MINING VOIDS AND THEIR INFLUENCE ON THE GROUND SURFACE

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Abstract: *The paper contains, generally, a mining engineering problem, but also an environmental engineering problem concerning the ground surface protection under the ore bodies underground mining influence and the social and industrial constructions protection.*

The knowledge of physical and mechanical rocks properties present importance by following aspects: are between the mains factors which influence the surrounding rocks movements of technological voids generated because the underground mining activities; constitute the data basis of underground workings design and stability analysis.

1. Identification of underground mining voids

In the case of Nistru mining perimeter was mined a pitching veins system ore bodies with cooper or gold mineralization.

The pitching veins were mined with stowing mining methods and stoping methods.

a)The stowing methods was used for veins with thickness ranged between 2 and 2.5m, over 50^o dip and stable and middle stability surrounding rocks. Also, in the case of several veins arisen argiliferous minerals, bone bands, veins apophysis and ramifications. The stowing materials proceed from workings or pockets driven in surrounding rocks. The blocks (panels) sizes, following the dip and the strike, range between 40m and 60m.

)The ore stoping methods are applied for the veins with thickness between 0.5m and 2.5m, with dip over 50^o and stable surrounding rocks. Depending on the thickness of the vein, ore type and hardness were used mining variants with or without protection pillars of preparatory workings. Following the dip and the strike, the mining block sizes were about 40-60m.

The veins with thickness ranging between 0.7m and 1.5m were mined with stowing methods and the veins with meddle thickness about 2.5m with ore stoping methods. The identification of underground mining voids was made taking into account topographical maps: the mining level H and the maximum mining level H_{max} and also the strike extension of 25 veins.

2. Displacement and deformation parameters of ground surface under the underground mining influence

For all types of ore bodies, the displacement and deformation phenomenon of ground surface are defined by the same parameters (see Figure 1):

-vertical displacement W_x , that define the subsidence profile;

-slope curve of subsidence profile T_x;

-curvature of subsidence K_x;

-horizontal displacement U_x;

-horizontal strain

The size of surface influenced zone are limited by the subsidence angle following the dip and strike , depending on the physical and mechanical characteristics of the rock mass.

The shape of ground surface displacement and deformation curvature are influenced by the following factors: ore bodies shape; ore bodies thickness; physical and mechanical characteristics of overburden rocks; underground mining depth.

The main parameters of ground surface subsidence are the followings:

Ssubsidence angle β, γ, δ (results from topographical measurements);

Smaximum vertical subsidence:

$$W_{\max} = q \cdot m \cdot \cos\alpha \,, \qquad [m]$$

where: m is the vein thickness; q – relative maximum settlement coefficient; α- vein dip.

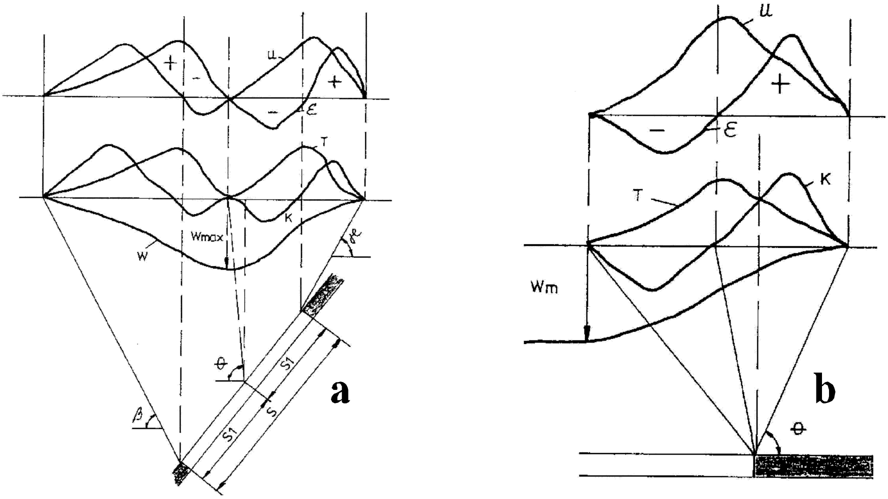

Figure 1. Ground surface displacement and deformation parameters under the influence of inclined ore bodies mining: a) following transversal direction; b)following the strike; *W* - vertical subsidence; *T* - slope curve of subsi-dence profile; *K* - curvature of subsidence; *U* - horizontal displacement;- horizontal strain

Smaximum slope for the ore bodies is recommended by the relation:

$$T_{max} = C_{12}\frac{W_{max}}{L}, \qquad [mm/m]$$

L is the development in the plane of subsidence semi-profile, m; C_{12}=2-2,3 is a coefficient from topographical measurements; W_{max} is maximum vertical subsidence, mm.

