AN EXPERIMENTAL STUDY ON THE INFLUENCE OF WATER DEPTH ON THE MEAN PARTICLE SIZE DIAMETER BY ELECTRIC EXPLOSION MODEL

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Abstract

Although the use of explosive energy to break the underwater rock and soil has been long and widely used, both in Vietnam and around the world but there are currently no studies on the calculation of the underwater rock drilling and blasting parameters in different geological and hydrological conditions. The article presents the selected and conducted research to analyze the basic theory and experiment about the influence of water depth on the mean particle size diameter after blasting by the charge placed in the borehole, to contribute to the completion of the study and calculation the parameters of underwater drill explosion.

Keywords: *Destroying rock; explode underwater; degree of rock breaking.*

1. Introduction

When using an explosive charge to break up rock, the original rockmass will be broken into smaller fragements. The degree of rock breaking shows the degree of fragments on stones created after the explosion, fragmentation is characterized by the size of the particle after explosion, depending on the initial rock mass characteristics and the characteristics of the explosion. Fragmentation is a composite indicator, along with the volume of destroyed rock, it is the most important indicators when considering the effect of the explosion.

The degree of fragmentation has a big influence on the efficiency of loading and transporting. In order to assess the quality of the blast, the parameter of fragments size is always applied when exploding such as: rate of oversized rock by volume (%); the number of oversized rocks per unit volume of rock which was broken; average diameter of rock after blasted.

Fragmentation is considered reasonable if it meets the component particle size in regulation, while ensuring the general requirements of blasting and lowering production costs.

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https://doi.org/10.56651/lqdtu.jst.v3.n01.72.sce

The theory of fragmentation when blasting has basically been studied quite thoroughly for surface blasting, however, until now, there has not been any research project on fragmentation for underwater blasting [1, 2, 3, 5, 7]. Currently, the practical trend is to exploit the potential of the sea, therefore, the research trend on the fragmentation of underwater blasting is a scientific and practical task.

2. Analysis on the scientific basis of the degree of fragmentation by explosion

Results from scientists show that: in case of surface blasting, when increasing the specific charge, at first, the breaking intensity of rockmass increase. After that, the state of the saturation starts, and finally, the process of energy consumption is unbeneficial and useless (Fig. 1). The breaking intensity will stop and then the curve changes beyond the boundary and runs parallel to the horizontal axis. At this moment, the redundancy energy is converted into the kinetic energy of the flying rocks after the explosion. Therefore, the fact that when wasted energy used for rock flying, this will reduce the degree of fragmentation.

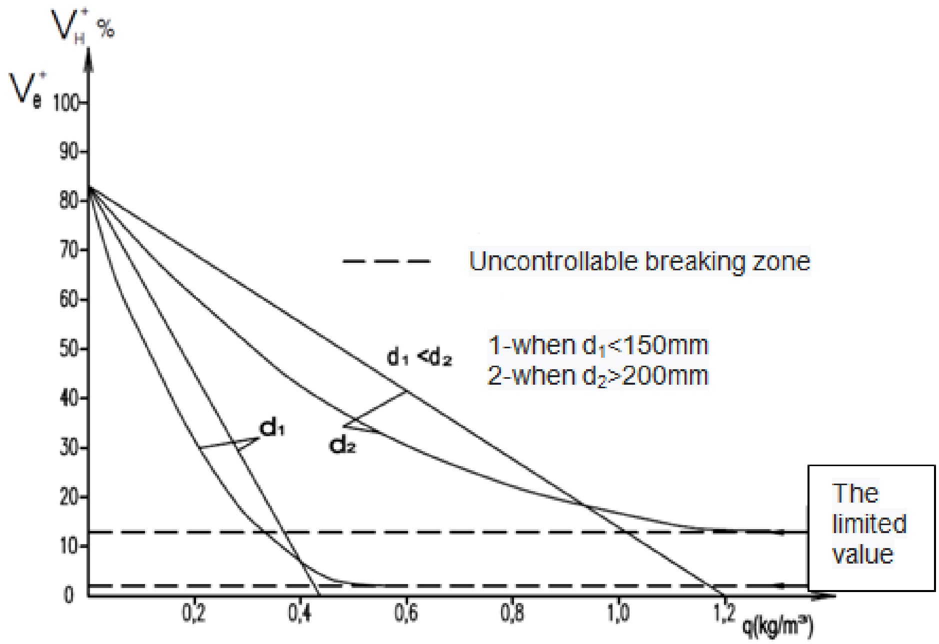

Figure 1. The dependence on ratio of oversized rock on powder factor

When carrying out the underwater explosion, under the influence of water, the following effects will appear [4, 6, 8, 9], water acts as a stemming, which prevents the flying of blasted rocks, thus increasing the duration effect of explosion, increasing mechanical effect of explosive energy, on the other hand, water prevents the flying of rocks. The degree of this influence depends on the increase in the water depth.

