# ANALYSIS OF SURFACE BEHAVIOR AS A RESULT OF UNDERGROUND MINING OF TWO COAL SEAMS

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**Abstract**
*The underground mining of a deposit leads inevitably to the deformation of the surface as well as to the destruction of the objectives located in the area of influence of the extraction. The problem of surface deformation as a result of underground mining has occupied and still occupies an important place in the mining field scientific research. Solving this problem makes it possible to predict the effects of the underground mining on the surface and offers the possibility of taking appropriate measures to protect the objectives located in the area of influence of the extraction. This paper analyzes the problem of surface deformation as a result of the simultaneous extraction of two horizontal coal seams, through applying the influence function method.*
**Key words**: *underground mining, subsidence, horizontal displacement, prognosis, influence function.*

## 1. Generalities

The need to study the phenomenon of surface deformation as a result of underground mining of useful mineral substances has occurred with the development of mining and, in particular, with the transition from a predominantly surface extraction (open-pit) to underground mining [3], [5].

The subsidence phenomenon is still being studied and will be studied in the future as it is a topical issue grounded upon the need to protect surfaces and constructions from surface or underground mining works, communication paths, utility networks, etc. [2].

In the case of the underground mining of two or more nearby seams, the problem of reducing the mining effects is very difficult. Thus, the objectives located in the area of influence of the extraction can be protected by a harmonic extraction of the seams, with the aim of reducing the tension and compressive stresses appearing on the surface. Otherwise, through a misalignment of the panel, these stresses may increase, leading to the destruction of the objectives located in the area of influence of the extraction [4].

In order to reduce the tensions appeared on the surface, it is necessary to extract the two seams concomitantly, with the offsetting of the panels. The gap between the panels, from the nearby seams, must take into account that deformations whose size exceeds the permissible limits must be compensated by the deformations of the sign contrary which are born in the rock massif.

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## 2. Influence function method

The influence function methods (figure 1) are based on the prognosis of the subsidence trough with the help of the influence area theory around the point of extraction [1], [6]. These methods can be applied to the extracted areas of different forms, but they are more difficult to calibrate and verify than the profile function methods [7], [10].

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

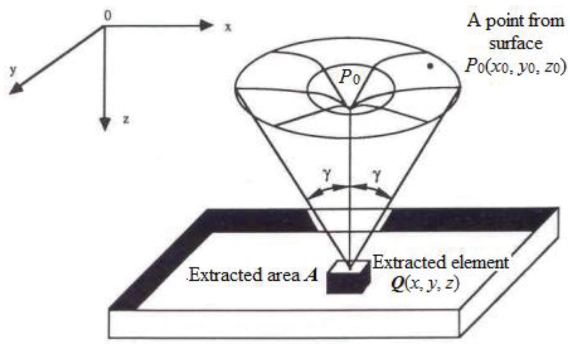


**Fig. 1.** *The influence of extracting the base element Q*

Different forms of influence functions were obtained by several researchers of subsidence events including - Bals 1932 Bayer, 1945; Sann 1949 Knothe 1957 Kochamanski 1957 Ehrhardt and Sauer 1961; Brauner 1973; Zich 1993, etc. [3], [8], [9].

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

This method is based on the Gaussian distribution of probabilities. According to this method, the math function is [6]:

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

### 3. Analysis of the influence of the concomitant underground mining of two seams on surface

To analyze the behavior of the surface as a consequence of the simultaneous extraction of two coal seams, the influence function method was applied. With this in view, we considered the extraction of two horizontal coal seams of equal thickness ($m$ = 10m), situated at a mining depth of 90m from each other, with a depth of extraction of the upper seam of 300m (figure 2).

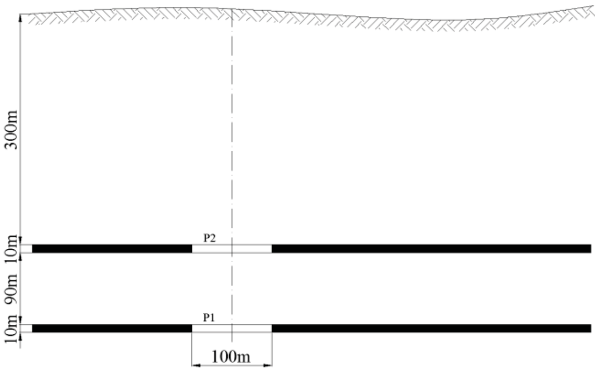


**Fig. 2.** *The layout of the coal seams for the considered case*

In order to study the influence of the underground mining of the two coal seams on the surface, 11 cases were considered. Thus, in the first case, we considered that the panels $P_1$ and $P_2$ are extracted on the two seams, with sizes of 100m each, vertically arranged one above the other so that the centers of the two panels coincide (see Figure 2). For the other analyzed cases, the two panels were offset with 20m, reaching in the last phase (case 11) at a distance between the central points of the two panels of $d$ = 200m (with a distance between the edges of the panels of $x$a= 100m, figure 3).

