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INTERRELATION BREAKUP PARAMETERS OF ROCK MASS WITH THE DIRECTION BREAKAGE UNDER EXPLOSIVE WORKING OFF OF HIGH LEDGES IN THE QUARRIES

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According to the analysis of known analytical dependencies to determine the height and width of the collapse of the rock mass when the blast working off of ledges height of 15 - 25 m made quantitative estimation of these parameters depending on the basic parameters of the explosion. Based recommendations on the orientation of the front breaking at schemes of short-delay explosion relatively non to the free surface of the ledge, and to the main fracture system.

Key words: explosion, quarry, explosion scheme, fracture, front of breaking, ledge.

ВЗАЄМОЗВ'ЯЗОК ПАРАМЕТРІВ РОЗВАЛУ ГІРСЬКОЇ МАСИ З НАПРЯМКОМ ВІДБІЙКИ ПРИ ВИБУХОВІЙ ОБРОБЦІ ВИСОКИХ УСТУПІВ НА КАР'ЄРАХ

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За результатами аналізу відомих аналітичних залежностей по визначенню висоти і ширини розвалу гірської маси при вибуховій обробці уступів висотою 15-25 м дана кількісна оцінка цих показників в залежності від основних параметрів вибуху. Обґрунтовано рекомендації щодо орієнтуванню фронту відбійки при КЗВ відносно не до вільної поверхні уступу, а до основних систем тріщин.

Ключові слова: вибух, кар'єр, схема підривання, тріщинуватість, фронт відбійки, уступ.

PROBLEM STATEMENT**.** Together with the achievement of high quality rock crushing in quarries, explosive works should provide parameters of breakup (width and height) of the rock mass, which lead to high performance and safe operation of excavators. At the same time the width along the ground on top and a height of breakup depends on the degree of loading effect of the explosion and the forces of resistance of destructible rock mass, implemented ceteris paribus, schemes of short-delay explosion (SSDE) in combination with other parameters of explosion (line of least resistance, grid of wells, type of explosive substances (ES), construction of charge, diameter of the wells). Essential value in the regulation of breakup parameters is working off of ledges in height 20-30 m, that is, when there may be instances of exceeding the height of breakup of the established norms for maximum digging height of the excavator.

In determining the parameters of breakup of rock mass proposed formulas by a number of authors, which not sufficiently take into account the indicators of rock properties and rock mass, parameters taken into account indicators of rock properties and rock mass, parameters of ledge and accepted a priori, most important, without taking into account the structural and textural features of the rock mass. Last interconnected with design of schemes SSDE and must take into account the direction of breaking charges of explosive substance (ES) relative to the main systems of cracks S and Q.

EXPERIMENTAL PART AND RESULTS OBTAINED. The basis of the well-known formulas for calculating the parameters of breakup of rock mass in the quarries is geometrization, interpreted by to form of triangle or trapezoid. Based on this, many of formula currently used in the practice of designing explosive works under certain conditions, therefore dwell on them in greater detail is not necessary, because their characteristics and the results of using sufficiently highlighted in scientific literature. In this regard, it is advisable to bring a brief analysis of the most used formulas.

According to the work [1] applied to the conditions of quarries construction materials the width of breakup of rock mass

$$B_p = 4{,}5 \cdot q_p \cdot \sqrt{W \cdot H}, \qquad (1)$$

where q_p – calculated specific consumption ES, кg/m^3;

W – line of least resistance, m; H – height of ledge, m.

In the same work is recommended to take the height of breakup of rock mass H_p : under two-row arrangement of charges – 0,7H; three-lane – 0,8H, four-row – (0,85 – 0,9)H.