With such an analysis, it can be noticed that in case of a strong blast, the increase in water depth will reduce the flying rocks and increase the mechanical effect of the explosion and increase fragmentation degree of rocks.

In order to assess the degree of fragmentation, the parameter of average particle size is used, which is usually calculated using either of the following two methods:

- According to the actual measurement method [1, 2, 5, 7]:

$$D_{tb} = \frac{\sum_{1}^{m} \alpha_i d_i}{100}, \text{ cm} \tag{1}$$

where d_i - average diameter of particle size i, cm; α_i - ratio of the ith particle size level in the muckpile; *m* - number of particle size division.

According to probability energy method

$$D_{tb} = \int_{0}^{\infty} x d(P_x), \text{ cm} \tag{2}$$

where P_x - probability of rocks having size ≤ *x*; it is the rules of size distribution after blasting; *x* - the size of a rock in the pile.

To clarify the influence of water on the mean particle size diameter after blasting, it is necessary to proceed experimental study on this issue should be carried out.

3. Experimental study of underwater explosion in fragile rock samples

3.1. Choose experimental models

To study the influence of water depth on the breaking effect of rock, may be conduct in the field or on a miniature model with real explosives or electric explosive device. However, field experiments or small scale models with explosions are very difficult in terms of funding and assurance. Therefore, choosing the testing method on electric explosion model.

The model shown in Figure 2 includes: an electric explosive device (1) that will generate explosive energy transmit to the explosive head (3) placed in the sample (4) through the conductor (2); The sample (4) is placed in a mesh bag (5) to facilitate the collection after explosion, a water tank (6) can change the height of water column accordingly.

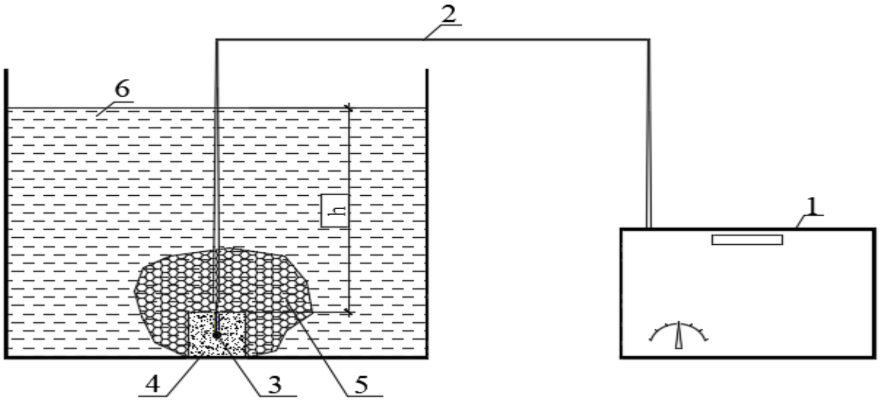

Figure 2. Experimental model

1 - Electric explosive device; 2 - Conductor; 3 - Explosion head ; 4 - Laboratory sample; 5 - Net bag to collect materials after explosion; 6 - Water tank.

Table 1. Description of parameters and characteristics of the test sample

No	**Sample type**	**Size of sample DxH**	**Volumetric mass (g/cm^3)**	**Compressive strength (MPa)**	**Speed of vertical wave (m/s)**
1	Cylindrical sample	27x27 mm	1,21	9,0	810

- The cylindrical samples made of plaster and sand have characteristics shown in table 1 which correspond to a fragile weak rock, and in accordance with the capacity of the electric explosive device in Academy.

- The Electric explosive device: able to generate explosive energy up to 500J.

- The Water tank: 30 cm diameter, 50 cm height.

- The D250mm standard sieve, hole 50 mm, 10 level (5, 10, 15, 20, 25, 30, 35, 40, 45, 50 mm).

- The actual equipment used is shown in Figure 3.

a) Electric explosive device *b) Plaster-sand samples* *c) Water tank* *d) Sieve size analysis*

Figure 3. Equipment and tools used for the experiment

3.2. Experimental description

The position of explosive charge in the sample is shown in Figure 4.

Range of the experimental research, experiment with high explosive consumption, corresponding to the case of a strong blast, means large excess energy to splash rock when exploding on land. Before explosive tests with different water column heights, auxiliary tests are conducted in the absence of water to select the minimum power level (the sufficient energy for the sample flown hard after being broken).

This energy level is defined as 100J. On that basis, experiments are done with 3 energy levels of 100J, 200J and 300J. Water depth varies from 0 to 10 times of the sample height.

