AN EXPERIMENTAL STUDY ON THE RELATIONSHIP BETWEEN ENERGY FACTOR AND PERCENTAGE OF OVERSIZE ROCK ON ELECTRIC EXPLOSION MODEL

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Abstract

This article has chosen and carried out a study to examine the theoretical and experimental basis of the influence of energy factor, and the number of free face in the tunnel on the proportion of oversized rock after explosion by the explosive charge in the borehole, established an empirical relationship between the percentage of oversized rocks and the energy factor under different number of free face, in order to study the completion of the tunnel rock breaking.

Keywords: *Oversized rock; energy factor (the explosive energy required to break a unit volume of rock, or the unit energy consumption); tunnel; free face.*

1. Introduction

The allowed rock size corresponding to the loading and unloading capacity of each type of excavator is always a concern in construction in general and underground work by explosive drilling in particular. Because if the size of the rock is large and the excavator cannot excavate or excavate it ineffectively, it is considered an oversized rock. Oversized rock must be blasted again. Having to blast the second time will increase production costs and reduce construction progress. The second blasting will raise production costs while slowing construction. During building and excavation, the rate of large rock produced by blasting is an essential technical and economic indication. At present, the rules for oversized rock are mainly published as explosive results under exposed rock strata conditions. When blasting in conditions of less free surface and hard-pressed free surface, there are few research works. Therefore, this research has studied the empirical law on the dependence of the proportion of oversized rock on the basic explosive parameters in the condition of few free faces. Research results show that when increasing the explosive criterion, the percentage of oversized rock decreases and vice versa.

2. Theoretical basis

Oversized rocks are rocks that are larger than the allowed size (D_{cp}). The allowable

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rock size D_{cp}, depends on the working capacity of the equipment, with large machines, is possible to load and transport large rocks so that D_{cp} is also large and vice versa.

D_{cp} is determined according to the excavating, transporting (or crushing, if applicable) conditions [1-4].

For single bucket excavator:

$$D_{cp} = 0.75\sqrt[3]{E}\text{ , m} \quad (1)$$

where E is the bucket capacity, m^3.

For transport equipment:

$$D_{cp} = 0.5\sqrt[3]{V}\text{ , m} \quad (2)$$

where V is the tank capacity, m^3.

In fact, current excavators of popular brands such as Komashu, Hitachi, Daewoo... have a bucket capacity of approximately 2.3 m^3, then follow (1) will have D_{cp} of about 1 m. All types of transport equipment with a tank capacity of approximately 5 m^3 to 13 m^3 equivalent to a load of approximately 8 tones to 20 tones, all of them can transport fragment size larger than 1 m. Thus, in general D_{cp} depends more on the bucket capacity than on the capacity of transport equipment.

Table 1. Allowable rock sizes with some actual equipments

No.	Equipment/Works actually used/ Company used	Bucket/tank capacity (m^3)	Allowable rock size (cm)
1	Excavator Lable Caterpilar 930H/Đeo Ca Road tunnels/ Song Da Company	2.3	98
2	Dump truck Lable Huyndai/Đeo Ca Road tunnels/Song Da Company	10	160
3	Excavator SK200/A6 Road tunnels on the Ha Noi - Lao Cai route/Lung Lo company	0.9	70
4	Dump truck Lable Kmaz/A6 Road tunnels on the Ha Noi - Lao Cai route/Lung Lo company	7	140

To determine the calculated excess of the particle size components after the explosion, different methods can be used such as:

The actual method of determining the muck-pile after the explosion includes: The method of measuring the dimensions of the rock on the surface; the method of selecting and classifying fragment sizes that exceed the calculated size; indirect methods of determining according to the consumption of explosives, methods of analyzing photographs, etc.

Theoretical methods for predicting the proportion of oversized rocks in surface blasting: according to the studies of Rosin-Rammler [6] or Goden-Andrep [2, 5].

According to Rosin-Rammler [5]:

$$P(x) = 1 - e^{-\alpha x^{\nu}} \tag{3}$$

where x is the size of the rocks in the muck-pile after explosion, cm; α is a coefficient that depends on the consunption of explosive energy, also known as the smash factor; ν is a quantity that depends on rock properties

According to Goden-Andrep [2, 5]:

$$P(x) = \left[\frac{x}{x_{\max}} \right]^m \tag{4}$$

where x is the size of the rocks in the muck-pile after explosion, cm; x_{max} is the size of the largest rock fragments in the pile, cm; m is the experimental coefficient.

As for explosions in tunnels, there are no specific studies on this issue.

3. Experimental investigation of relationship between explosive criteria and percentage of oversized rock on electric explosion model

3.1. Description of experiments on electric explosion model

- Tools used in the experiment include: Electric explosive device providing explosion energy up to 500J, discharge wire, plaster samples, explosion chamber, standard sieve set, precision balance (Figures 1 to 3).

- The samples made of plaster and sand including types 1 and 2, respectively arranged and exploded in tunnels with 1- free surface and 2- free surfaces

The samples made of plaster and sand were cast in an iron mold, like the edge of a tunnel. Sample size and shape see Table 2 and Figure 4...

