STUDY ON THE REASONABLE SPACING OF FLAT CHARGE IN THE FORM OF LONG AND PARALLEL CYLINDRICAL CHARGES FOR BREAKING ROCK

Trong Thang Dam[1,*], Tri Ta Nguyen[1], Xuan Bang Vu[2]

[1]*Le Quy Don Technical University*

[2]*Institute of Technical Engineering*

Abstract

In practice, the flat charge is often used in the form of a group of long cylindrical charge set parallel and equidistant from each other and lying in the same plane. However, until now, the theory of the rock-destroying effect of flat charge has only mentioned flat charge as a flat plate explosive. Therefore, on the basis of the hydrodynamic theory of the destructive effect of a single charge, we have established a computational model, built a calculation program based on the Matlab programming language. Surveys of the explosive energy field of a group of long cylindrical charge set parallel and lying in the same plane were carried out when the relative distance parameter between the charges was changed. The results have shown that the reasonable range of the relative distance parameter between the corresponding charges receives the best destruction performance and also depends on the rock characteristics. The more stable the rock is, the smaller the reasonable distance between the long cylindrical charges is, and vice versa. The reasonable distance between long cylindrical charges is 10 to 15 times the blasting hole diameter when blasting in an endless rocky environment and 23 to 27 times the blasting hole diameter when smoldered blasting in claystone in water.

Keywords: *Explosion; flat charge; rock blasting; effectiveness of explosion.*

1. Introduction

Studies in several countries have shown that, when the flat charge is detonated, the effective explosive factor is greater than that of the concentrated charge and the long cylindrical charge [1-9]. The perfect flat charge is one of the fixed thickness and the size of the two sides of the charge is much larger than the thickness of the charge [1, 10-12]. This type of absolute flat charge is difficult to create holes that contain explosives in rock, so it is only reasonable to apply in conditions where the explosives are not buried in the rocky environment, such as stamping, welding, and compaction of soil and rock. In order to apply the effect of flat charges, in practice when detonating in the general soil and rock environment, flat charges are designed from a group of long cylindrical charges placed in the borehole, parallel to each other and lying on the same

[*] Email: thangdt@lqdtu.edu.vn
https://doi.org/10.56651/lqdtu.jst.v4.n02.343.sce

plane [4, 5, 7, 9, 13-16]. In this case, it can be called a flat-shaped charge. Flat-shaped charges are widely and effectively used in directional blasting to move soil and rock for construction and mining. However, until now, reasonable parameters of flat-shaped charges have only been mentioned in directional explosion designs in order to achieve efficient when moving rock [4, 9, 13]. The reasonable parameters of flat-shaped charges to achieve destructive or fragmenting efficiency have not been comprehensively studied in underground explosion conditions. Therefore, it is necessary to study and analyze the relationship between the distance parameter between the long cylindrical charges of the flat-shaped charges to the explosive energy field (EEF) or the explosive wave field (EWF) and the volume of the explosive destruction zone, to derive the interval of reasonable values of the distance between long cylindrical charges to obtain high destruction efficiency.

2. Theoretical basis of the explosive energy field in rocky environment

2.1. O.E. Vlasov's the hydrodynamic theory of explosion on the explosive energy field of the single charge in the rocky environment

According to the hydrodynamic theory of explosion, when detonating in rocky environment, the amount of explosive after detonation will transform the explosive from the initial state to the gaseous state with an extremely pressure from tens to thousands of times higher than the compressive strength of rock, while the temperature suddenly increases up to several thousand degrees Celsius, causing the rock to be strongly and suddenly compressed, and the explosive effect on the rock is similar to the explosive effect in the incompressible liquid environment. The difference is that the liquid has a strength corresponding to the type of rock. Based on this opinion, O.E. Vlasov gave the boundary condition of the problem as follows [4]:

- The environment of rock and soil is continuous, incompressible and homogeneous;

- Explosion effect is carried out immediately;

- EEF or EWF of explosive types is a dynamic ellipsoid.

In 1957, O.E. Vlasov found the general equation describing the shape of charge and its EWF development shape in the form of a family of ellipsoids with the same focal point as follows [4]:

$$\frac{x^2}{a^2+\lambda}+\frac{y^2}{b^2+\lambda}+\frac{z^2}{c^2+\lambda}=1 \tag{1}$$

where a, b, c are the semi-axes of the charge, centered at the origin O; λ has the value: $0 \le \lambda \le \infty$.

When $\lambda = 0$, then equation (1) is the equation of the surface of charge, which is also the explosive iso-energetic surface at the wall of the blasthole. When the semi-axis $a=b=c$, equation (1) becomes the equation describing the spherical charge. When $a=b$ and c is very large, then equation (1) becomes the equation describing the cylindrical charge with c axis. When c is very small and a and b are very large, then equation (1) becomes the equation describing the flat-shaped charge. When λ is greater than 0, this is the iso-energetic surface description of that charge. From equation (1), it is easy to see that when λ is much larger than the size of the charge, this equation becomes the equation of the spherical explosive wave.

