ASPECTS REGARDING SIDE DISPLACEMENT AND DEFORMATION AS EFFECT OF THE SUBSIDENCE PROCESS CAUSED BY THE EXPLOITATION OF MINERAL UNDERGROUND DEPOSITE

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***Abstract**: This paper addresses two aspects related to the manifestation of the subsidence process on the surface, caused by the exploitation of deposits of useful mineral substances (coal, ores and salt), respectively the analysis of the functional - stochastic model used to determine the displacement and deformation parameters of the surface. Taken into account, was the subject of previous research by the authors. In order to determine the displacement parameters, the rigorously processed repeated measurement method was used.*

***Keywords:** subsidence process, moving parameters, mineral deposits, diving bed, repeat measurements*

1. Introduction

Following the excavation of the mineral deposits in the underground, voids are created which, due to the gravitational forces, tend to be occupied by the covering rocks. A process of motion is thus formed, which spreads from the excavated area to the surface, where the aliquots of diving are formed in the case of coal deposits, or congestion cones for mineral deposits and salt. The complex movement of the rock package to the surface of the land constitutes the subsidence process.

Regardless of the current manifestation of the subsidence process, it will cause damage to the cultivated land and especially to the industrial and civil objectives located in the exploitation perimeters. Thus, because of the formed pits and the change of the water drainage regime, the cultivated land becomes completely unusable. Diving can influence the underground water regime by raising or lowering its hydrostatic level, sometimes resulting in landslides. In the buildings there are cracks, the pipes break and the railways curve. The maximum intensity of the deformations occurs in the marginal area of the diving bed.

The effects of surface subsidence on the exploitation of a thick layer of medium-gradient coal, excavated by horizontal slices with frontal absections and advancing in the direction are shown in Figures 1 to 3, and Figures 4 to 8 show the effects of subsidence in the exploitation of salt.

Fig.1 Field rupture due to the exploitation of the layer

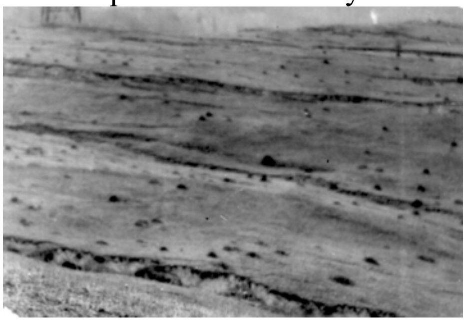

Fig. 2 Tears after multiple exploitation sides

Fig. 5 Initial cone edge, Ocna Mures

Fig. 6 Secondary displacements around the cone, Street M. Eminescu

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Fig. 7 "Plus" Supermarket during the collapse, Ocna Mures

Fig. 8 Lakes formed above Ocna Mures exploitation sites

2. Materials and Methods

The manifestation of the subsidence process is determined by a number of factors, of which the physico-mechanical properties of the rocks, from the anisotropic and slightly homogeneous geological profile, to the excavated area, are of particular importance.

In layered sedimentary deposits, where they are cantonated to coal deposits, in the first phase, the direct roof breaks down after the layering plan, collapsing into the created gap.

This surprise extends to a small height due to the breakdown of broken rocks (zone 1, fig.9). In the second phase, the material is squeezed and dropped under the weight of the more resistant rock benches, which bend with the loss of the continuity of the layers (zone 2, fig. 9), forming new voids, creating successive surges up to the alluvial area where linear bends occur (zone 3, fig. 9), and a diving bed is formed on the surface (zone 4, fig. 9).

In the case of sandstone or limestone in the covering of rocks, the drainage is made much slower and the depleted area turns into a natural contour with irregular profile (fig.10). In this case the effect on the surface is much stronger and leads to collapses and large ruptures (fig.1).