Scurvature of maximum subsidence, recommended by the ore bodies is:

$$K_{p\,max} = C_{K1}\frac{m}{H^2}\left(m^{-1}\cdot k_m^{-1}\right)$$

where: C_{k1} is the empirical coefficient established for every ore bodies (ranging between 2 and 1); *m* – vein thickness, m; *H*- underground mining depth; k_m- middle settlement coefficient.

Smaximum horizontal displacement is determined with relations:

a) $U_{max} = K_H$ ÆT_{max} , [mm]

b) $U_{max} =$ *a* ÆW_{max} , [mm]

where: k_H = (0.15 ÷ 0.18) ÆH - for ore veins; *a* = 0.35 + 0.8 @*p*; *p* = tg*a* @*a*/*H* - coefficient; *h is* overburden rocks.

Shorizontal strain for ore bodies is calculated with formula:

$$\varepsilon_{max} = 3\cdot k_H\frac{W_{max}}{L^2}, \qquad [mm/m]$$

S the total period of displacement and deformation subsidence phenomenon-depending on the workings depth, speed of face advancement, mechanical properties of the rocks:

$$T_t = k_T\frac{H}{T} \qquad [month,\ years]$$

where: *H* is the mining depth; *C*- speed of face advancement, m/month or m/year; k_T=0.8-1.1-coefficent for the little thickness ore bodies.

3. Prognosis methods of ground surface deformation along the strike and transversal alignments on the ore bodies

For to study the displacement and deformation process under the underground mining influence is not sufficient to determine only maximum values, but is necessary to know the parameters values in every point of subsidence profile, in view to protect the constructions situated on the ground surface.

Taking into account the mathematical dependency between the ground surface deformation, the researchers Zemâsev and Kollunkowa established the following relations:

$$W_{xz} = \frac{KW_{\max}}{2}\left[\varphi\left(\frac{D_1 - x + h}{\sqrt{yh}}\right) + \varphi\left(\frac{D_1 + x + h}{\sqrt{yh}}\right)\right]$$

$$U_{xz} = \frac{KW_{\max}}{4}\left[\varphi\left(\frac{D_1 - x + y + h}{\sqrt{yh}}\right) + \varphi\left(\frac{D_1 + x + y_1 + h}{\sqrt{yh}}\right)\right] - \\ - \left[\varphi\left(\frac{D_1 - x + y + h}{\sqrt{yh}}\right) + \varphi\left(\frac{D_1 + x + y_1 + h}{\sqrt{yh}}\right)\right]$$

$$T_{xz} = \frac{KW_{\max}}{2\sqrt{yh}}\left[\varphi'\left(\frac{D_1 - x + h}{\sqrt{yh}}\right) - \varphi'\left(\frac{D_1 - x + h}{\sqrt{yh}}\right)\right]$$

$$K_{xz} = \frac{KW_{\max}}{2yh}\left[\varphi''\left(\frac{D_1 + x + h}{\sqrt{yh}}\right) - \varphi''\left(\frac{D_1 - x + h}{\sqrt{yh}}\right)\right]$$

$$\varepsilon_{xz} = \frac{KW_{\max}}{4}\sqrt{yh}\left[\varphi'\left(\frac{D_1 + x - y_1 + h}{\sqrt{yh}}\right) - \varphi'\left(\frac{D_1 - x + y_1 + h}{\sqrt{yh}}\right)\right] - \\ - \left[\varphi'\left(\frac{D_1 + x + y + h}{\sqrt{yh}}\right) + \varphi'\left(\frac{D_1 - x - y_1 + h}{\sqrt{yh}}\right)\right]$$

where: φ is the Laplace's function; φ', φ''- the first and second differential of Laplace's function; x - point abscissa on the strike or transversal alignments; y - vertical distance between non-regular caving zone and a line of roof rock mass where is applied the superposition effect principle; D_1 – distance from the maximum point of subsidence profile and the inflection point of the subsidence profile.

By consequence of subsidence profile parameters calculus using the Zemisev relations where obtained the graphics shown in the Figure 2 and Figure 3.