Table 2. Description of parameters and characteristics of the test sample

No.	Sample type	Size of sample L × W × H (mm)	Volumetric mass (g/cm^3)	Compressive strength (MPa)	Speed of vertical wave (m/s)
1	Type 1	40 × 40 × 80	1.21	9.0	810
2	Type 2	40 × 40 × 80	1.21	9.0	810

- The electric explosive pulse generator wires are arranged in the center of the sample face, the explosive particle depth is 20 mm, respectively for type 1 and type 2 samples, see Figure 4.

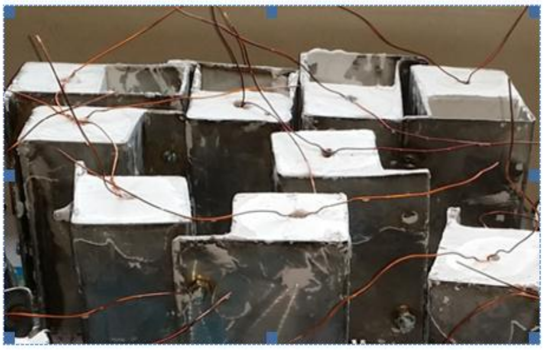

Figure 1. Samples used in the experiments.

Figure 2. Standard sieve set.

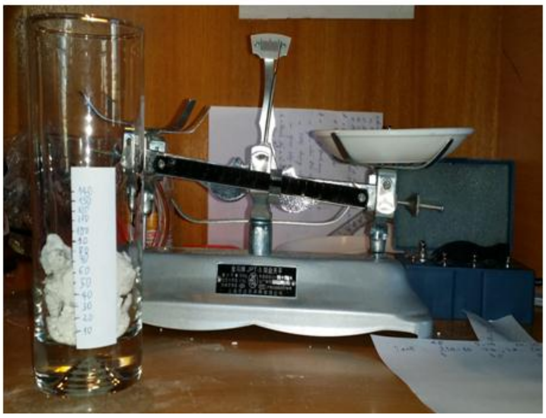

Figure 3. Weighing and measuring samples.

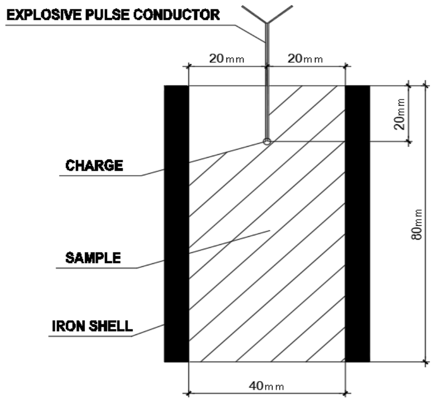

Figure 4. Electrical explosion arrangement.

3.2. Experimental procedures

- Explodes with low to high energy levels.

- Classify the particle size after blasting by standard sieves.

- Determine the weight of each type of particle size by microbalance with an accuracy of 0.5 g.

- Determine the percentage of each particle size, determine the average particle size.

3.3. Experimental results

The experimental results are shown in Table 3.

3.4. Analyze experimental results

Determining the size of an oversized rock: As described, an oversized rocks is a rock larger than D_{cp}, while D_{cp} depends on the capacity of the device, so it can be seen that D_{cp} is an equivalent value. With the experimental model in this study, in turn choose D_{cp} = 35 mm to study the law of change according to the energy factor.

From the results in Table 3, the determination of the proportion of oversized rocks according to the energy factor as follows:

- Oversized rock ratio P_{qc} is calculated as follows:

$$P_{qc} = 1 - P_{cp}\ (\%) \tag{5}$$

where P_{cp} is the percentage of particle size smaller than x, corresponding to each energy factor in Table 3.

Table 3. Results with experimental model

	Energy factor (J/cm^3)	Smaller particle size percentage 35 mm (%)		Energy factor (J/cm^3)	Smaller particle size percentage 35 mm (%)
1 free face	4.71	0.490	2 free faces	4.7	0.560
	5.19	0.580		4.9	0.580
	5.43	0.590		5.7	0.860
	6.24	0.780		6.1	0.890
	6.44	0.833		8.02	0.933
	6.81	0.830		8.68	0.939
	7.92	0.903		10.68	1
	9.47	0.902		11.2	1
	11.15	0		11.46	1
	11.56	0		11.66	1
	11.93	0		11.93	1

Table 4. Oversize rock ratio with D_{cp} = 35 mm

	Energy factor (J/cm^3)	Ratio of over size rock (%)		Energy factor (J/cm^3)	Ratio of over size rock (%)
1 free face	4.71	0.51	2 free faces	4.7	0.44
	5.19	0.42		4.9	0.42
	5.43	0.41		5.7	0.14
	6.24	0.22		6.1	0.11
	6.44	0.167		8.02	0.067
	6.81	0.17		8.68	0.061
	7.92	0.107		10.68	0
	9.47	0.108		11.2	0
	11.15	0		11.46	0
	11.56	0		11.66	0
	11.93	0		11.95	0

Building the relationship between the proportion of oversized rocks and the energy factor in Figure 5.