Practically similar with the work [1] is formulas for determining B_p and H_p, shown in the work [2] respectively:

$$B_p = 6{,}5 \cdot q \cdot \sqrt{W \cdot H} \qquad (2)$$

$$H_p = (0{,}7 - 0{,}9) \cdot H. \qquad (3)$$

As recommended in the work [3] value B_p under SSDE can be approximately determined by the formula

$$B_p \approx K_z \cdot B_0 + (n+1)b, \qquad (4)$$

where K_z – coefficient of range kickback of blasted overburden, depending on the time interval slowdown (see: [3], p.94);

n – the number of rows of wells charges;

b – the distance between rows of charges, m;

B_0 – the width of collapse of the rock at the instant single-row explosion, m (see. [3], formula IV.24 on p.93).

Further in the [3] noted, that the value H_p at multiple-row SSDE does not exceed H, while increasing the number of rows of charges H_p in the middle and rear its parts exceeds H on 5-30 %.

Parameters of collapse of the the rock mass, as noted in [4], depend on many factors, including the schemes SSDE, due to these schemes can be done to reduce or increase the range of movement of the rock mass more than 2 times. In the general case, $B_p = A + \Delta B_p$ (where A – width of blasting stope, m; ΔB_p – the range of movement of the blasted from overburden slope ledge, m).

It is shown, that the maximum value B_p is achieved by blasting scheme. Taking into account the change in direction of breaking row n charges due to the angle orientation of the front breaking to the line the free surface of the ledge

$$B_p = \Delta B_{\Pi} \cdot \left(0{,}73 + 0{,}27 \cdot \cos 2\alpha_{f.u}\right), \tag{5}$$

where ΔB_{Π} – the width of collapse of the rock during gradual scheme of blasting, m;

$\alpha_{f.u}$ – angle between the direction of the slope shoulder and line simultaneously exploding charges, hail.

Value of ΔB_{Π} with diagonal ($\alpha_{f.u}$ =45°) and gradually, transverse ($\alpha_{f.u}$ =90°) schemes of blasting is 0,73B_p and 0,46B_p.

The maximum height of collapse of the rock mass

$$H_p = K_p \cdot H \cdot \left[1 - \left(1 + \frac{K_p \cdot H \cdot A}{\Delta B_p^2}\right)^{-2}\right]. \tag{6}$$

According to normative reference for drilling blast works [6]

$$B_p = 3{,}5 \cdot H \cdot \sqrt[4]{F^3} \cdot \sqrt{q/H} \cdot (0{,}65 + 0{,}35 \cdot \cos \alpha_{f.u}); \tag{7}$$

$$H_p = H \cdot \sqrt[4]{N/H_q}, \tag{8}$$

where F – group of soils according to SNIP;

$\alpha_{f.u}$ - angle between the direction of the slope shoulder and line simultaneously exploding charges, hail.;

N – number of explosive rows hole charges.

Thus, recommended the formula for determining, B_p (1), (2), (4) used in the practice of blasting operations excluding the impact of the direction of blasting. Formulas (5), (7), (8) take into account the direction of the front breaking relative to the main fracture system, which to some extent reduces the possibility of regulation quality of preparation the rock mass and the width of the collapse. Analogical approach observed in determining the value H_p.

The aim of the work – estimation of parameters of the collapse of the rock mass in relation to the direction of breaking, schemes SSDE at working out benching fractured mountain massifs in the quarries.

In Soviet and modern practice in the production of explosive works there are examples of mining and rock ledges height 20-30 m. Thus excavator loading of the rock mass at H to 30 m made with the division of the approaches.

At H = 20-30 m adopt schemes SSDE and parameters of explosive works in such a way, that H_p does not exceed 1,5 digging height (H_{ch}) excavator, employed in loading of the rock mass. In this case H_p should be (0,5-0,8) H depending on the type of excavator (table 1).

Table 1 – The maximum value of H_{ch} (m) rock mass of mining shovels

Model of excavator	Source			Remark
	[3]	[7]	[8]	
EKG – 4,6B	-	10,3	10,3	Coincides
EKG – 5	11,0	11,7	10,3	Coincides slightly
EKG – 8I	12,5	12,5	14,0	Does not coincide
EKG – 12,5	15,6	10,0	10,1	
EKG - 20	18,0	11,6	17,0	

For conformity assessment H_{ch} different models of excavators type EKG height of camber make calculations of by the formulas (3), (6) and (9), the results of which are built graphic dependences $H_p = f(H)$.