O.E. Vlasov established the velocity potential φ of a single charge in the form of a circular ellipsoid with the semi-axes a, b, c and in the case of long cylindrical charge ($a = c$) the function φ is equal to [10, 12]:

$$\varphi = \frac{2A}{\sqrt{b^2-a^2}} \ln \frac{\sqrt{b^2+\lambda} + \sqrt{b^2-a^2}}{\sqrt{a^2+\lambda}} \tag{2}$$

where A is a constant determined by the formula: $A = \sqrt{\dfrac{E\sqrt{b^2-a^2}}{8\pi\rho \ln\left(\dfrac{b+\sqrt{b^2-a^2}}{a}\right)}}$

E is energy of the explosive; λ has the value $0 \le \lambda \le \infty$, each value of λ corresponds to an ellipsoid equipotential surface with the same focal point as the equation for the surface of the charge.

The symbol V is the velocity of an environmental element and u, v, w are the velocity of the environmental element in the x, y, z directions, then they are determined as follows [4]:

$$u = -\frac{\partial \varphi}{\partial x};\ v = -\frac{\partial \varphi}{\partial y};\ z = -\frac{\partial \varphi}{\partial z} \tag{3}$$

Knowing the velocity potential, we can calculate the kinetic energy of the environment, which transfers energy into the environment. Therefore, the energy density of the environment at point M (x, y, z) is [4]:

$$E_d = \frac{\rho V^2}{2}; \quad \text{or} \quad E_d = \frac{\rho}{2}\left[\left(\frac{\partial \varphi}{\partial x}\right)^2 + \left(\frac{\partial \varphi}{\partial y}\right)^2 + \left(\frac{\partial \varphi}{\partial z}\right)^2\right] \tag{4}$$

2.2. Setting the explosive energy field of the parallel long cylindrical charge group

Consider a group of long cylindrical charge Ni ($i = 0 \div n$) in the form of a circular ellipsoid with semi-axes a, b, c ($a = c, b >> a$) placed parallel and equidistant from each other at a distance l_a in an environment with an environmental density is ρ, where O is the origin of the Cartesian coordinates Oxyz. Consider any point M in the environment with coordinates (x,y,z) and its projection on the Oxz plane as shown in Fig. 1.

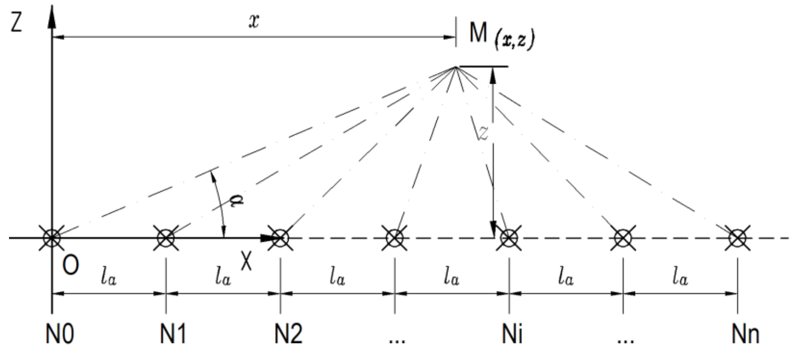

Fig. 1. Model of a group of long cylindrical charges N_i and projection of point M.

The velocity potential at point M caused by the charge Ni is calculated by the following formula:

$$\varphi_{M_i} = \sqrt{\frac{E}{2\pi\rho.\sqrt{b^2-a^2}.\ln\left(\frac{b+\sqrt{b^2-a^2}}{a}\right)}}.\ln\frac{\sqrt{b^2+\lambda_i}+\sqrt{b^2-a^2}}{\sqrt{a^2+\lambda_i}} \tag{5}$$

where λ_i is satisfied the following condition:

$$\frac{\left(x-i.l_a\right)^2+z^2}{a^2+\lambda_i}+\frac{y^2}{b^2+\lambda_i}=1;\ i=0\div n \tag{6}$$

In order to determine the environmental energy density caused by a group of long cylindrical charges at a point, it is necessary to determine the combined velocity potential of all the charges induced at that point. The symbol Φ is the combined velocity potential caused by all charges N_i, calculated as follows:

$$\Phi = \sum_{i=0}^{n}\varphi_i \tag{7}$$

The environmental energy density at a point caused by all the long cylindrical charges is calculated as follows:

$$E_d = \frac{\rho}{2}\left[\left(\frac{\partial\Phi}{\partial x}\right)^2+\left(\frac{\partial\Phi}{\partial y}\right)^2+\left(\frac{\partial\Phi}{\partial z}\right)^2\right] \tag{8}$$

Determining the explosive energy field in the environment by direct calculation according to the expression is very complicated, so it is necessary to build a calculation program to survey and analyze for research.

3. Building a computer program to calculate and survey by numerical method

3.1. Program description

Based on the established formulas, using Matlab programming language, the author has built a calculation program for research, application calculation, survey of velocity potential and explosive energy field of the parallel long cylindrical charge group in the same plane.

The input data for calculation include: parameters of charges, number of charges, distance between charges, density of environment.

The output data include: environmental energy density at the survey site, explosive energy distribution field.

When determining the energy density at the survey site, based on the critical energy level at which the environment is destroyed, we can determine the area of the environment that is likely to be destroyed.