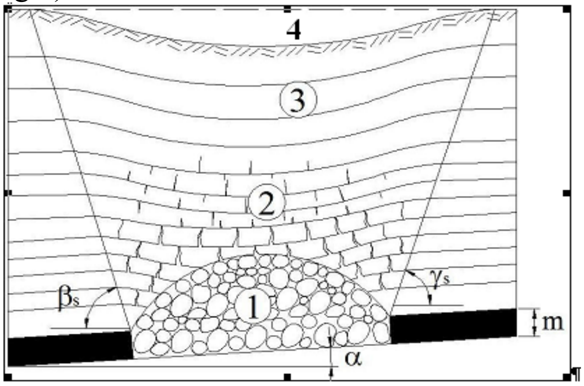

Fig. 9 Movement of stratified rocks

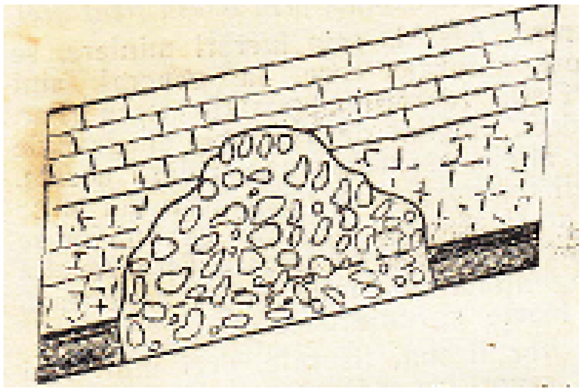

Fig. 10 Moving the rocks with the formation of a natural contour with irregular profile

In the case of eruptive rocks, gaps resulting from mineral underground deposite do not produce surprises, which are transmitted to the surface. High mechanical strength, compaction and high cohesion make these rocks not bend or break. Even if there is a crack of cracked rocks, it will stop soon after building a regular natural vault that can stand without drowning for hundreds of years.

Based on the laboratory tests obtained for the mechanical strengths of salt, it has been shown that chamber and pylon operating methods provide stability to the salt ceiling. If the dilatation and arheological parameters are taken into account, then the resistance elements will find themselves in a limiting state, which explains the occurrence of cracks in the pillars and floors, cracks that can lead, over time, to instability phenomena.

In the case of salt deposits exploited by underground mining works, the thickness of the resistance slab is 30-60 m and behaves like a double rebar. The thickness of the resistance ceiling is diminished by the dissolution of salt under the action of water, exfoliation and coptic, which under the action of gravitational forces descend from the ceiling.

When the thickness of the slab reaches a dimension whose compressive strength is lower than the pressure of the lithostatic column and of the surface targets, the resistance ceiling cracks to form the cone (fig. 4).

After the cone formation, in the second phase, the surrounding terrain moves towards it, causing deformations in the field and construction (fig.6, fig.7).

Other factors that influence the movement of rocks and surfaces can be summarized as: thickness and inclination of the reservoir, the way of directing the pressure in the abutment (sinking or overflowing), the depth of exploitation, the speed of advancement of the fronts, the presence of the faults, the hydrographic regime water, etc.

Following the direction of movement of a surface A from the surface (fig.11), it is noted that the motion vector is directed towards the middle of the pit (the created gap). The movement of the point A in space has a helical shape, occupying the positions 1 to 8 depending on the advance of the abode.