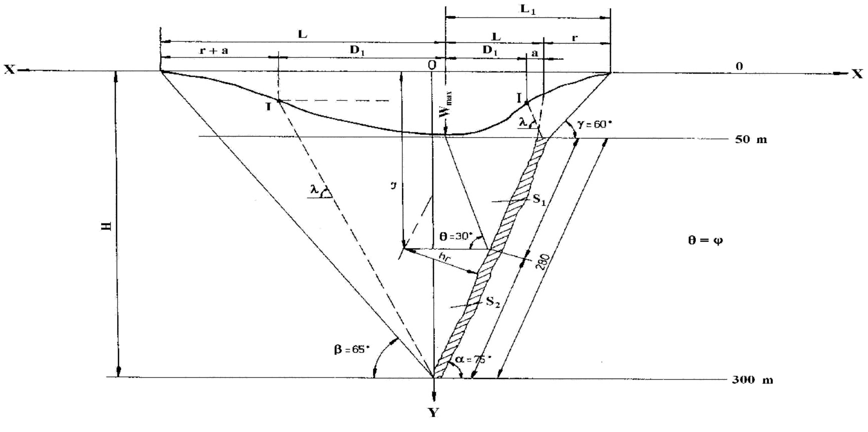

Figure 2. Graphical representation of subsidence parameters, following the transversal direction.

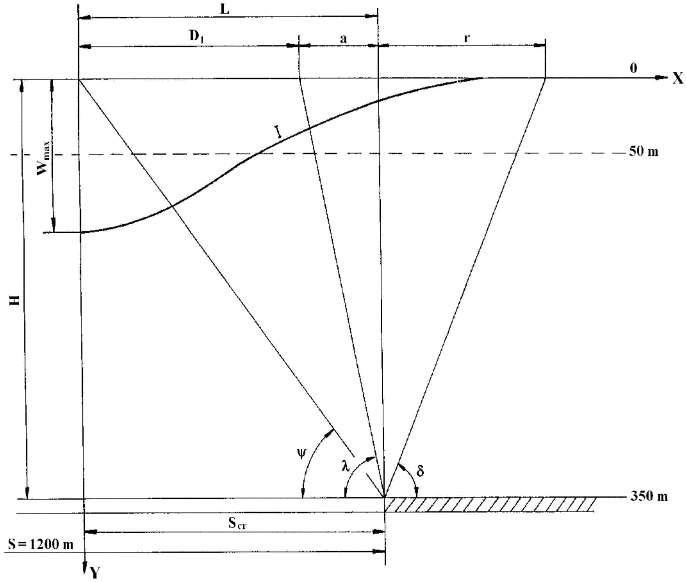

Figure 3. Graphical representation of subsidence parameters, following the ore bodies strike.

The simulation was made for the following data: the vein thickness 2.8m; dip size 280m; mining depth 350m.

Surface displacement and deformation parameters, following the transversal and strike direction, are presented in the Tab 1, Tab 2, and graphical in Fig. 4 and Fig. 5.

Table 1. The surface displacement and deformation parameters following the transversal of ore bodies

x, m	**Distance**	W_x, mm	T_x, mm/m	K_x, km^{-1}	U_x, mm/m	g , mm/m
0	0	1306	0	0	0	0
0.2	16	1040	4.2	+6.76	-1075	-1.8
0.4	32	780	19.68	-3.8	2150	-0.9
0.6	48	520	19.68	+3.8	3050	+1
0.8	64	260	6.35	-6.76	1025	+1. 6.768
1	80	0	0	0	0	0
I	40	653	25.4	6.76	3787	-
0	0	1360	0	-	0	-
-0.1	16.6	1000	5.5	-	885	-
-0.2	32.2	740	10.5	-6.76	1770	+1.8
-0.3	49.8	620	15.02	-	3540	-
-0.4	66.4	530	12.5	-	2950	-
-0.5	83	440	10.0	-	2360	-
-0.6	99.6	350	7.5	-	1770	-
-0.7	116.2	260	5.00	-	1180	-
-0.8	132.8	170	2.5	-6.76	590	-1.8
-0.9	148.8	80	1.2	-	210	-
-1	166	0	0	-	0	-
I	52.4	653	16.06	-6.76	3787	1.8

Table 2. The surface displacement and deformation parameters following the strike of ore bodies.

x, m	Distance, m	W_x, mm	T_x, mm/m	K_x, km^{-1}	U_x, mm/m	g , mm/m
0	0	1306	0	0	0	-
0.1	43.8	1175.4	1.41	-2.27	947	-
0.2	87.6	1044.8	2.87	-4.51	1296	-
0.3	131.4	914.2	4.23	-2.26	1896	-
0.4	175.2	783.6	5.64	-1.36	1896	-
0.5	219	653	4.23	2.26	1896	-
0.6	262.8	522.4	2.87	4.51	1296	-
0.7	306.6	391.8	1.41	+6.76	947	-
0.8	350.4	261.2	0.9	4.51	745	-
0.9	394.2	130.6	0.5	2.26	631	-
1	438	0	0	0	0	-
X1	186.5	658	-	-	3787	-
X2	107.6	-	-6.76	-	-	-1.8
X3	306.6	-	+6.7	-	-	+1.8