3.2. Input data for the survey

In order to study the effect of the relative distance parameter between charges on the rock destruction area, use the program created to conduct a survey of the damage area with the following data:

Type of rock to survey: Survey in an infinite environment with three different types of rock with density: 150 kG.s^2/m^4 (Type 1: soft rock, easy to break); 230 kG.s^2/m^4 (Type 2: medium hardness rock, normal smash) and 280 kG.s^2/m^4 (Type 3: hard rock, hard to break);

Explosive type: Emulsion explosives TNP-1E, with an average density of explosives: 1150 kg/m^3;

The diameter of charge to survey: d = 0.032 m and d = 0.06 m;

The broken volume is calculated for 1 m of the length of the destroyed area, along the length of the charge, according to the following formula:

$$V_{ph} = S_{ph}.l_{ph} \text{ , (m}^3\text{)}$$

where S_{ph} is cross-sectional area of the destroyed area (m^2). Because the charge is very long, for convenience of calculation, we take the area at the cross section y = 0; l_{ph} is the length of the destroyed area, taken as 1 m.

The survey was carried out with a flat-shaped charge which is a group of 15 long cylindrical charges lying parallel in the same plane, equidistant from each other at a distance l_a, the long cylindrical charge is considered to be a circular ellipsoid of 2 types with semi-axes as follows: $a = c = 0.016$ m, $b = 5$ m and $a = c = 0.03$ m, $b = 5$ m.

To calculate the critical energy level at which the environment is likely to be destroyed (symbol is E_{th}), based on the powder factor of smoldered blasting corresponding to that type of rock [1, 17], the critical energy can be calculated as:

The density of the environment ρ = 150 kG.s^2/m^4, q_o = 0.3 kg/m^3:

$$E_{th-1} = q_o * E_0 = 0.3*427*1000 = 128100 \ (\text{kG/m}^2)$$

The density of the environment ρ = 230 kG.s^2/m^4, q_o = 0.4 kg/m^3:

$$E_{th-2} = q_o * E_0 = 0.4*427*1000 = 170800 \ (\text{kG/m}^2)$$

The density of the environment ρ = 280 kG.s^2/m^4, q_o = 0.6 kg/m^3:

$$E_{th-3} = q_o * E_0 = 0.6*427*1000 = 256200 \ (\text{kG/m}^2)$$

where q_o is powder factor of smoldered blasting; E_0 is the specific energy of the explosive.

3.3. Survey results by numerical method

Based on the calculation program and data set, the results of the survey are presented in Tables 1 and 2 as follows:

Table 1. The dependence of the broken volume on the relative spacing ratio l_a/d for the charge d = 0.032 m

E_{th-1}	l_a/d	1	10	13	14	15	17	20	25	30	35
	V_{ph} (m^3)	1.75	2.69	2.92	2.95	2.93	2.82	2.58	2.10	1.99	1.92
E_{th-2}	l_a/d	1	10	11	12	13	14	15	20	25	35
	V_{ph} (m^3)	1.33	2.26	2.28	2.34	2.25	2.23	2.17	1.73	1.50	1.45
E_{th-3}	l_a/d	1	5	9	10	11	13	15	20	25	35
	V_{ph} (m^3)	0.90	1.17	1.57	1.60	1.53	1.43	1.34	1.05	0.96	0.91

Table 2. The dependence of the broken volume on the relative spacing ratio l_a/d for the charge d = 0.06 m

E_{th-1}	l_a/d	1	10	14	15	16	20	25	30	35	
	V_{ph} (m^3)	6.44	9.58	10.26	10.29	10.09	8.79	7.46	7.12	7.04	
E_{th-2}	l_a/d	1	10	12	13	14	15	17	20	25	35
	V_{ph} (m^3)	4.94	7.47	7.80	8.06	7.79	7.62	7.06	5.82	5.55	5.27
E_{th-3}	l_a/d	1	5	9	10	11	13	15	20	25	35
	V_{ph} (m^3)	3.40	4.26	5.52	5.56	5.49	5.22	4.62	3.86	3.66	3.56

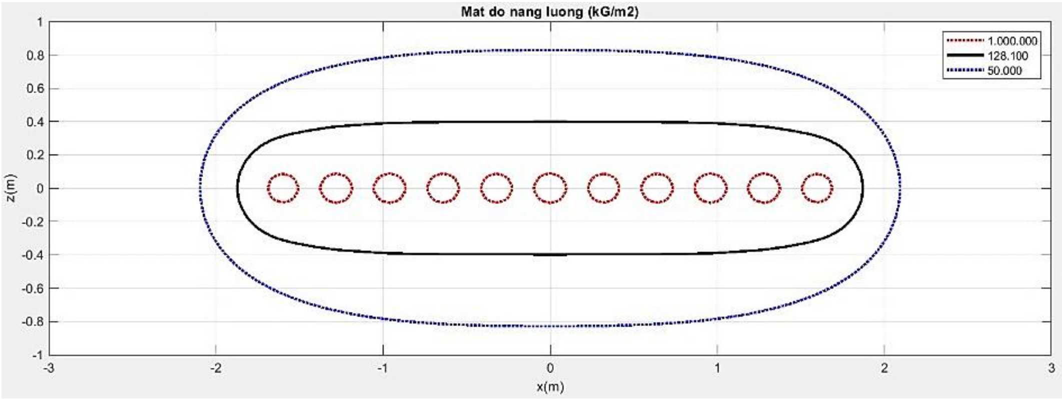

Fig. 2. Cross-section of the destroyed area of the flat-shaped charge when l=10d (ρ = 150 kG.s^2/m^4, d = 0.032 m).