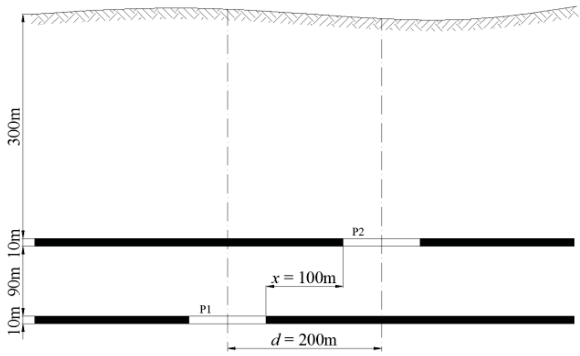


**Fig. 3.** *The position of the two panels for the last analyzed case*

The third dimension of the excavation has been chosen so as not to affect the way that surface moves in the area of interest.

Following the calculations performed, subsidence and horizontal displacement were predicted for all 11 studied cases.

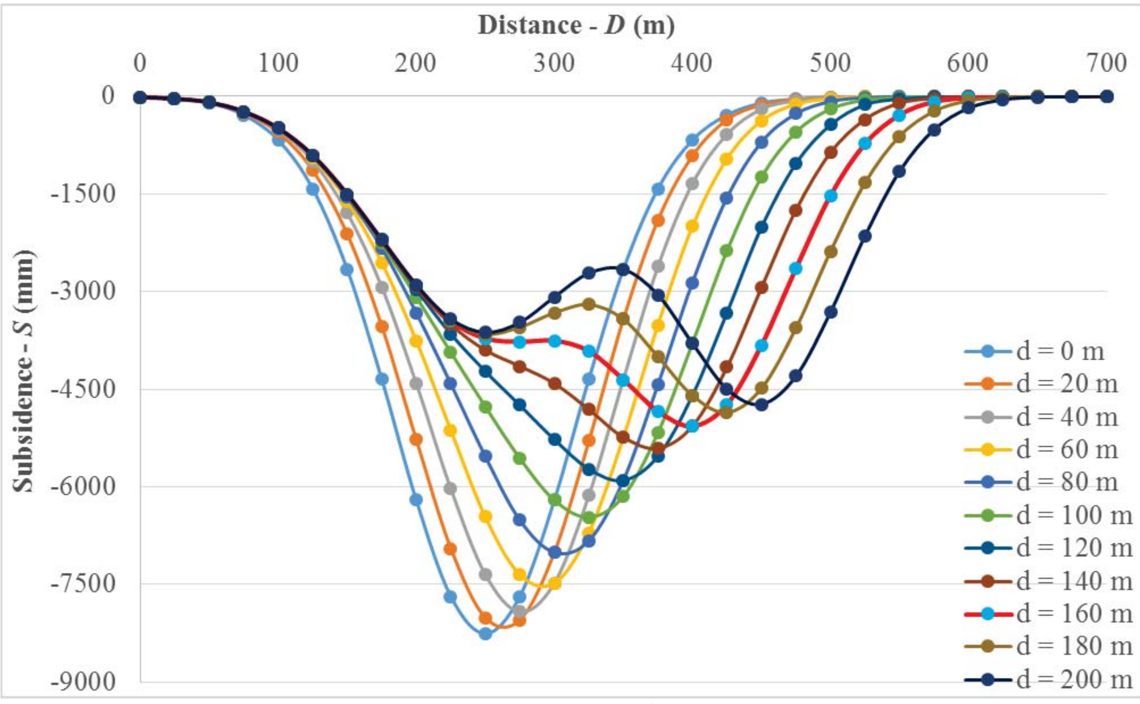


**Fig. 4.** *Subsidence curves predicted for the 11 cases studied*

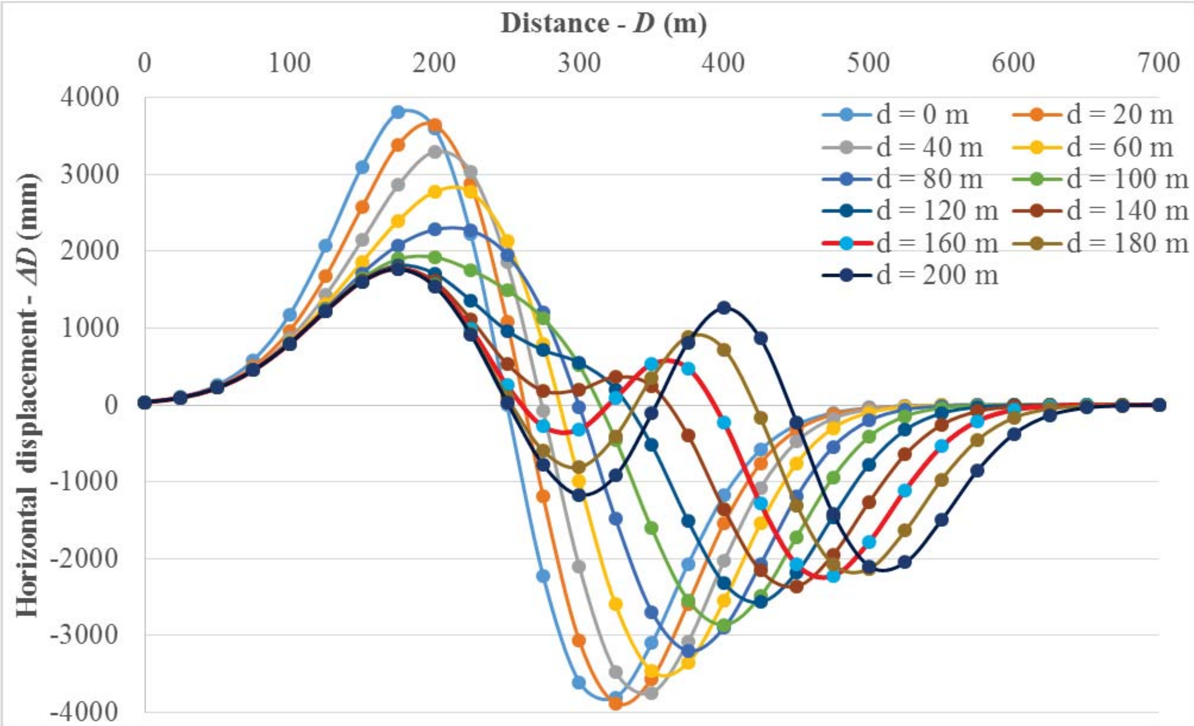


**Fig. 5.** *Horizontal displacement curves predicted for the 11 cases studied*

Figure 4 shows the subsidence curves predicted by the influence function method and Figure 5 displays the predicted curves of horizontal displacement.

The analysis of the predicted subsidence and horizontal displacement curves shows that the maximum subsidence and horizontal displacement decreases with the lag of the two panels, but the sizes of the subsidence trough are larger (the area affected by the underground mining is bigger).

From the safety point of view of the buildings, it can be said that under the considered conditions, the ideal case is where the gap between the two panels is maintained at approximately $d$ = 150-160m (namely $x$ = 50-60m). In this case, we may observe that the subsidence in the central area of the subsidence trough is approximately constant and the horizontal displacement in this area is minimal, therefore the tensile and compressive stresses are minimal. For a better image of the surface movement, figures 6 and 7 show the subsidence and horizontal displacements, predicted for the case when $d$a= 100m, in a 3D representation.