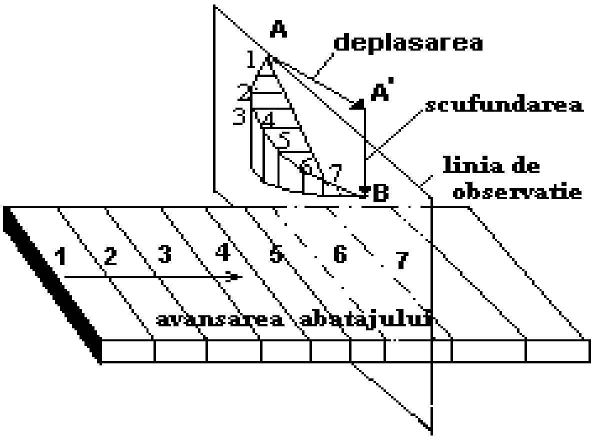

Fig. 11 Movement of a point from the ground surface

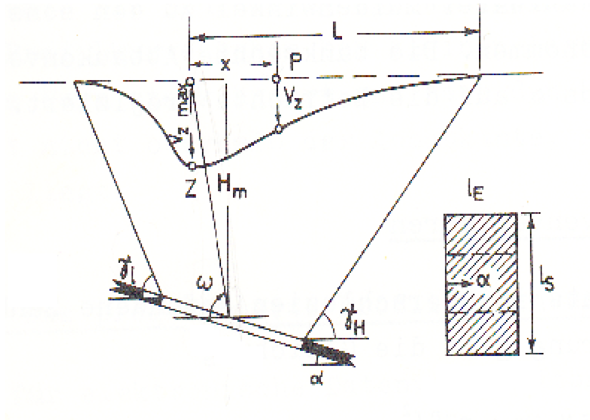

Fig. 12 The bed dipping after Kratzsch

By monitoring the subsidence process, the process of surface displacement and deformation is determined, based on topographical measurements in the tracking stations located above the operating perimeters.

The elements that characterize and qualitatively assess the movement process, calculate the safety pillars, or establish other measures to protect the surface and underground objects, are parameters of the displacement and deformation process.

The parameters of displacement and deformation of the surface consist of: the diving bed (fig.12), the diving (fig.13, curve 1), the inclination, the curvature, the horizontal displacements (fig.13, curve 2, curve 3), diving angles and area of influence (fig.14).

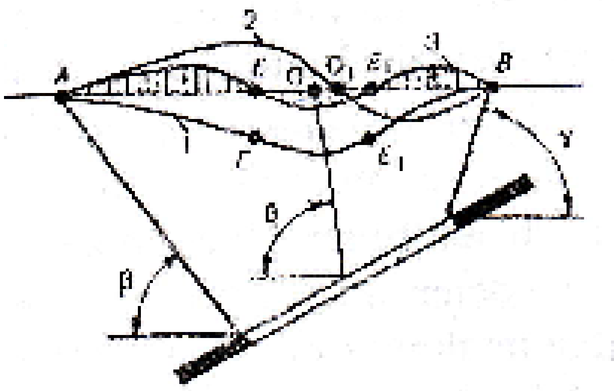

Fig. 13 Displacement parameters

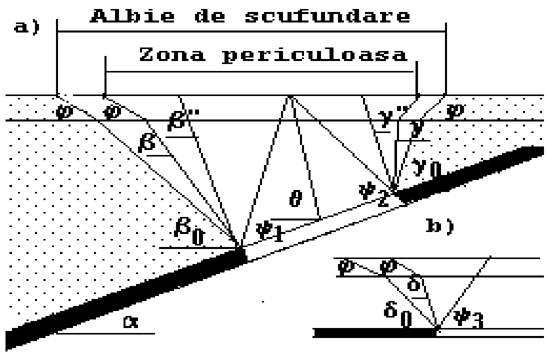

Fig. 14 Angular cross-sectional and directional parameters

For a correlation and a unitary interpretation of the various theories and hypotheses presented in the specialized literature, table 1 presents the main symbols used for the marking of surface displacement and deformation parameters.