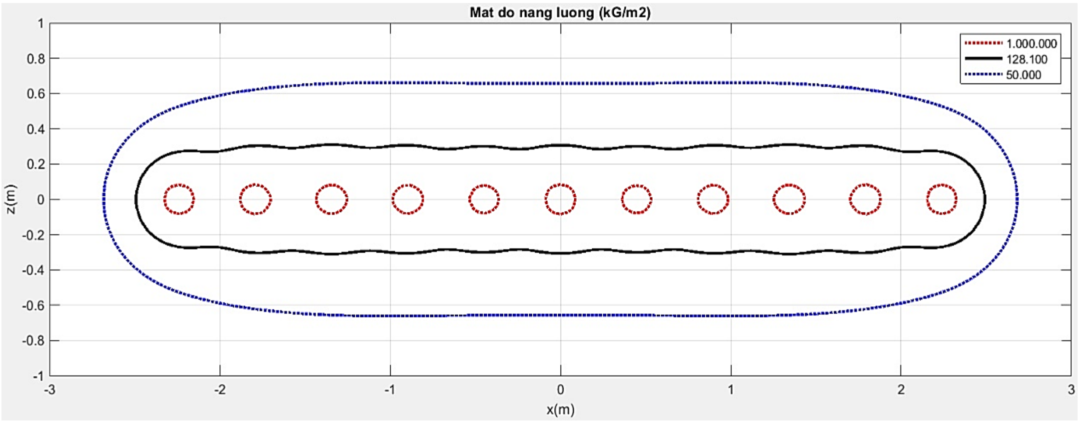

Fig. 3. Cross-section of the destroyed area of the flat-shaped charge when l=14d (ρ = 150 kG.s^2/m^4, d = 0.032 m).

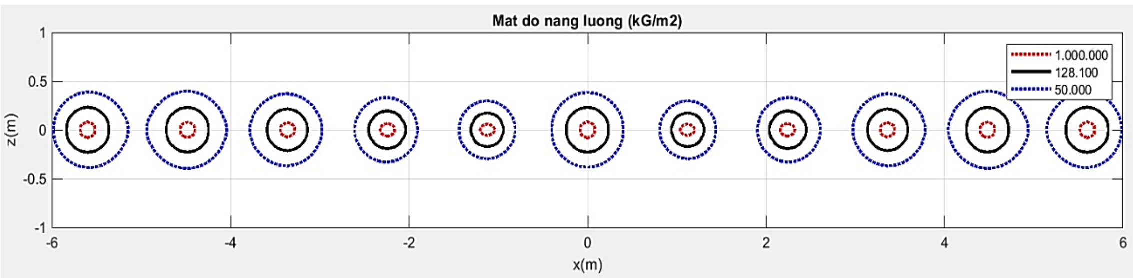

Fig. 4. Cross-section of the destroyed area of the flat-shaped charge when l=35d (ρ = 150 kG.s^2/m^4, d = 0.032 m).

From the two data tables in Table 1 and Table 2, we can build a graph of the influence of the relative spacing l_a/d to the destroyed area with different types of rock.

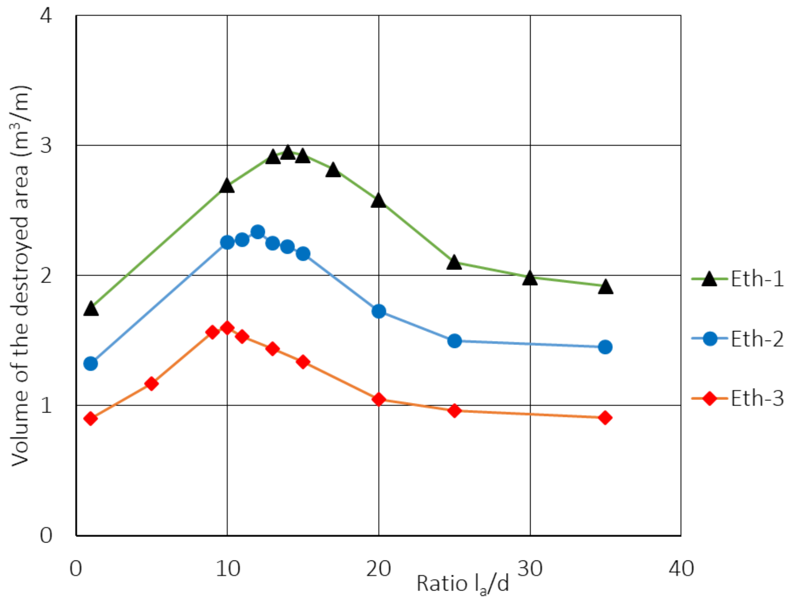

Fig. 5. The effect of the relative distance ratio l_a/d to the destroyed area with the charge d = 0.032 m.