On the Fig.1, according to (3), shows the change H_p to the ledge height 15-23 m.

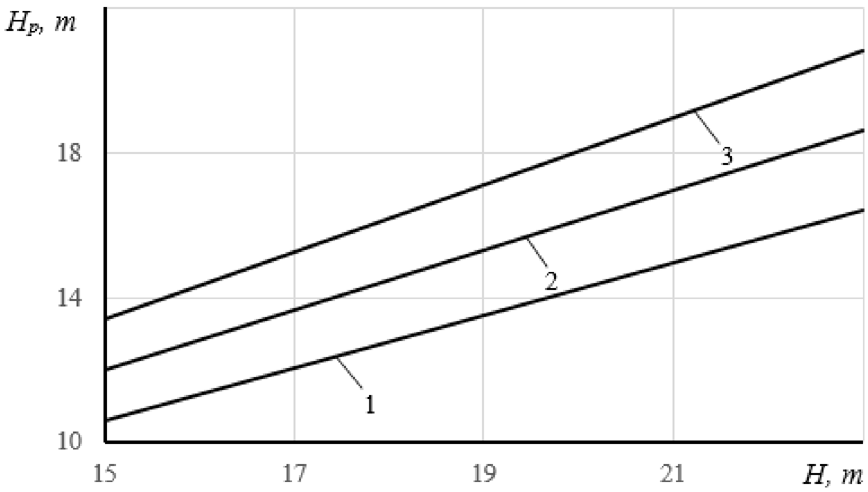

Figure 1 – The graphic dependence H_p from H: 1 – at 0,7H; 2 – at 0,8H; 3 – at 0,9H

In general, with increasing H value H_p increase from 10,5 to 13,5 m (at H_0 = 15 m), from 11,9 to 15,3 m (at H = 17 m), from 14,7 to 18,9 m (at H = 21 m) and from 16,1 to 20, 7 m (at H = 23 m). From the analysis of these data shows that H_p rock mass for these models of excavators does not exceed *H* and H_{ch}. However taking into account the schemes of explosion, directed breaking and other blasting operations parameters the value H_p can change significantly.

Value H_p affect the value of stope blasting *A*. In formula (6) taken into account, except *H*, value K_p, *A* and ΔB_p. On the Fig.2 shows the graphic dependences $H_p = f(H, A)$, built on the results of the calculation of the following parameters: $H = 15$ m, $K_p = 1{,}2$; $A = 20$ m; $\Delta B_p = 25$ m. With increasing *H* from 15 to 23 m the value H_p also increases from 10,8 to 19,9 m (dependence 1). Thus H_p does not exceed (0,8 – 0,9)*H*, that fully satisfies the regulatory requirements for this process.

With increasing *A* from 10 to 30 m value H_p increases from 7,2 to 12,8 m (dependence 2). Value *A* adopted, starting from the condition: $W = b = 5$ m (where *b* – the distance between rows of charges, m: 10 m – 2 series, 15 m – 3, 20 m – 4, 25 – 5, 30 m – 6 series).

Obtained value H_p by the formula (6) also satisfy designs of excavators type mehlopata on condition of compliance H_{ch} the value of this parameter.

With the increase of the specific consumption BB from 0,8 to 1,2*N* kg/m^3, according to the formula (9), when $H = 15$ m and $N = 5$, value H_p decrease from 12,5 to 11 m. Given circumstances indicate that, that a decrease H_p with increasing q associated with an increased impact of the explosion energy at the ruined rock mass due to of this indicator, and hence, and increased range of garbage rock mass slope of the ledge. For this reason, there is an increased width and camber rock mass. Thus large width of camber caused by irrational parameters of blasting operations. In general, this parameter varies between 20 – 60 m [9].

