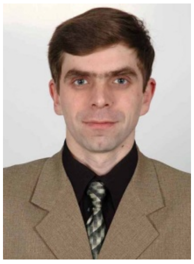
UDK 622.272.4

Modeling of stopes in soft ores during ore mining

Nikolay Stupnik
D.Sc. in engineering, professor,
discharging responsibilities of rector of Public higher education institution
Kryvyi Rih National University,
head of Underground mine development chair

Vsevolod Kalinichenko
D.Sc. in engineering, professor
Kryvyi Rih National University

Valeriy Kolosov
Sc. in engineering,
Director General of "Ukrrudprom" association
Kryvyi Rih



Sergey Pismennyy
PhD in Technical Sciences, docent
Kryvyi Rih National University

Aleksandr Shepel'
Master, teaching assistant of Underground mine development chair
Kryvyi Rih National University

Abstract
Results of physical modeling of stopes in soft ores on substitutes are presented. Stope of cusp form is found to be more stable as compared with square chambers.
Keywords: STOPE, CUSP FORM, TIME, VOLUME

Introduction

Ore deposits of Kryvyi Rih iron-ore basin are divided into solid and parallel – contiguous. A lot of researches, fulfilled by Malakhov G.M., Kaplenko Yu.P., Shchelkanov V.A., Lavrinenko V.F., Dedyulin V.V., Rymarchuk B.I., Andreev B.N., Storchak S.A., Tsarikovskiy V.V., Faustov G.T., Stupnik N.I., Kalinichenko V.O., Khivrenko O.Ya., are devoted to the questions of underground development of solid deposits of Kryvyi Rih iron-ore basin.

They suggested different variants of supporting systems; definition methods for: degree of extraction, structural members of supporting system, reasonable output, delivery and breaking-out out of ore were developed [1-4].

From the mining depth, mining and geological conditions are complicated by: variable power and dip angle, difference in mechanical-and-physical properties within mine section and also presence of dirt inclusions.

The authors developed classification of complex-structural ore deposits, which allows to simplify the choice of supporting system during development of substantial and non- substantial ores [3]. Existing supporting systems during development of complex-structural deposits in soft ores lead to increased losses of ore, because of increase in width of solid blocks during application of systems with open face or chocking – system with mass caving of ore and overlying rock [5-6].

Statement of a problem

With the help of theoretical researches [6] it is stated that while processing of complex-structural deposits in soft various- module mass, the usage of system with mass ore caving and overlying rock with stope of cusp form closed to the maximum allowable stable contour of cropping, fig. 1.

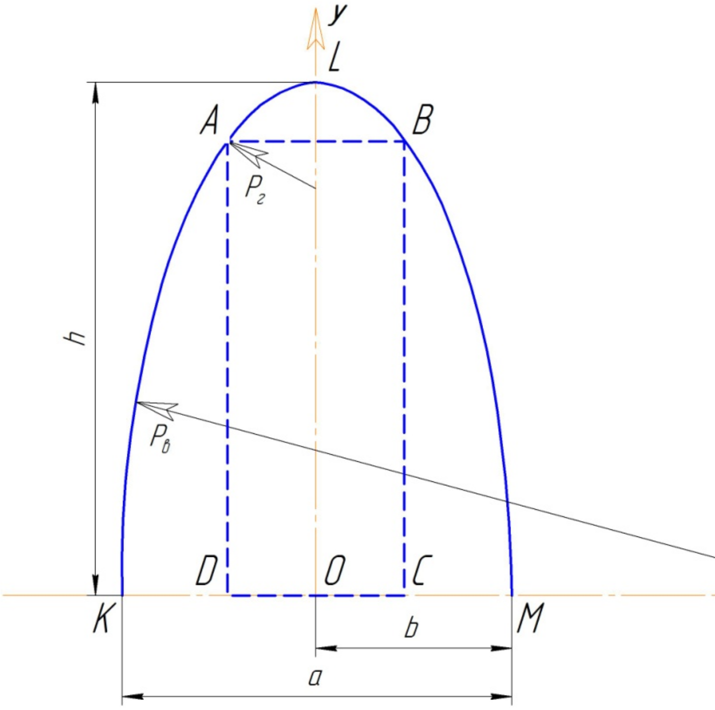


Figure 1 The scheme of stope of cusp form

The stope of cusp form provides its stiffness due to decrease of cropping passage and its optimal parameters [7]. Parameters of the stope are determined from the formula

$$\frac{h}{a} = \sqrt[3]{\frac{8 \cdot P_v}{P_h}} \quad (1)$$

where h and b – vertical and horizontal semi-axis of the curve, m; P_h, P_v – radius of maximum allowable stable horizontal and vertical respectively stope of cusp form, m (in accordance with pilot testing for conditions of Kryvyi Rih iron-ore basin make P_h = 1-6 m, P_v= 30-90 m).