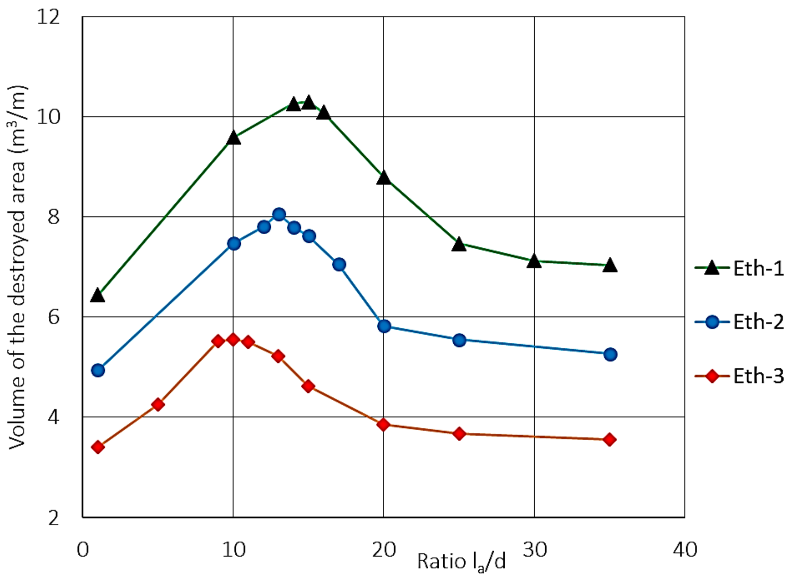

Fig. 6. The effect of the relative distance ratio l_a/d to the destroyed area with the charge d = 0.06 m.

Discussion:

The analysis of Fig. 5 and Fig. 6 shows that, as the spacing between the charges in the group increases from 1*d* (the charges are closely spaced), the broken volume also increases to a certain value where the broken volume reaches its maximum value, then the spacing between the charges continues to increase, the broken volume will decrease and reach a constant value. The broken volume attains a constant value when the spacing between the charges in the group reaches the value at which the charges act as independent long cylindrical charges. Fig. 2 shows the destroyed area when the charges in the group interact with each other, similar to the case of flat charges, so the plane of the boundary of the destroyed area is an isoenergy plane, it has the shape as a flat surface. Fig. 3 shows the maximum value of the destroyed area, the single charges in the group interact with each other, it is just enough to form a flat-shaped destroyed area. In the Fig. 3, we can see that the boundary of the destroyed area of each charge starts to shrink. The destroyed area shown in Fig. 4 is caused by single charges, they are separated from each other, even though the spacing between the charges is increased, the destroyed area does not change.

4. Field experiment

4.1. Experimental model

Experiments were carried out on claystone (grade IV) in the area of Dai Xuyen commune - Van Don district - Quang Ninh province. Tides range from 0 to 4 m. Drill hole diameter of 0.042 m, drilling depth of 2.5 m, stemming depth of 0.5 m, charge length in borehole of 2 m, and 11 holes drilled in a row. The explosive used in the experiment is emulsion explosive TNP-1E, detonated by a non-electrical detonator. Detonating device is a non-electrical igniter. Each experiments is carried out 2-3 times. Blasting parameters used in the experiment are described in Table 3 and Fig. 7.

Table 3. Arrange explosives corresponding to each experiment

No.	Experiment code	Number of holes drilled in a row, hole	Spacing between drill holes, l_a, m	Mass of explosives in hole, kg	Total explosive quantity, kg
1	TN1 (15d)	11	0.48	1.8	19.8
2	TN2 (20d)	11	0.64	1.8	19.8
3	TN3 (25d)	11	0.80	1.8	19.8
4	TN4 (30d)	11	0.96	1.8	19.8
5	TN5 (35d)	11	1.12	1.8	19.8
6	TN6 (40d)	11	1.28	1.8	19.8

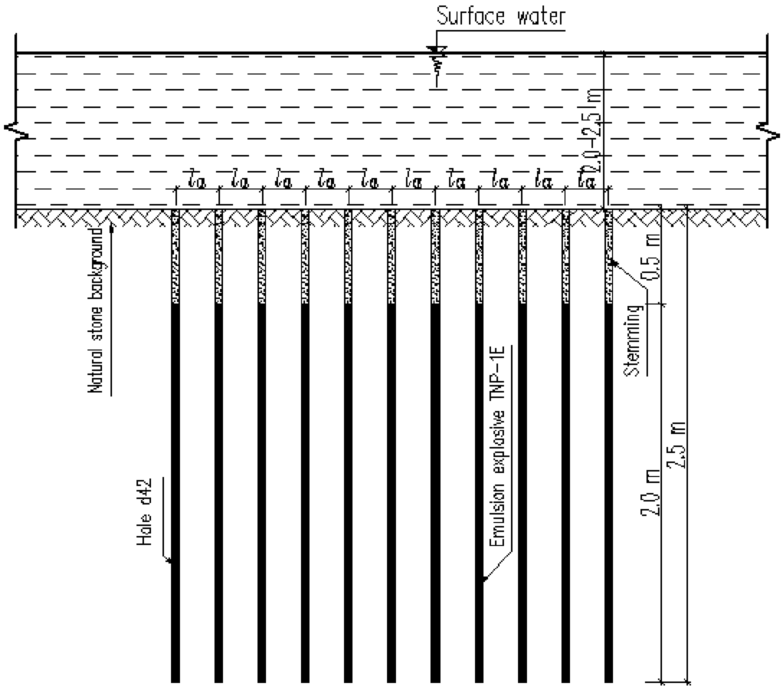

Fig. 7. Experimental model using flat charges to break rocks.