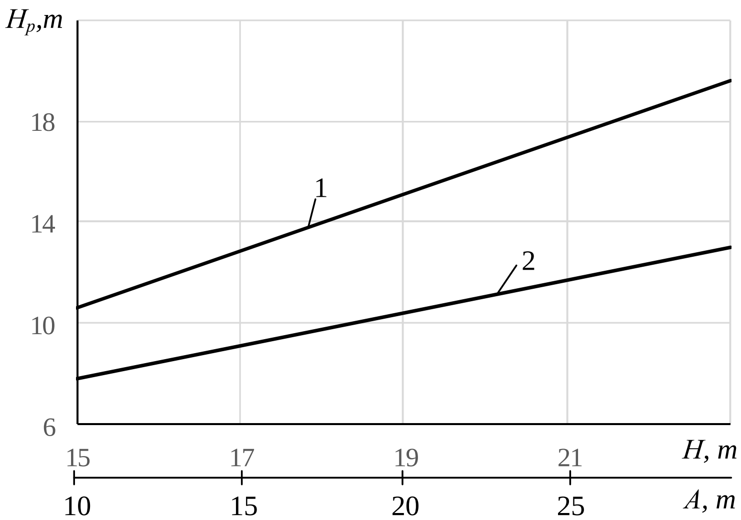

Figure 2 – The graphic dependence the changes H_p from *H*(1) and *H*(2)

Executed calculations by the formulas, given above, show that B_p takes the following value: by (1) – 32 m; by (2) – 45 m and by (4) – 57 m. In the calculations accepted: $n = 5$; $b = 5$ m; $B_0 = 30$ m; $K_з$ (at $t_з = 25$ ms) = 0,90.

In determining the B_p depending on the orientation of the front breaking rock mass charges ES with respect to the free surface of the ledge by the formulas (5), (7) and (8) conflicting results are obtained (Fig. 3).

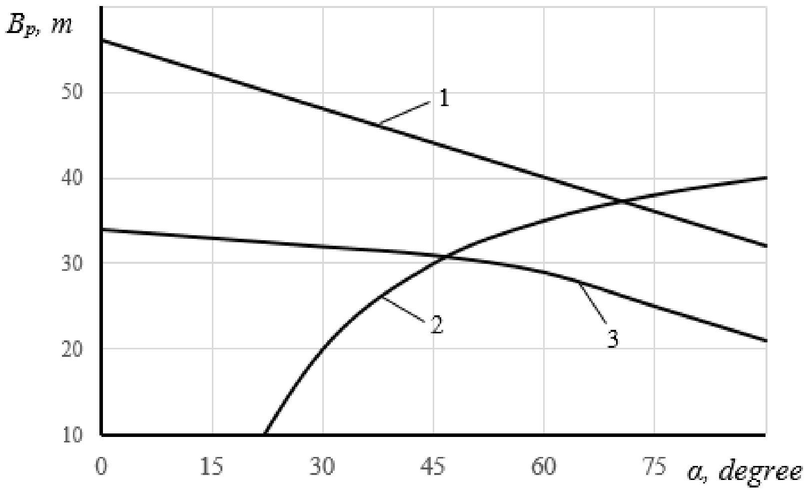

Figure 3 – The graphic dependence the changes B_p on the angle of orientation of the front breaking the free surface of ledge $\alpha_{f.u}$: 1 – by the formula (5); 2 – by the formula (7); 3 – by the formula (8)

According to (5) with increasing $\alpha_{f.u}$ from 0 to 90° the value B_p decreases from 50,8 to 29,2 m (dependence 1), and the formula (7) – increases from 10 to 40 m (dependence 2). The discrepancy between the results observed in $\alpha_{f.u}$ = from 0° to 50°, and at $\alpha_{f.u}$ = 50–90° the value B_p has approximately the same value. Similarly, depending 1 value changes B_p, calculated according to the formula (8), that with increasing $\alpha_{f.u}$ decreases from 34,2 to 22,2 m (dependence 3). This fact is obviously explained by some differences in the approach of the authors [4, 6] to the mechanism of explosive destruction.