In order to confirm theoretical researches, it is necessary to fulfill laboratory studies for determination of stable parameters of the stope in the non-stable various-module mass.

Research results

For determination of stiffness of stope of cusp form, laboratory studies on substitute models were fulfilled. 1:100 geometric scale value of modeling was adopted. Substitute material in respect with modeling scale was selected in accordance with physic-mechanical properties of subsurface rock of “Yubileinaya” mine.

There were carried out 16 series of laboratory studies, which differ from each other by stope form and tensile strength in uniaxial compression (rock hardness), table 1. Each study repeated 3-5 times.

Substitute material, which was loaded by external stress corresponding to the depth of development (1260m) in respect with modeling scale determined under the expression given below, set into laboratory model

$$\frac{N_m}{\gamma_m \cdot l_m} = \frac{N_p}{\gamma_p \cdot l_p} = M \qquad (2)$$

where N_m, N_p – some characteristic of model or prototype material, having force dimension, modified to the unit of area (compressive strength, extension, etc, elasticity, stress modulus); γ_m, γ_p – material density, model and prototype respectively; l_p, l_m – linear dimensions, in model and prototype respectively; M - a nondimensional number, which is characteristic criterion of similarity.

According to the calculations under the formula [2], vertical and horizontal pressure in the model makes 13,2 and 6,4 kg/sm^2 at 1260 m depth of the development and 0.25 Poison's ratio. In 3 days substitute material from back side was cut out, creating the necessary form of the stope with 45 sm^3 volume, and within 36 days (which corresponds to 12 months in prototype) they inspect its conduct.

During modeling in accordance with behavior of vertical stope, within 12 days (4 months), the stope keeps its initial parameters, table 1. After 15 days, there observed cleaving of substitute in the top part of the stope and giving it domed shape.

Table 1 Results of modeling of stope stiffness in unstable rock

No of experiment	Stope parameters, sm			Ore hardness	Volume of the stope since its existence, months				
	height	length	width		4	6	8	10	12
stope rectangular in shape									
1	90	50	10	4	46	55	63	71	75
2	90	50	10	6	45	51	61	66	71
3	90	50	10	8	45	47	58	62	68
4	90	50	10	10	45	45	47	55	66
5	30	150	10	4	53	64	80	-	-
6	30	150	10	6	51	60	68	79	-
7	30	150	10	8	48	55	67	73	80
8	30	150	10	10	46	54	66	72	78
hipped stope									
9	90	75/25	10	4	45	48	53	54	55
10	90	75/25	10	6	45	47	50	50	50
11	90	75/25	10	8	45	45	47	48	50
12	90	75/25	10	10	45	45	45	46	49
stope of cusp form									
13	75	50	10	4	45	45	47	48	50
14	75	50	10	6	45	45	45	46	48
15	75	50	10	8	45	45	45	45	45
16	75	50	10	10	45	45	45	45	45

With the increase of stope lifetime up to 36 days, its shape becomes of ellipsoid form; this fact confirms the results of Kulinkov's researches [8]. It should be marked that changing of mountain mass hardness from 10 to 4, the volume of stope increases 1.5-1.6 times respectively without sacrificing its stiffness in time up to 12 sec.

During modeling of horizontal stope stiffness, experiments No5-8, table 1, it was found that if one increases stope volume more than 1.6 times, it will be destroyed (experiment No 5,6, table 1). During modeling there was observed formation of destruction crown on the top part of the stope. After 18-20 days, depending on the tensile strength of substitute, there observed cleaving of the material not only in the top part but also from the side of its blocks. Stability analysis of the stope of hipped form while modeling showed that destruction of substitute along the outline of the stope flows less intensively as compared with stopes, rectangular in shape. It should be marked that after 30 days the stope of hipped form takes cusp form, and its volume increases not more than 1.1 -1.2 times within 36 days (a year) of existence.

The stope fractures mainly in its top part. With the help of laboratory studies it was found that destruction power, affecting the sides of stope will be the lowest.

The results of laboratory modeling (fig.2) confirm that formation of the stope of cusp form increases its stiffness without disturbance of substitute along its perimeter. The table 1 shows that within 36 days the stope of cusp form has expanded not more than 1.1 times.