Fig. 8. Pictures of test blasts in the sea of Van Don district.

4.2. Measurement method to get data

The broken volume is measured by field mapping with the help of excavator, manual, tapered and metric rulers.

4.3. Results and analysis of experimental results on the influence of the spacing between the charges on the broken volume and the specific consumption of explosives

The experimental results are shown in Table 4 and Fig. 9, Fig. 10.

Table 4. Experimental results of explosion in claystone

No.	The relative spacing between drill holes	Spacing between drill holes, m	Average depth of excavation, m	Average width of excavation, m	Average length of excavation, m	Volume of excavation, V, m^3	Specific consumption of explosives, q, kg/m^3
1	l_a=15d	0.48	2.3	1.35	5.48	11.54	1.72
2	l_a=15d	0.48	2.37	1.35	5.48	11.89	1.67
3	l_a=15d	0.48	2.32	1.35	5.48	11.64	1.70
4	l_a=20d	0.64	2.22	1.74	7.27	24.46	0.81
5	l_a=20d	0.64	2.32	1.74	7.27	25.56	0.77
6	l_a=20d	0.64	2.24	1.74	7.27	24.68	0.80
7	l_a=25d	0.8	2.23	1.82	8.91	32.91	0.60
8	l_a=25d	0.8	2.19	1.81	8.91	31.95	0.62
9	l_a=25d	0.8	2.2	1.79	8.89	31.28	0.63
10	l_a=30d	0.96	2.15	1.62	10.41	29.52	0.67
11	l_a=30d	0.96	2.22	1.59	10.39	29.02	0.68
12	l_a=35d	1.12	2.16	1.46	11.93	27.46	0.72
13	l_a=35d	1.12	2.21	1.43	11.92	27.00	0.73
14	l_a=40d	1.28	2.1	1.29	13.44	23.42	0.85
15	l_a=40d	1.28	2.1	1.23	13.41	21.17	0.94

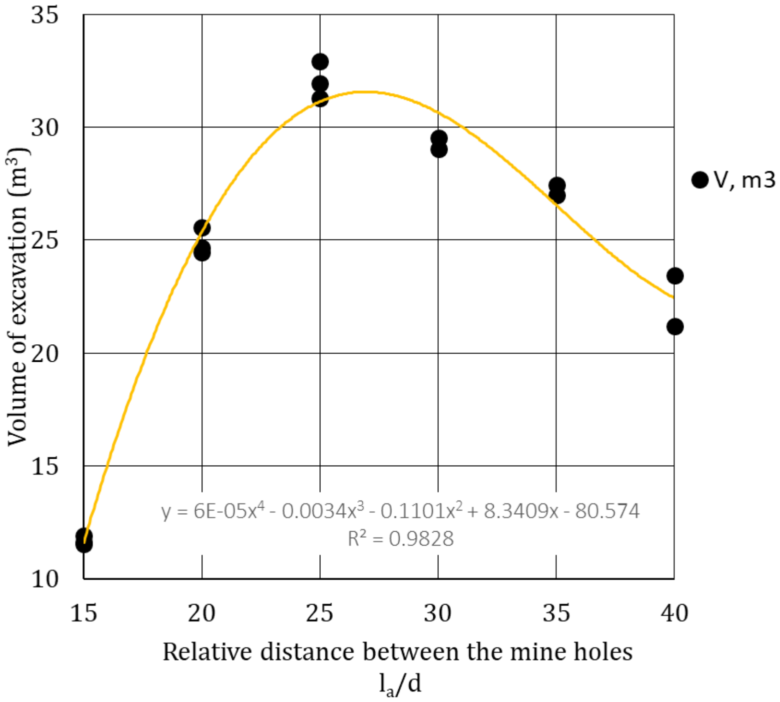

Fig. 9. The dependence of the broken volume on the relative spacing between the blastholes.

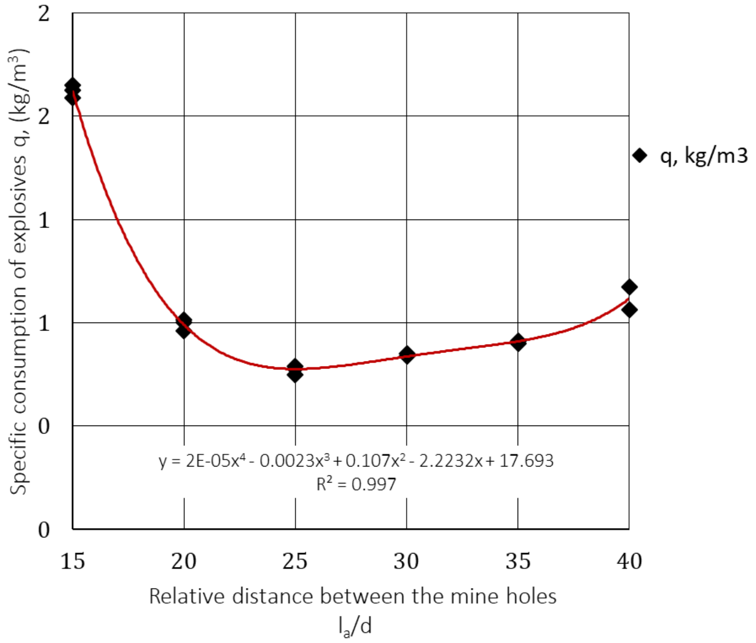

Fig. 10. The dependence of the specific consumption of explosives on the relative spacing between the blastholes.