Table 1

Parameter name	Symbolic notation of subsidence parameters					
	Romania	Germany	Poland	Russia	France	England
Sinking	S	Vz	W	η	A	S
Maximum sinking for critical areas	Smax	Vz voll	Wmax	η_0	Am	Smax
Maximum sinking for subcritical areas	St	Vz teil	Wt	η_t	At	St
Inclination	I	V'x	T	i	i	I
Curvature	K	V''x	K	K	C	K
Horizontal displacement	D*	Vx	u	ξ	D	V
Horizontal deformations	ε	ε	ε	ε	ε	ε
Conventional displacement angles	β, γ, δ	β_H, β_L, δ	β, γ, δ	β, γ, δ		β, γ, δ
Limit angle	β_l , γ_l, δ_l	$\gamma_H, \gamma_L\ \gamma$	γ	β_0	γ_a, γ_A	γ
Breaking angles	$\beta r, \gamma r, \delta r$	-	$\beta'', \gamma'', \delta''$	$\beta'', \gamma'', \delta''$	-	$\beta'', \gamma'', \delta''$
Angles of complete displacement	ψ_1, ψ_2, ψ_3	-	ψ_1, ψ_2, ψ_3	ψ_1, ψ_2, ψ_3	-	-
Angle of maximum displacement	θ	ω	θ	θ	θ	θ
Angles of shifts in alluviums	φ	φ	φ	φ	φ	φ

In order to determine the displacement parameters and deformation of the surface, as a result of the underground voids resulting from the mineral underground deposit exploitation, surface tracking stations consisting of transverse and directional alignments on the site were designed and developed at the surface of the operating perimeters. It is advisable that these alignments pass through the center of the slabs, where the parameter values are maximum.

High precision levels (Ni 002, Ni 007), and special inverse grooms were used to determine vertical displacements. In order to determine the planimetric position of the tracking station's parts, the electro-optical telemetry E.O.T.2000 and the Leica TC 307 total station were used.

For the determination of the displacement parameters, repeat measurements were performed at different times, rigorously processed by the matrix solved conditional measurements. Processing of displacement parameters and graphical representations was performed using the Excel utility.

Following below there are represented the values of the dredges obtained in the case of coal deposits (fig.15) and the inclinations (fig.16), respectively the dives recorded in the salt deposits in Ocna Mures, before the cone formation and Lake "Plus" (fig.17, 18).

3. Results and Discussion

The transverse alignment placed on the VI block at I.M.Lonea is 558 m long and has been materialized with 35 landmarks at 10-20 m. The alignment was designed with only one stable end as in the upstream area of the bed operation began long ago. At the date of the alignment (April 1985), the subsidence phenomenon appeared at the surface of the land, which is why the transient sinking of the 29-35 landmarks did not reach the total maximum values (fig.15), because of the lost sinking (sinkings recorded by the field before to materialize the alignment). The profile of the diving bed (S.X94, fig.15) is characteristic of a supracritic area, where several points record the maximum sinking.

The maximum values of the displacement and deformation parameters of the surface, on the transverse alignment to I.M.Lonea, are presented in Table 2.