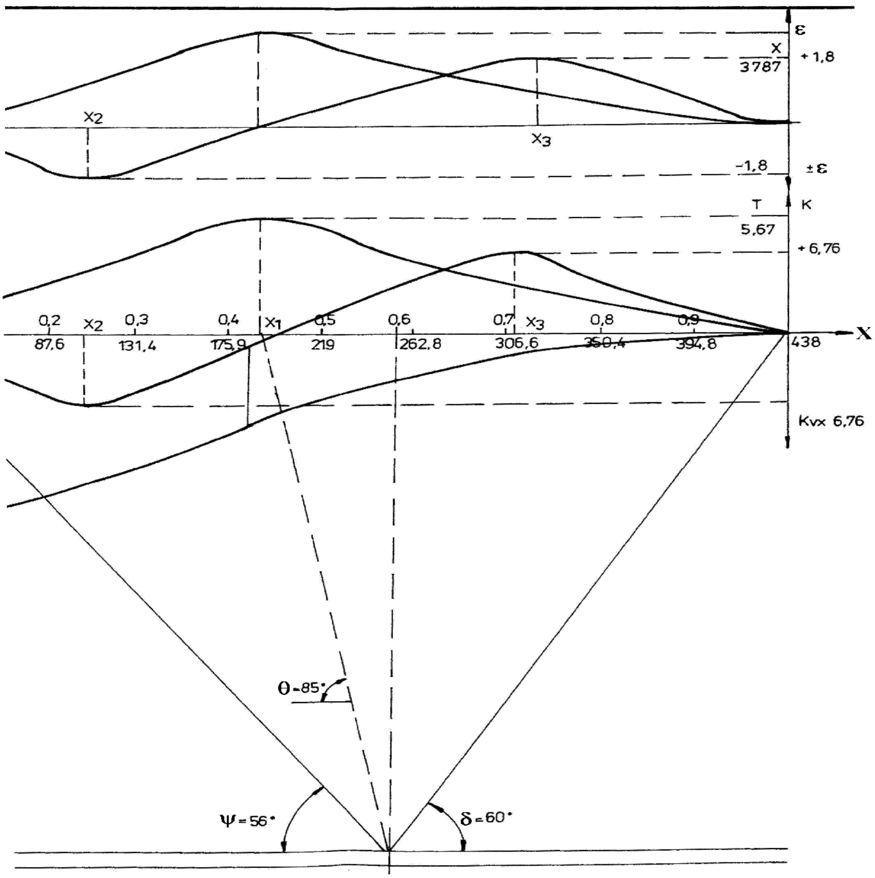

Figure 4. Graphical representation of subsidence displacement and deformation parameters.

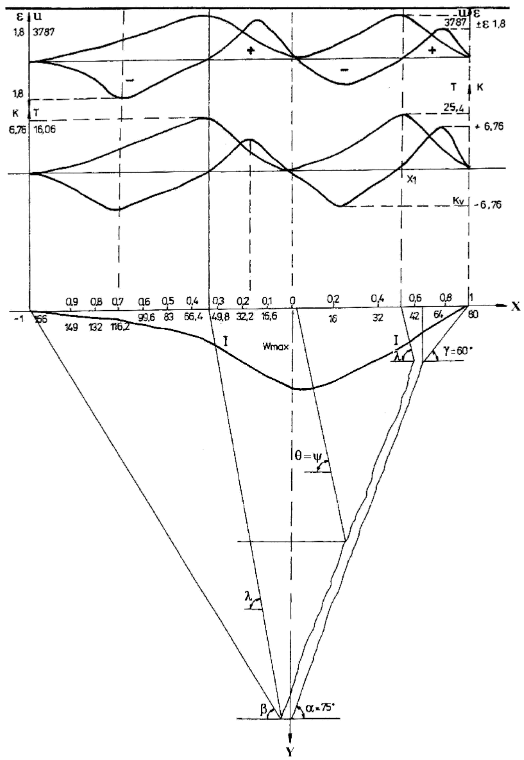

Figure 5. Graphical representation of subsidence displacement and deformation parameters.

Conclusions

By consequence of previous study could be pointed the following conclusions:

- following the strike and transversal direction it's possible to arise on the ground surface the subsidence profiles with ellipsoidal shapes and the discontinues displacements and deformations at the subsidence limits, fissures and cracks with different sizes, in function of the ground morphology;
- the main parameter, the horizontal strain, by respect to vein thickness and mining depth, ranging into ± 1.8 mm/m and a maximum of 3.47mm/m- for the first protection category-, with little displacements and insignificant derangements of ground surface;
- the maximum vertical subsidence is situated between 466mm and 1306mm, normal values for the previous mining conditions, inclusively the lode outcropping zones;
- the ore bodies mining of Nistru perimeter could not influence the adjacent mining perimeters.

References

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