To obtain rational parameters of camber rock mass, satisfying for normalized indicators constructive model power shovels, necessary to make breaking the rock mass the use of alternate-diagonal schemes of SSDE. With the help of such schemes explosion possible to carry out the direction of breaking charges, oriented with respect to the main systems of vertical cracks occurrence, and not with respect to the line of slope the ledge [10]. This condition can provide a more compact collapse of the rock mass and productivity of excavators in the process of loading in means of transport.

Important factors that affect the range of expansion and collapse of the parameters are schemes SSDE deceleration intervals of 25 ms and the charge structure. To obtain H_p less than H should apply the diagonal ordinal scheme explosion. It should be noted that the use of a downhole charge air spaces increases the range of movement of the rock mass and therefore reduces the amount of H_p in 1,2 – 1,3 times. At the same time, the use of schemes SSDE should take into account the direction of breaking on the main fracture systems. Due to the angle of orientation of the front against fracture systems α_T can be adjusted parameters of the rock mass.

Empirical relationship for evaluating the impact of these factors on the value of H_p, can be represented as follows:

$$H_p = K_C \cdot K_K \cdot \left(\frac{H}{q}\right) \cdot (1{,}3 + 0{,}11 \sin \alpha_T), \tag{9}$$

where K_c – coefficient taking into account the type of scheme used SSDE (K_c = 0,6–0,7);

$K_к$ – coefficient taking into account the design of the charge EW ($K_к$= 0,7–0,8).

On the Fig. 4 shows the dependence $H_p = f(\alpha_m, H)$. In the calculations, the following parameters were used: K_c = 0,7; $K_к$ =0,8; q = 0,8 kg/m^3.

From the analysis of Fig. 4 we can see, that with increasing $\alpha_т$ from 0° to 90° value H_p increases from 13,7 to 14,8 m; at H = 20 m – from 18,2 to 19,7 m; at H = 25 m – from 22,8 to 24,7 m; at H = 30 m – from 27,3 to 29,6 m. In general, for these values of the angle of orientation with respect to the front breaking cracks the rock mass for the cases examined H value H_p increase in 1,1 times.

With increasing q from 0,8 to 1,2 kg/m^3 value H_p reduced. Max H_p observed at q = 0,8 kg/m^3 and the average values for the adopted α_T (0°, 30°, 60°, 90°) equally 14,3 m.

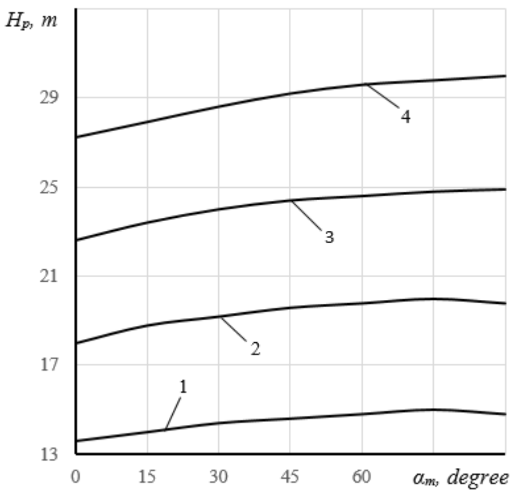

Figure 4 – A graphical representation of changes H_p from α_T at the height of the shoulder H: 1 – 15 m; 2 – 20 m; 3 – 25 m; 4 – 30 m

On average, q = 0,8-1,2 kg/m^3 value H_p decrease with H = 15 and 20 m in 1,5 times.