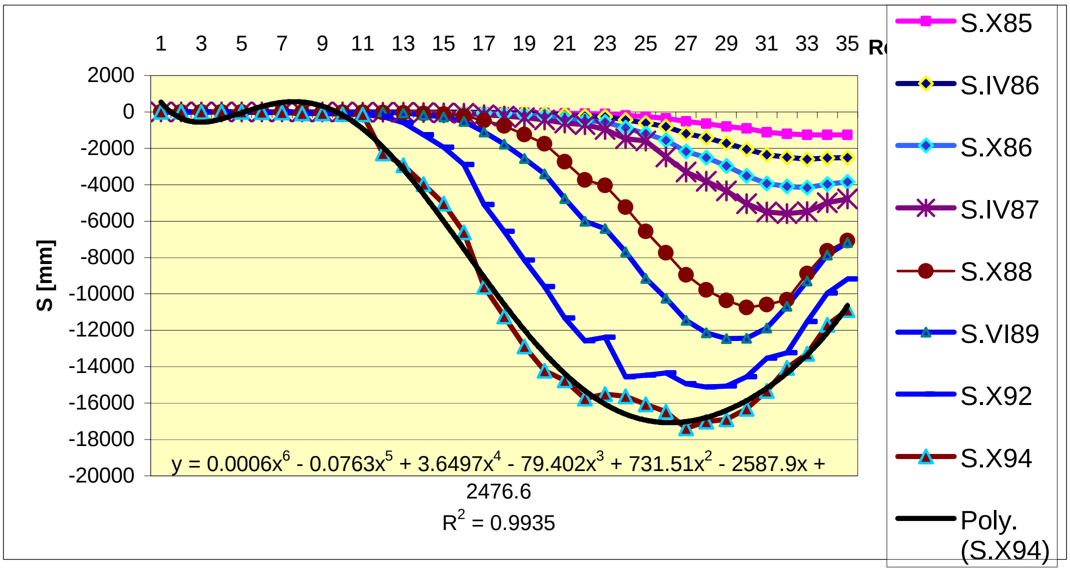

Fig. 15 Values of the dredges obtained in the case of coal deposits

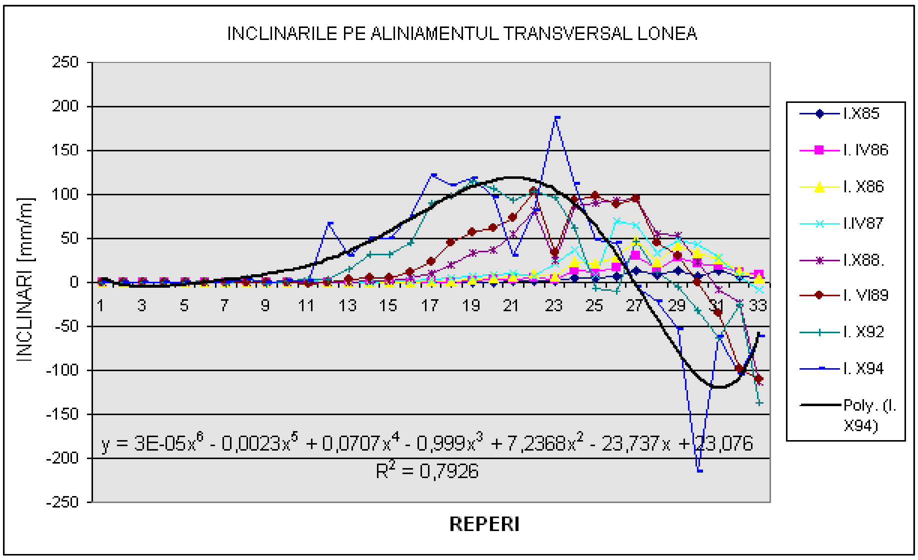

Fig. 16 Inclinations on „Lonea" transverse alignment

Table 2

Parametres	Measurement
Smax [mm]	16400
Imax [mm/m]	+130.53, -156.30
D*max [mm]	-696, +1691
ε_{max} [mm/m]	-51.85, +77.88

In the case of the Ocna Mure salt mine, the extraction of the salt from the deposit was made in the past by the dry exploitation at the top of the deposit and by the deepening of the kinetic in-depth at present. It should be noted that surface stability was not directly affected by mining activities for underground salt mining.

Dives recorded on the topographical landmarks in the Ocna Mureş mining perimeter were influenced by the existence of a phreatic layer of highly permeable coarse alluvial formations that led to the natural phenomenon of slow, continuous and uncontrolled dissolution of the salt cover. This led to the lowering of the ceiling plane and implicitly to the decrease of its resistance, which yields under the lithological weight of the covering rocks.

The ceiling pavilion behaves like a recessed beam at the ends, which before collapsing it flex, aspect of the increase of surface sinking.