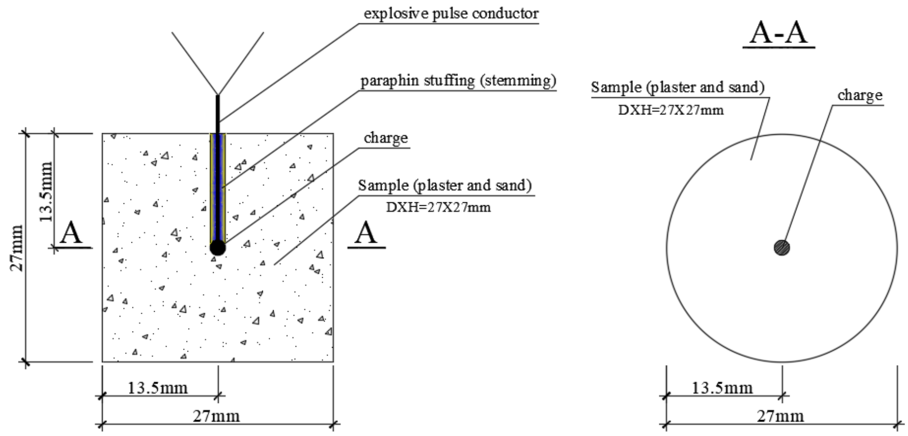

Figure 4. Arrangement of electrical explosion in the sample

The electrical explosion in the sample, upper borehole portion is filled with paraffin (stemming)

3.3. Results and analysis of experimental results

The experimental results are as follows: When detonating with energy levels from 100J to 300J, the samples were completely destroyed, the average fragment size is presented in Table 2.

For each type of rock, from the results of experimental blasts, the theoretical function of the relationship between unit energy consumption (*e*) and the average fragment size (D_{tb}) into the water depth (*h*) can be formed.

Analysis of experimental explosion results seen in Table 2 by using the least squares method, with the support of Excel 2016 software, the dependence of the average fragment size on the water depth has the form:

With the explosive energy E = 100J (the sample breaking energy is 90J, the device's accumulated energy is 10J), corresponding to the energy consumption density w = 5,82 J/cm^3 received:

$$D_{tb} = 1,9313 h^{-0.056}; R^2 = 0,9995 \tag{3}$$

Table 2. Experimental results

No	Level energy, E (J)	Depth water (cm)	Original weight (g)	Average size of sample after explosion D_{tb} (cm)	No	Level energy (J)	Depth water (cm)	Original weight (g)	Average size of sample after explosion D_{tb} (cm)
1	100	0	18,50	2,00	1	200	16,2	17,90	1,62
2		0	17,20	2,09	2		16,2	17,90	1,65
3		0	18,90	2,11	3		16,2	17,70	1,46
1	100	8,1	17,60	1,79	1	200	24,3	17,70	1,56
2		8,1	18,40	1,68	2		24,3	18,20	1,61
3		8,1	17,80	1,71	3		24,3	18,60	1,67
1	100	16,2	18,00	1,57	1	300	0	16,40	1,66
2		16,2	17,80	1,70	2		0	16,70	1,68
3		16,2	18,30	1,69	3		0	17,40	1,66
1	100	24,3	17,70	1,59	1	300	8,1	17,20	1,56
2		24,3	18,00	1,53	2		8,1	17,50	1,61
3		24,3	18,80	1,72	3		8,1	17,50	1,60
1	200	0	18,50	1,91	1	300	16,2	16,00	1,56
2		0	18,20	1,93	2		16,2	16,00	1,53
3		0	18,80	1,72	3		16,2	17,00	1,51
1	200	8,1	18,80	1,75	1	300	24,3	17,20	1,53
2		8,1	17,70	1,71	2		24,3	16,50	1,57
3		8,1	17,50	1,72	3		24,3	16,80	1,48

With the explosive energy E = 200J (the sample breaking energy is 190J, the device's accumulated energy is 10J), corresponding to the energy consumption density w = 12,30 J/cm^3 received:

$$D_{tb} = 1,8342h^{-0,038}; R^2 = 0,8753 \quad (4)$$

With the explosive energy E = 300J (the sample breaking energy is 290J, the device's accumulated energy is 10J), corresponding to the energy consumption density w = 18,77 J/cm^3 received:

$$D_{tb} = 1,6318h^{-0.019}; R^2 = 0,9507 \quad (5)$$

R^2 is correlation coefficient.