Value α_T indicates a smaller influence on H_p compared to H. Thus, when q = 0,8 kg/m^3 maximum value H_p depending on $\alpha_т$ increases from 13,7 to 14,8 m, i.e. to 1,1 m. At q = 1,2 kg/m^3 there is a minimum value H_p and varies from 9,1 to 9,9 m with an increase of 0,8 m.

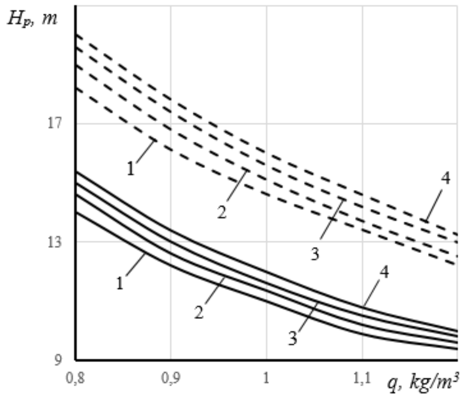

Figure 5 – A graphical representation of changes H_p from q at the height of the ledge H = 15 m (solid line) and H = 20 m (the dotted line) for α_T: 1 – 0°; 2 – 30°; 3 – 60°; 4 – 90°

Change the width of the collapse of the rock mass B_p depending on α_T can be calculated by the following relationship:

$$B_p = \Delta B_p + \left(\frac{H}{q}\right) \cdot (1{,}2 - 0{,}11 \sin \alpha_T), \quad (10)$$

where ΔB_p – the width of the stope blasting to blast blocks of rocks, m.

According to the formula (10) the calculations of changes B_p from α_T for different height of the ledge H. In this $\Delta B_p = W + b(n-1)$, where b – the distance between the rows of hole charges, m; n – the number of rows on charges exploding blocks. In the calculations made: $W = b = 5$ m, n – 5 series. Then $\Delta B_p = 5+5 \cdot 4 = 25$ m. Change B_p from α_T and H shown in the graph Fig. 6, from the analysis which shows that with the increase α_T: from 0° to 90° value B_p decrease in average 1,7-1,8 times. The maximum value of B_p observed at $\alpha_T = 0°$, and the minimum - at $\alpha_T = 90°$. If you change H from 15 to 30 m ($\alpha_т = 0°$) B_p increases from 47,6 to 67 m, i.e. in 1,4 times, and when α_T = 90° – in 1,1 times (from 28,8 to 32,5 m).

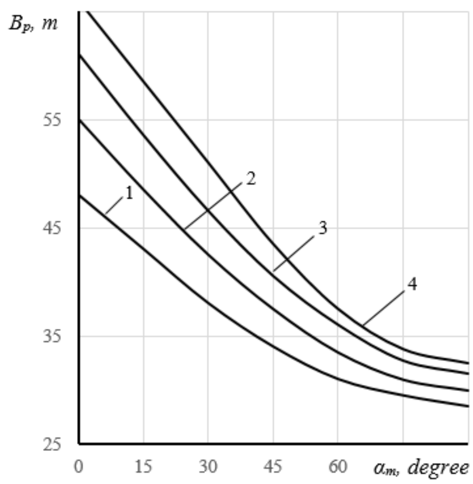

Figure 6 – A graphical representation of changes B_p from α_T at the height of the ledge H: 1 – 15 m; 2 – 20 m; 3 – 25 m; 4 – 30 m

An estimate of the B_p the known and recommended formula is made with the following parameters: H = 15 m; q = 1,2 kg/m^3; ΔB_p = 25 m; F = 9; B_1 = 40 m (table.2).