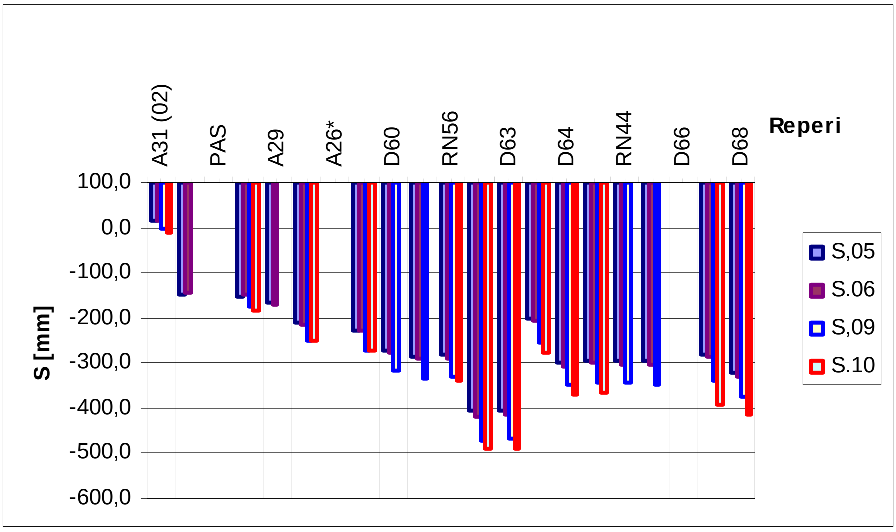

Fig. 17 Landmarks sinking on Mihai Eminescu Street

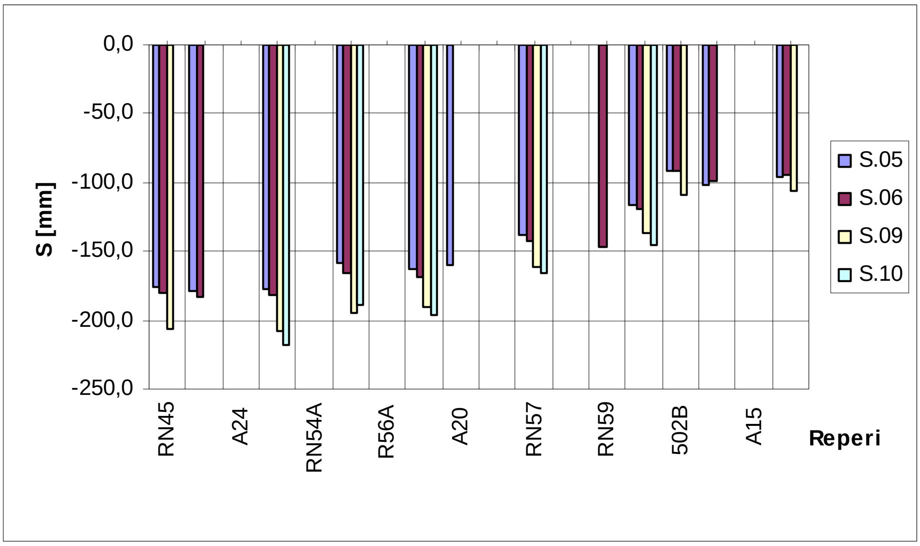

Fig. 18 Landmarks sinking on Nicolae Iorga Street

4. Conclusions

Gaps in the topographic landmarks, represented by figures 17 and 18, had as basis measurements the basis points determined in 1982. Comparing the manner of manifestation of the subsidence process in the case of coal and salt deposits, there is a slow evolution, almost

30 years, in the case of salt deposits and a faster evolution (10 years), with higher values of dives.

Based on the displacement and deformation parameters, determined by topographic measurements, the conventional displacement angles (β,γ,δ), used to determine the zones of influence and the design of the safety pylons for coal are determined.

Although coal and salt deposits are cantonized in the same type of sedimentation, the mode of manifestation of the subsidence process is totally different. In coal, a fall of the direct cover occurs, followed by a slow slump of the loose rocks, and in the first phase the salt is slow, a period that extends for decades, followed by a drawing of the plan of which the resistance to compression and tension is less than the forces in the roof.

The determination of displacement parameters and deformation of the surface by topographical measurements compete with the elaboration and calibration of some forecasting models of the subsidence process as well as the establishment of areas of influence of the exploitation on the surface.

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