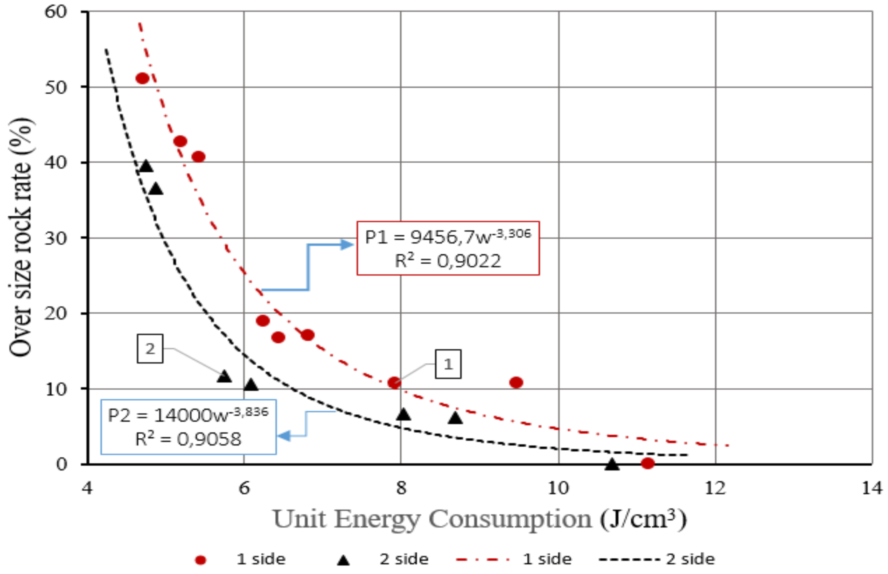

Figure 5. Relationship between oversized rock ratio and energy factor.

• ***Discussion:***

Observing the graph in Figure 5, with the curves describing the empirical rules, it can be noticed:

In fact, as the explosive energy increases, the rock will be crushed more, so the number of large stones will decrease and the percentage of oversized rocks will also decrease. The above results also reflect the reliability of the experimental model.

- The curve describing the empirical rule of the case of 2 free faces is below the curve describing the experimental law of the case of 1 free face, which means that the same level of energy consumption then the proportion of oversized rocks in the case of the 2 free faces is less, representing the degree of rock breaking of 2 free surfaces is better than 1 free face. This is also consistent with other studies on the extent of rock breaking.

- When the energy factor increases to a certain level, the percentage of oversized rocks does not change much (empirical data show that the rate of oversized rocks is zero when the unit explosion energy exceeds a certain level), this shows that when the explosion energy increases to a certain level, the degree of rock fragmentation will not increase, but will increase the flying kinetic energy of the rocks after the explosion.

- With the correlation coefficient of the experimental function being relatively high (both greater than 0.9), it can be proposed that the empirical relationship function between the proportion of oversized rock and the energy factor is:

$$P = a.w^b \text{ (\%)} \qquad (6)$$

where P is the oversize rock rate (%); w is energy factor (J/cm^3); a and b are the coefficients depending on the explosive conditions and rock characteristics.

4. Conclusion

The percentage of oversized rocks decreases as energy factor increases, but this relationship is not linear. With explosions in 2 free faces tunnels, the percentage of oversized rocks is lower than in 1 free face tunnels with the same explosive energy level.

If we continue to increase the explosion energy level, it is possible to suppress the proportion of oversized rocks with the large allowable rock size, but with the small allowable rock size, it can only increase the flying kinetic energy without eliminating all oversized rocks.

To generate a set of experimental data that can be referenced in the construction of underground works, more research on the explosion model using real explosives and explosive settings that are near to actual construction conditions is required.

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NGHIÊN CỨU THỰC NGHIỆM QUAN HỆ GIỮA CHỈ TIÊU NĂNG LƯỢNG NỔ VỚI TỈ LỆ ĐÁ QUÁ CỠ TRÊN MÔ HÌNH NỔ ĐIỆN

Vũ Trọng Hiếu

Tóm tắt: *Bài báo đã lựa chọn và tiến hành nghiên cứu phân tích cơ sở lý thuyết và thực nghiệm về ảnh hưởng chỉ tiêu năng lượng nổ và số lượng mặt thoáng trong đường hầm đến tỉ lệ đá quá cỡ sau nổ, thiết lập mối quan hệ thực nghiệm giữa tỉ lệ phần trăm đá quá cỡ và chỉ tiêu năng lượng nổ trong các điều kiện số mặt thoáng, để góp phần hoàn thiện việc nghiên cứu về mức độ đập vỡ đất đá trong đường hầm.*

Từ khóa: Đá quá cỡ; chỉ tiêu năng lượng nổ; đường hầm; mặt thoáng.

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