Using Excel software to analyze experimental data in Table 4, it is possible to obtain the experimental dependence of the broken volume (V_p) and the specific consumption of explosives (q) on the relative spacing between the blastholes (l_a/d), with the test conditions in grade IV claystone of the following form:

$$V_p = 0.00006\left(\frac{l_a}{d}\right)^4 - 0.0034\left(\frac{l_a}{d}\right)^3 + 0.1101\left(\frac{l_a}{d}\right)^2 + 8.3409\frac{l_a}{d} - 80.574\,,\, R^2 = 0.983 \quad (9)$$

$$q = 0.00002\left(\frac{l_a}{d}\right)^4 - 0.0023\left(\frac{l_a}{d}\right)^3 + 0.107\left(\frac{l_a}{d}\right)^2 - 2.2232\frac{l_a}{d} + 17.693\,,\, R^2 = 0.998 \quad (10)$$

Analysis of the results in Table 4, Fig. 9 and Fig. 10 shows that, when changing the relative spacing between blastholes from 15*d* to 40*d*, the broken volume increases gradually to the maximum value in the range (23- 27)*d* and then if the spacing between the blastholes continues to increase, the broken volume decreases gradually. On the other hand, when changing the relative spacing between blastholes from 15*d* to 40*d*, the specific consumption of explosives decreases to a minimum value also in the range of (23-27)*d* and then if the spacing between the blastholes continues to increase, the specific consumption of explosives continues to increase. The characteristic curve found by the experiment is relatively consistent with the theoretical characteristic found above.

5. Results and discussions

The results of research and survey of the influence of the spacing parameter between long cylindrical charges of the flat-shaped charge on the efficiency of breaking rock in an endless environment by theoretical methods (numerical survey) and field experiment allows to draw the following observations:

When the distance between the long cylindrical charges gradually increases from very close to each other (closely) to the critical spacing value, the broken volume gradually increases and reaches a maximum value, then if the spacing between the long cylindrical charges continues to increase, the broken volume will gradually decrease. A reasonable value of the spacing between the long cylindrical charges is obtained when the broken volume reaches its maximum value. Theoretical research results by numerical method allow to realize that the reasonable spacing between the long cylindrical charges will correspond to the appearance of the critical explosive energy region that breaking rocks in flat form.

According to the numerical survey results (see Fig. 5, Fig. 6), the reasonable spacing between the long cylindrical charges to achieve the largest broken volume ranges from 8 to 18 times the diameter of charge. The softer the rock is, the greater the reasonable distance is, and vice versa. The claystone in the field experiment is approximated as corresponding to the rock type 1 in the numerical experiment. The value of reasonable distance between the long cylindrical charges in claystone obtained from field experiments is larger than the theoretical value (corresponding to 15 -18 times the diameter of charge). This is explained by the fact that the density of the water is less than the density of the rock, so when an underground explosion breaks claystone underwater, the destruction effect is greater than when an underground explosion occurs in the endless claystone environment.

6. Conclusion and recommendation

On the basis of theoretical and experimental research, we have some comments as follows:

When detonating flat charge in the form of long cylindrical charge groups placed parallel in the same plane, the reasonable value of the spacing parameter between the blastholes is proportional to the diameter of the blasthole and depends on the type of rock. The larger the hole diameter is, the more stable the rock type is, the smaller the distance between the drill holes is, and vice versa;

When the spacing between blastholes is arranged reasonably, the destruction efficiency is the highest and the level of rock fragmentation is the greatest;

When blasting in claystone (grade IV) in water, the broken volume reaches the maximum value and the specific consumption of explosives reaches the minimum value in the range of the spacing between charges in the range (23-27) times of the blasthole diameter.

***Recommendation*:** In order to improve blasting efficiency when using flat charges, it is necessary to select and control the drilling and blasting reports to ensure that the relative spacing between two adjacent blastholes is within a reasonable range to obtain the broken volume is the largest and the average size of the broken rock is the smallest.

References

[1] Hồ Sĩ Giao, Đàm Trọng Thắng, Lê Văn Quyển, Hoàng Tuấn Chung, "Nổ hóa học lý thuyết và thực tiễn", *Nxb Khoa học và Kỹ thuật*, Hà Nội, 2010.

[2] Đàm Trọng Thắng, Nguyễn Trí Tá, Vũ Xuân Bảng, "Nghiên cứu ảnh hưởng của hình dạng lượng nổ đến mức độ đập vỡ đất đá bằng phương pháp thực nghiệm", *Tạp chí Khoa học và Kỹ thuật*, ISSN 1859-0209, Học viện Kỹ thuật quân sự, 2018.

[3] Nguyễn Xuân Kiều, Đàm Trọng Thắng, "Đánh giá ảnh hưởng của lớp nước đến mức độ phá huỷ đất đá bằng sóng phản xạ khi nổ mìn phá đá dưới nước", *Tạp chí Công nghiệp Mỏ*, số 2, tháng 7/2013, 2013.