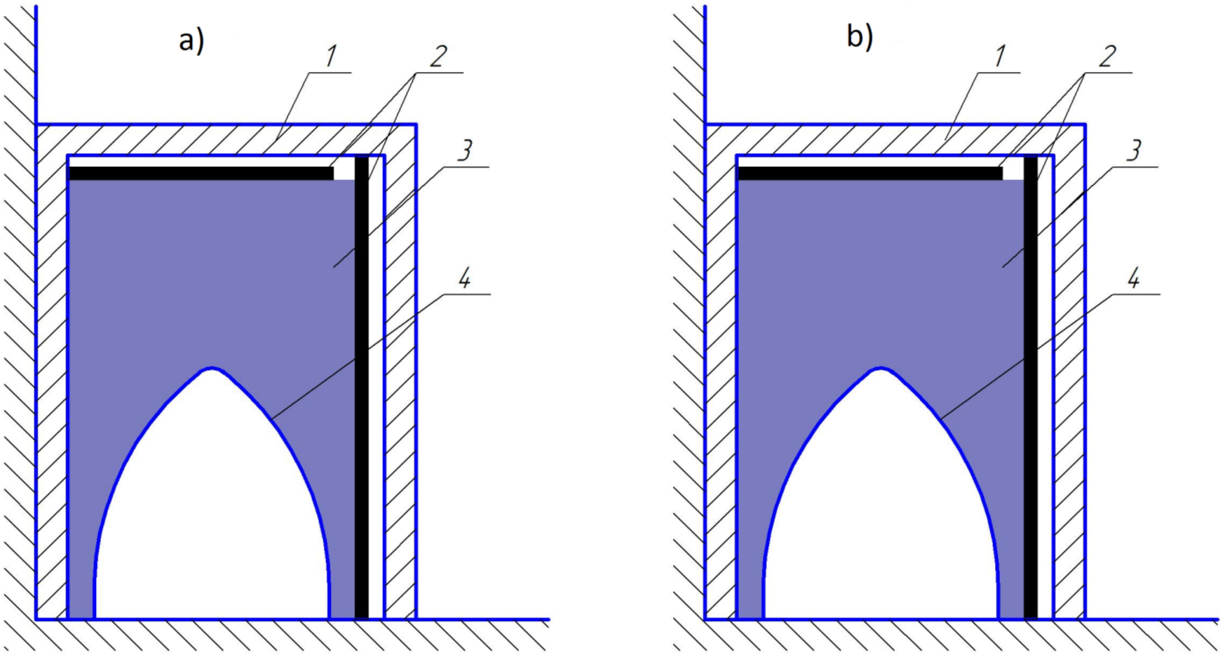


Figure 2 Modeling of stope stiffness of cusp form with substitute tensile strength corresponding specifically 100 MPa: a, b- stages of modeling, before and after modeling respectively; 1 - laboratory model; 2 - external loading; 3 – substitute (mountain mass); 4 – horizontal stope.

In such a way, the results of theoretical researches may be confirmed, and the expression (1) is true.

Figure 3 reflects combined outlines of stopes before and after modeling with substitute tensile strength, which equals specifically 100 MPa (10 on-scale of prof. Protod'yakonov).

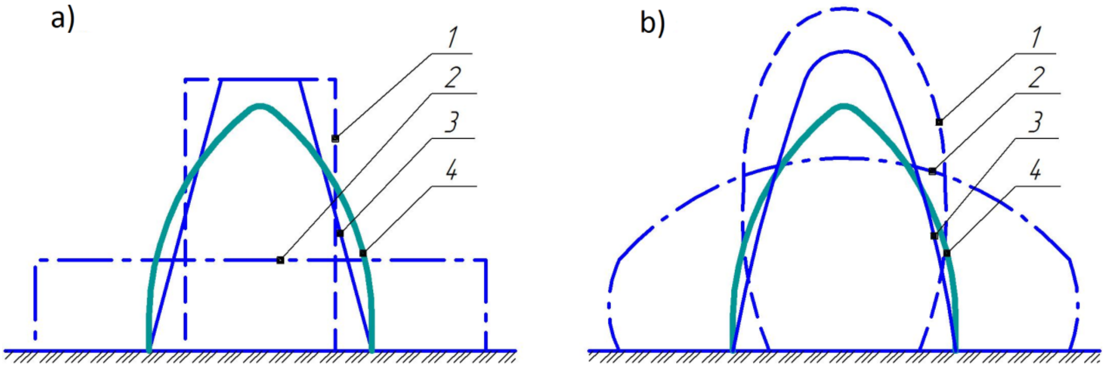


Figure 3 Combined outlines of stopes: a,b – stope configuration before and after modeling

Analysis of the figure 3 shows that in geological conditions, when vertical stresses more than horizontal ones, stopes of vertical and hipped form take cusp form in course of time.