Table 2 – Comparative evaluation of changes B_p from α_T

Source, formula	Value B_p, m depending on α_T, hail.						
	0	15	30	45	60	75	90
[5], (7)	0	10,4	20,0	28,4	34,8	38,4	40,0
[6], (8)	45,4	45,0	43,1	40,0	37,7	33,6	29,5
(11)	47,6	42,7	38,2	34,2	31,7	29,5	28,8

From the analysis of table 2 see, that with increasing $\alpha_т$ value B_p by the formula (7) increases, and by (8) and (10), conversely, decreases. These results can be obtained in different approaches to the orientation of the front line breaking or direction, as a free surface of the ledge slope, and systems of cracks. Depending on this value B_p may take the opposite values. However, preference should be given an order diagonal patterns SSDE orientation with respect to the direction of the front breaking fracture systems massif. In this case, a minimum value B_p and max H_p, and hence more intense crushing rocks with a minimum of oversized fraction in the collapse of the rock mass.

The dependence $B_p = f\,(\alpha_T)$ confirmed the results of previous studies using geological and diagonal schemes SSDE (table 3).

Table 3 – The results of the experimental data processing massive explosions on the granite quarries

The village - 1				The village - 2			
Horizont, m	The number of explosions	α_T, hail	B_p, m	Horizont, m	The number of explosions	α_T, hail	B_p, m
162	4	30	41-49	183	4	50	31-38
150	5	36	37-42	170	3	67	22-27

An analysis of the data shows that an increase $\alpha_т$ reduces B_p . Within this range an increase α_T from 30 to 67° value B_p decrease in average in 1,8 times.

CONCLUSIONS. Based on the analysis performed to determine the analytical dependences H_p and B_p quantify the changes in these parameters from $\alpha_{f.u}$, H, A and q. However, some consider the impact depending on the orientation of the front line of the slope with respect to breaking the ledge. It is shown that in order to improve the quality of the crushing of the rock mass and achieve a compact its collapse (H_{max} , $B_{p\ min}$) it is appropriate to apply the diagonal decent scheme SSDE with the direction of the front breaking crack rock mass, and not to the free surface of the ledge. This condition is confirmed by the results of experimental explosions in granite quarries.

The calculations give reason to believe that, in the quarries stable supply parameters collapse at working ledges height 15-35 m is quite possible.

REFERENCES

1. Blejman I.L (1972). «Study of the basic parameters of blasting rock of hole charges of explosive waves in the quarries of building materials» Abstract. PhD. tehn. sciences: specialty. 05.312 «Open development and exploitation of coal, ore and non-ore deposits», Frunze, USSR.
2. Afonin V. G., Gejman L.M. and Komir V.M. (1982). «A reference manual for blasting operations in construction» 2nd revised. and. ext. Kiev, USSR.
3. Rzhevskij V.V (1974). *Processy otkritych gornych rabot,* Nedra, Moscow, USSR.
4. Repin N.Y., Bogatyrev V.P., Butkin V.D. and others (1987). «Drilling and blasting operations at coal mines», Nedra, Moscow, USSR.
5. Efremov E.I., Kravcov V.S., Myachina N.I. and others (1987). «Destruction of rocks by explosion energy» , Naukova dumka, Kiev, USSR.
6. F.A. Avdeev, V.L. Baron, N.V. Gurov and V.H. Kantor (1986). «Regulatory reference book on explosives works».5th ed., rev. and add. Nedra, Moscow, USSR.
7. Melnikov N.V. (1982). «Short Guide to open cast mining». 4th ed., rev. and add. Nedra, Moscow, USSR.
8. Xoxryakov V.S (1991). «Open pit mining of minerals». A textbook for technicums.5th ed., rev. and add. Nedra, Moscow, USSR.
9. I.V. Klevcov and P.I. Fedorenko (1981) *Skhemy vzryvaniya na kar'yerakh i kachestvo drobleniya gornoy massy* /«Scheme blasting in quarries and crushing the rock mass quality» .Tekchnika, Kiev, USSR.
10. Tverdaya O.Y. and V.D. Vorobev (2014) «Improving the quality of crushing fractured rock through optimal amended by breaking hole charges» *Up-to-date re-sourse- and energy- saving technologies in mining industry. Science. magazine.* Edition. 2/2014(14), pp. 13-24.
11. Research and development of rational methods of blasting to ensure rational parameters of the collapse of the rock mass while maintaining the quality of crushing and seismic stability of industrial and civil objects: Research report (final)/ Institute of Geophysics named. S.I. Subbotina AN USRR. № GR 01.8.80|051824; Inv. № 02.8.90|061773. – K., 1989. – 191 p.