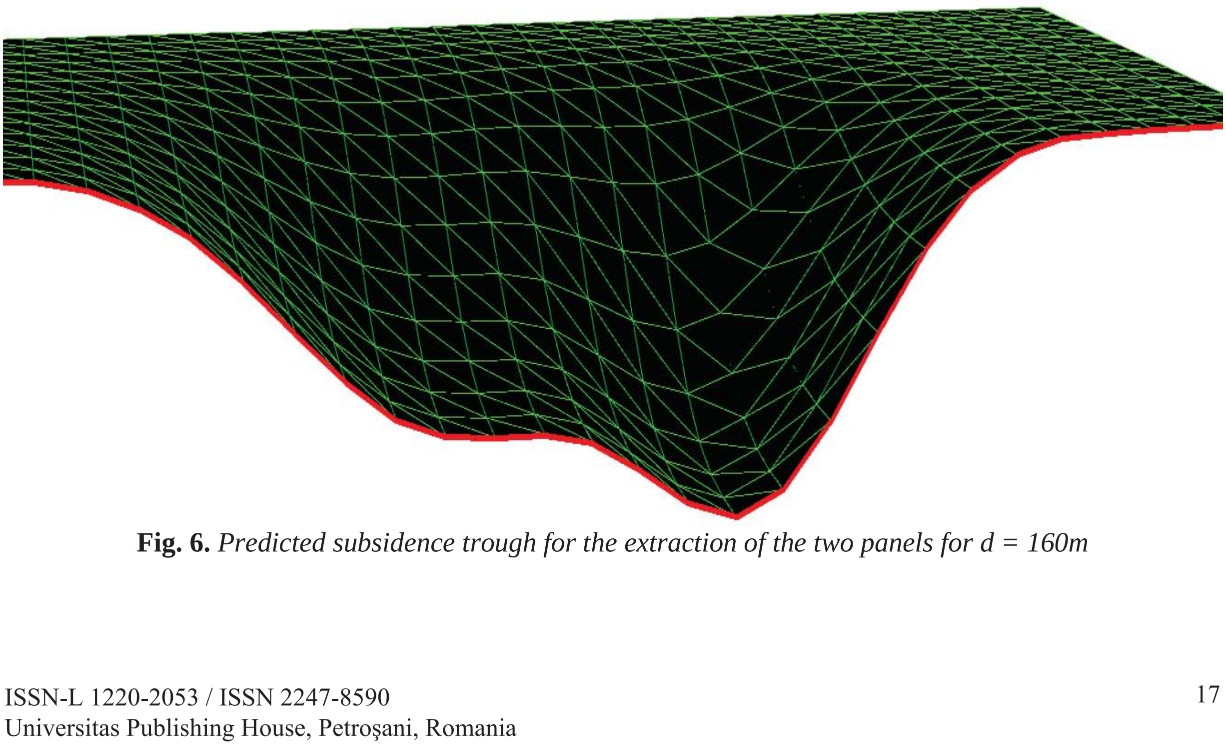

**Fig. 6.** *Predicted subsidence trough for the extraction of the two panels for d = 160m*

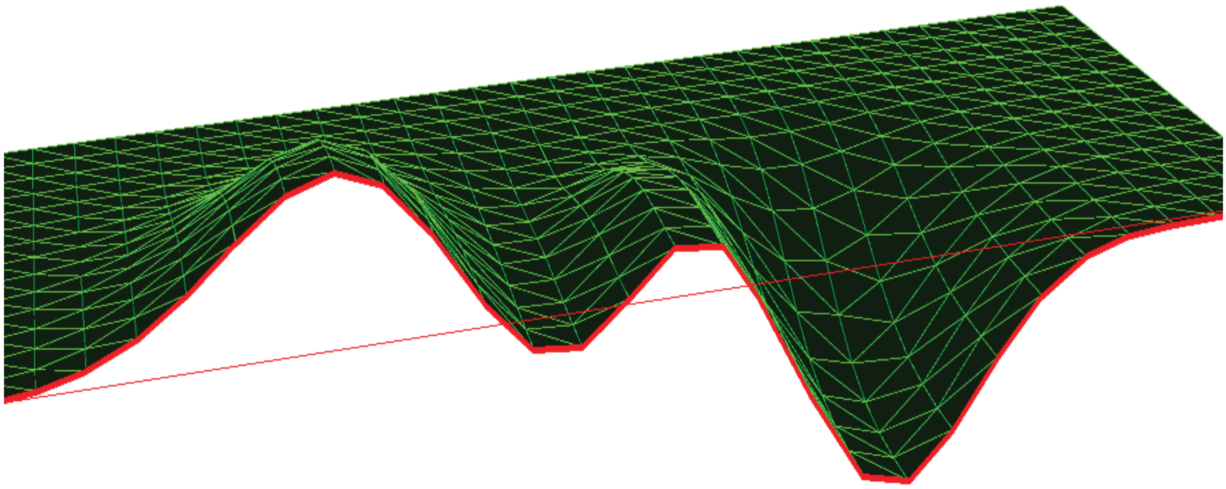

**Fig.7.** *Predicted horizontal displacement for the extraction of the two panels, for d = 160m*

## 4. Conclusions

The influence function 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.

The applying of the influence function method in the case of the current paper resulted in an overview of the deformation of the surface as a result of underground mining of two panels, located on two horizontal coal seams of equal thickness ($m$ = 10m), placed at a depth of 90m apart, with a mining depth of the top seam of 300m.

To observe how the mutual position of the two panels influences the deformation of the surface, 11 situations were analyzed (in the first case the two panels are vertically arranged one above the other, and for the other situations the distance between the centers of the two panels was gradually increased with 20m for each case).

Analyzing the results obtained, we may assert that in all analyzed cases a common subsidence trough emerged at surface, resulted from the superposition of the effects of the two extracted panels. In the case when the distance between the two panels is wider (estimated to be approximately x = 200m), two subsidence troughs would result on the surface for the extraction of each panel.

It can also be seen that if the two panels are perfectly superimposed, subsidence reaches a maximum value of approx. 8200mm (for given conditions) and the horizontal displacement is approx. 400mm.

With the lag of the two panel centers, the maximum subsidence decreases, but the affected area is larger.

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