[4] Власов О.Е., "Основы терии действия взрыва", *ВИА*, Москва, 1957.

[5] Александр Анатольевич Черниговский, "Метод плоских систем зарядов в горном деле и строительстве", *Недра*, Москва, 243 с, 1971.

[6] Кутузов Б.Н., "Методы ведения взрывных работ. Часть 1. Разрушение горных пород взрывом", Москва, 471 с, 2009.

[7] Кутузов Б.Н., "Методы ведения взрывных работ. Часть 2. Взрывные работы в горном деле и промышленности", М.: Горная книга, 512 с, 2011.

[8] Ханукаев А.Н., "Физические процессы при отбойке горных пород взрывом", Недра, 1974.

[9] Черниговский А.А., "Расчет плоских зарядов для вскрытия полезных ископаемых", *Недра*, Москва, 1965.

[10] Vũ Xuân Bảng, Đàm Trọng Thắng, "Nghiên cứu thực nghiệm về ảnh hưởng của chỉ tiêu thuốc nổ đến quy luật đập vỡ đất đá khi nổ lượng nổ tập trung trên mô hình", *Tạp chí Công nghiệp Mỏ*, 2019.

[11] Г.И. Покровский, "Зависимость формы зоны действия взрыва от формы и расположения зарядов", *Взрывное дело*, №54/11, Недра, Москва, 1954.

[12] Josef Henrych, "The dynamic of explosion and its use", *Academia Prague*, 1979.

[13] Thang Trong Dam, Ta Tri Nguyen, Bang Xuan Vu and Hieu Trong Vu, "*Studying the rule of distribution of rock breaking size according to the distance from the center of concentrated charge*", International Symposium on Rock Mechanics and Engineering for Sustainable, 2019.

[14] Dam Trong Thang, Nguyen Tri Ta, Vu Xuan Bang, "Study on the velocity potential field of the group of parallel long cylindrical charges", *Tạp chí Khoa học và Kỹ thuật,* Học viện Kỹ thuật quân sự, ISSN 1859-0209, số 207, 2020.

[15] Кутузов Б.Н., Белин В.А., "Проектирование и организация взрывных работ" Москва, Горная книга, 416 с, 2012.

[16] Кутузов Б.Н., Рубцов В.К., "Физика взрывного разрушения горных пород", *МГГУ*, Москва, 1970.

[17] Đàm Trọng Thắng, Bùi Xuân Nam, Trần Quang Hiếu, "Nổ mìn trong ngành mỏ và công trình", *Nxb Khoa học tự nhiên và Công nghệ,* Hà Nội, 2015.

NGHIÊN CỨU KHOẢNG CÁCH HỢP LÝ CỦA LƯỢNG NỔ PHẲNG DẠNG NHÓM LƯỢNG NỔ DÀI SONG SONG ĐỂ PHÁ HỦY ĐẤT ĐÁ

Đàm Trọng Thắng, Nguyễn Trí Tá, Vũ Xuân Bảng

Tóm tắt: *Trong thực tế thường sử dụng lượng nổ phẳng ở dạng một nhóm lượng nổ dài song song cách đều nhau và cùng nằm trên một mặt phẳng. Tuy nhiên, đến nay lý thuyết về tác dụng của lượng nổ phẳng phá hủy đất đá mới chỉ đề cập với dạng lượng nổ phẳng là một khối thuốc nổ liên tục. Dựa trên cơ sở lý thuyết thủy động lực học về tác dụng phá hủy của lượng nổ đơn, tiến hành thiết lập mô hình tính, xây dựng một chương trình tính toán trên ngôn ngữ Matlab và tiến hành khảo sát trường năng lượng nổ của nhóm lượng nổ dài song song nằm trên cùng một mặt phẳng ki thay đổi thông số khoảng cách tương đối giữa các lượng nổ. Dựa trên đặc tính lý thuyết nhận được, tiến hành nghiên cứu thực nghiệm xác định thể tích vùng phá hủy nổ khi thay đổi khoảng cách giữa các lỗ mìn trong đá sét kết. Phân tích kết quả nghiên cứu khảo sát lý thuyết trong một số cấp đất đá và thực nghiệm trong đá sét kết đã chỉ ra được vùng trị số hợp lý của thông số khoảng cách giữa các lượng nổ tương ứng nhận được hiệu suất phá hủy tốt nhất tỉ lệ thuận với đường kính lượng nổ và phụ thuộc vào đặc tính đất đá. Đất đá càng bền vững thì khoảng cách hợp lý giữa các lượng nổ dài càng nhỏ và ngược lại. Trị số khoảng cách hợp lý giữa các lượng nổ bằng 10 đến 15 lần đường kính lỗ mìn khi nổ trong môi trường đất đá vô tận và bằng 23 đến 27 đường kính lỗ mìn khi nổ ngầm trong đá sét kết dưới nước.*

Từ khóa: Nổ phá; lượng nổ phẳng; phá hủy đất đá; hiệu quả nổ.

Received: 07/11/2021; *Revised:* 27/11/2021; *Accepted for publication:* 28/12/2021

❑