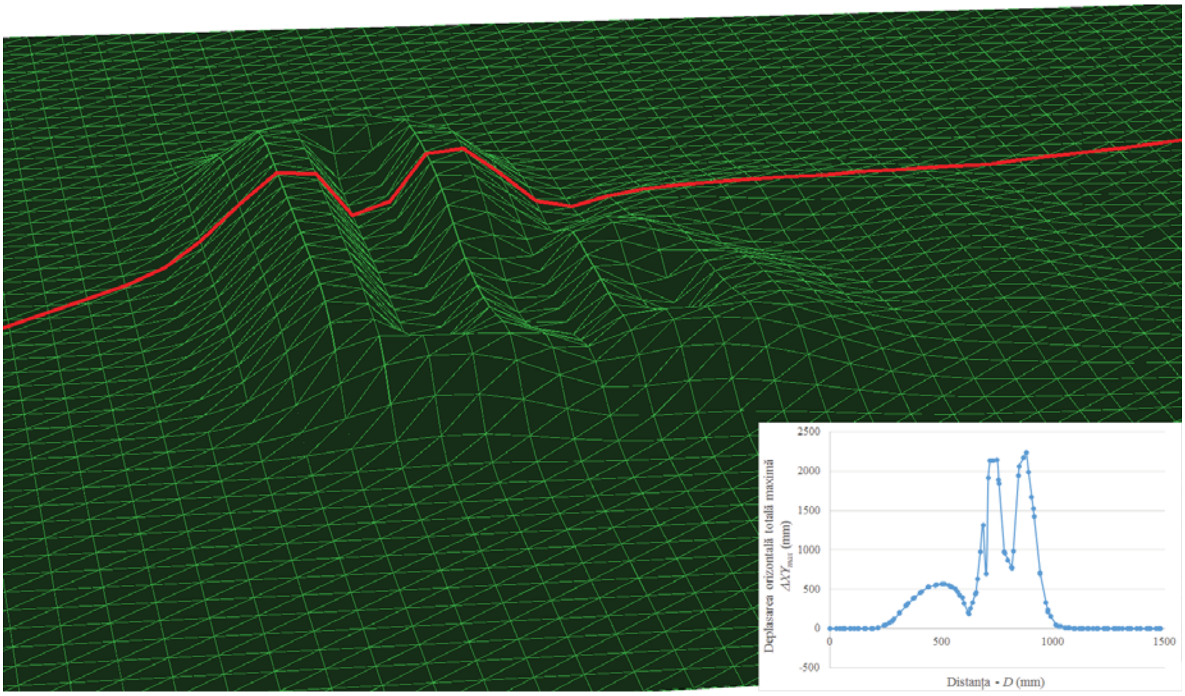

Fig.7. *Total horizontal displacement*

6. CONCLUSIONS

The influence functions method belongs to the empirical methods group applied for the prognosis of the surface deformation due to underground mining. Unlike the profile functions method, this method can be applied and operated in the case of several extracted areas, or in the case of the extracted areas with difficult configurations.

By applying the profile function method in the case of the current paper, an overview on the influence of the extracted areas was obtained (and thus on the access road located in the influence area of the underground mining).

Therefore, through the interpretation of the results it is expected that after the maximum vertical displacement of the object to be about 5 m, and the maximum longitudinal horizontal displacement to be about 2m.

Although the area has a monitoring station, the disappearance of the monitoring benchmarks (and their subsequent replacement with others), this does not provide comprehensive data on the deformation of this objective.

The current monitoring station in the case of Livezeni mine is made up of 50 benchmarks, in which are measured every three 3 months, the movement and deformation of the surface as a result of underground mining af seam 3 with four fully mechanized long fronts by the total collapse of the surrounding rocks, in panels (3-4), 5, 5A and 6.

The subsidence trough measured in the station has a very complicated shape, being the result of the underground mining of seam 3 in the four close panels, and the station is located on each side of the four extracted panels (an area in which the transversal displacement is substantial, a maximum displacement of 550mm resulted from the predicted models). Moreover, due to the fact that the monitoring benchmarks are not located on a depth above the freezing level, they are affected by the enlargement of the land during wintertime (which is what is shown in Fig. 2, where the ground enlarges rather than subside at two successive measurements).

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