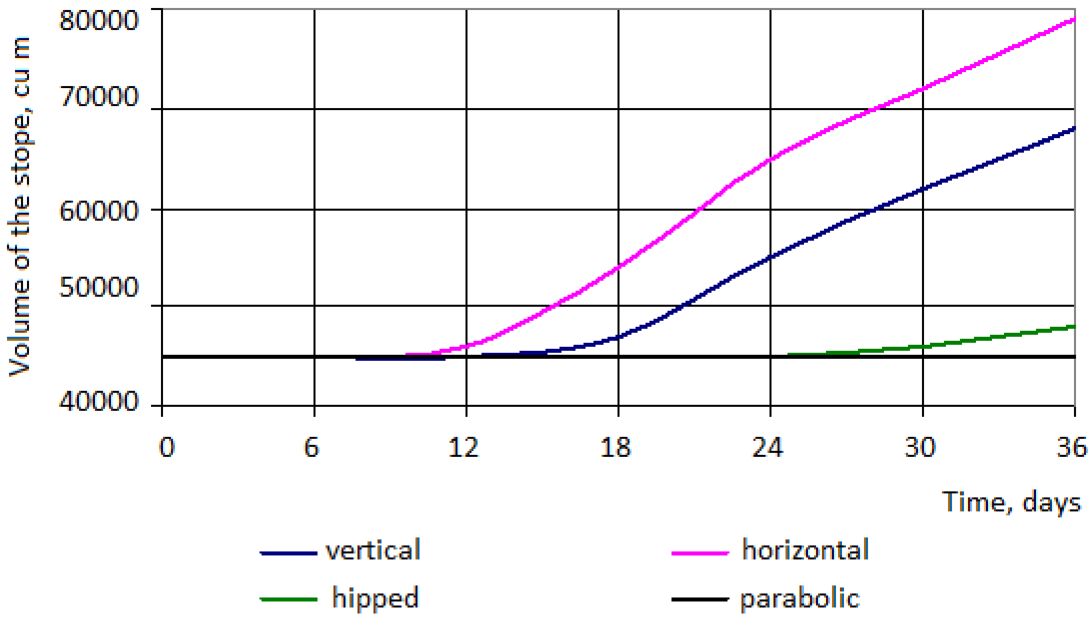


Figure 4 Dependences of change of stope volume on its lifetime and its shape at substitute tensile strength, which equals specifically 100 MPa.

Figure 4 shows that at substitute tensile strength, which equals specifically 100 MPa and lifetime of the stope of cusp form stays constant, square stopes in their turn start expanding in 6-12 days.

Conclusions

The results obtained showed that the stope of cusp form in unstable rock is more stable as compared with stopes of rectangular or hipped shape. Also while modeling it is proved that the volume of stope increases not more than 1.1 times under the characteristics determined by theoretical researches.

References

1. Malakhov, G.M., Lavrinenko, V.F., Kucheryavenko, I.A. (1961) Reasonable course of stoped excavation for mines of Krivorozhskyi basin. *Gornyy zhurnal*, No3, pp. 19-24.
2. Shchelkanov V.A., Khivrenko O.A., Khivrenko V.O. (2002). Analysis og complex-structure deposits of Krivbass basin. *Ore mining. Kryvyi Rih, KTU*, No7, pp. 30-35.
3. Stupnik N., Kalinichenko V., Pismennyi S. Pillars sizing at magnetite quartzites room-work. Mining of Mineral Deposite. A Balkema Book. 2013, pp. 11-15.
4. Korzh V.A., Kudryavtsev M.S., Lavrinenko A.F. (1985). Calculation methods of stay bar value of superincumbent bed of broken ore. *Ore mining. Kryvyi Rih, KTU*, No40, pp. 48-52.
5. Stupnik, N.I. Pis'mennyy, S.V. (2013). Parameters of store- pillar mining of ferruginous quartzite with inclined pillars. *Girnichiy visnik,* No 96, pp. 89-93.
6. Stupnik, N.I., Pis'mennyy, S.V. (2012). Advanced technological variants of further treatment of iron-ore deposits by systems of mass caving of ore. *Visnik Krivoriz'kogo natsional'nogo universitetu,* No 30, pp.3-7.
7. Pis'mennyy S.V., Khivrenko V.O., Sbitnev V.A., Polukhina N.V. (2002). Parameter determination of balance chamber of domed shape. *Ore mining. Kryvyi Rih, KTU*, No79, pp. 48-52.
8. Kulikov V.V. Vypusk rudy (Ore drawing). *Moscow, Nedra*, 1980, 303 p.