ВЗАИМОСВЯЗЬ ПАРАМЕТРОВ РАЗВАЛА ГОРНОЙ МАССЫ С НАПРАВЛЕНИЕМ ОТБОЙКИ ПРИ ВЗРЫВНОЙ ОТРАБОТКЕ ВЫСОКИХ УСТУПОВ НА КАРЬЕРАХ

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По результатам анализа известных аналитических зависимостей по определению высоты и ширины развала горной массы при взрывной отработке уступов высотой 15-25 м дана количественная оценка этих показателей в зависимости от основных параметров взрыва. Обоснованы рекомендации по

ориентировке фронта отбойки при КЗВ относительно не к свободной поверхности уступа, а к основным системам трещин.

Ключевые слова: взрыв, карьер, схема взрывания, трещиноватость, фронт отбойки, уступ.

ЛИТЕРАТУРА

1. Блейман И.Л. Исследование основных параметров взрывной отбойки породы скважинными зарядами ВВ на карьерах строительных материалов: автореф. на соиск. уч. степени канд. техн. наук: спец. 05.312 «Открытая разработка и эксплуатация угольных, рудных и нерудных месторождений» / И.Л. Блейман. – Фрунзе, 1972. – 28 с.

2. Афонин В.Г. Справочное пособие по взрывным работам в строительстве/ Афонин В.Г., Гейман Л.М., Комир В.М. Изд. 2-е перераб. и доп. – К.: Будівельник, 1982. – 176 с.

3. Ржевский В.В. ґпроцессы открытых горнах работ / Ржевский В.В. – М.: Недра, 1974. – 520 с.

4. Буровзрывные работы на угольных разрезах / [Репин Н.Я., Богатырев В.П., Буткин В.Д. и др.]; под общ.ред. Н.Я. Репина. – М.: Недра, 1987. – 254 с.

5. Разрушение горных пород энергией взрыва / [Ефремов Э.И., Кравцов В.С., Мячина Н.И. и др.]; под ред. И.Э. Ефремова. – К.: Наукова думка, 1987. – 264 с.

6. Нормативный справочник по буровзрывным работам / Ф.А. Авдеев, В.Л. Барон, Н.В. Гуров, В.Х. Кантор: 5-е изд., перераб. и доп. – М.: Недра, 1986. – 511 с.

7. Мельников Н.В. Краткий справочник по открытым горным работам / Мельников Н.В.; 4-е изд., перераб. и доп. – М.: Недра, 1982. – 414 с.

8. Хохряков В.С. Открытая разработка месторождений полезных ископаемых / Хохряков В.С.: Учеб.для техникумов. – 5-е изд., перераб. и доп. - М.: Недра, 1991. – 336 с.

9. Клевцов И.В. Схемы взрывания на карьерах и качество дробления горной массы / И.В. Клевцов, П.И. Федоренко. – К.: Техника, 1981. – 104 с.

10.Твердая О.Я. Повышение качества дробления трещиноватых скальных пород за счет оптимального поправления отбойки скважинными зарядами / О.Я. Твердая, В.Д. Воробьев // Сучасні ресурсозберігаючі технології гірничого виробництва. Наук.-виробн. журнал. – 2014. – Вип. 2/2014(14). – С.13–24.

11.Исследование и разработка рациональных методов взрывных работ для обеспечения рациональных параметров развала горной массы с сохранением качества дробления и сейсмостойкости промышленных и гражданских объектов: Отчет о НИР (заключительный)/ Ин-т геофизики им. СИ. Субботина АН УССР. №ГР01.8.80|051824; Инв. № 02.8.90|061773. – К., 1989. – 191 с.

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