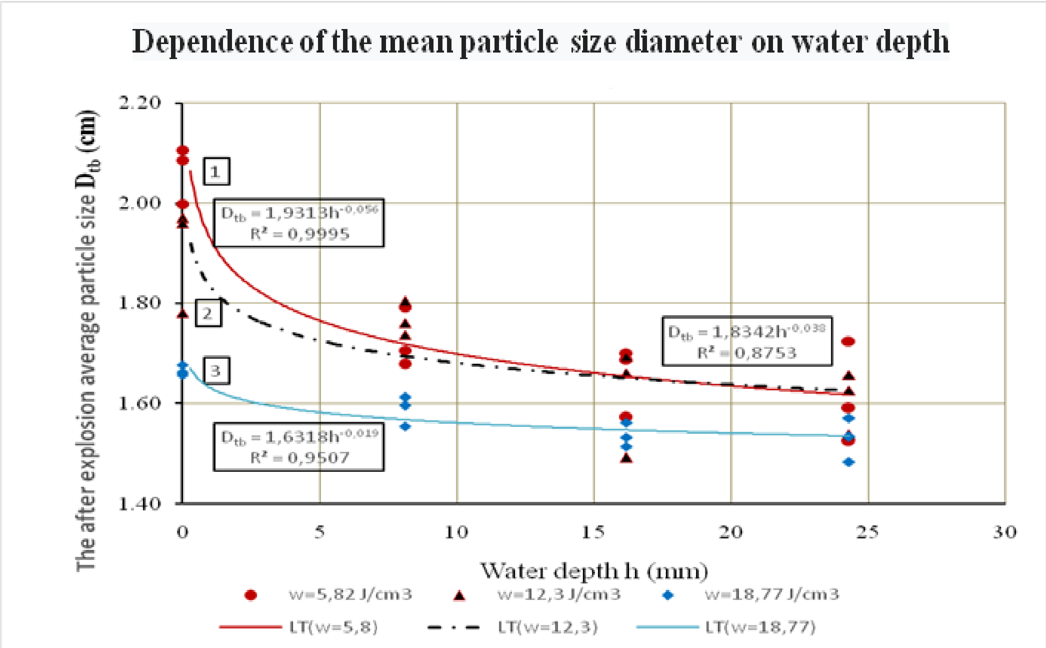

Figure 5. Establish dependence of the mean particle size diameter on water depth

Comments:

In Figure 5, it is found that when the depth of water in the region increases from 0 to 10 times the height of the sample (h from 0 to 24,3 cm), with the same explosive energy consumption, the level of rock breaking increases (D_{tb} decreases).

Along with the complete destruction of the samples, it can be explained that this is a case of strong test blast, the consumed energy transforms into the kinetic energy of the flying rocks. Therefore, when increasing the depth of water, the rock will be limited flying ability and the mechanical effects of explosion goes up which increases the effect of rock breaking.

Experimental results are suitable for scientific basis analysis, reflecting the characteristics of rock breaking by explosive placed in underwater boreholes.

When increasing the unit energy consumption, the degree of rock fragmentation also increases, this is suitable with reality. This energy consumption increases not only the degree of fragmentation but also flying ability.

Three curves have the same tendency when increasing water depth, showing the reliability of the experimental results. Curves 1 and 2 intersect, express the fact that in experimental study sometimes the results are not absolute convergence and need more empirical data to increase the accuracy of the results

The correlation coefficient of the theoretical function reaches a high value, respectively, 0,8753; 0,9507; 0,9995 showing that the form of the selection function is appropriate.

From the results of the above empirical function, the relationship between D_{tb} and h can be brought on to the following general form:

$$D_{tb} = a.h^{\alpha} \tag{6}$$

where a and α depend on unit energy consumption: with w = 5,821 J/cm^2, a = 1,9313, α = -0,056; where w = 12,31 J/cm^2 then a = 1,8324; α = -0,038; where w = 18,77 J/cm^2 then a = 1,6318; α = -0,019.

So, the a and α coefficients are variable when changing the unit energy consumption, which is suitable with one of the most basic rules of rock breaking explosion theory is that the blast efficiency depends on the explosion conditions and the rock characteristics (in this experiment, the soil and rock characteristics are constant, so it only depends on explosion conditions).

4. Conclusions and recommendations

From the above research results, the following conclusions are withdrawn:

- Water depth has an influence on rock breaking effect underwater by the charge placed in the borehole.

- Within the experimental range, the mean particle size diameter after blasting is inverse proportional to the water depth.

- More studies should be further carrying out to determine the influence of water depth on rock breaking effect underwater by the explosive charge placed in the borehole, for different rock types with different hardness and different range of explosive energy consumptions, or in different range of water depth. In particular, it is necessary to continue experimental research on the model of using explosive energy and experiment in real conditions.

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NGHIÊN CỨU THỰC NGHIỆM ẢNH HƯỞNG CỦA CHIỀU SÂU NƯỚC ĐẾN KÍCH THƯỚC TRUNG BÌNH CỦA CỤC ĐÁ SAU NỔ TRÊN MÔ HÌNH NỔ ĐIỆN

Tóm tắt: *Mặc dù việc ứng dụng năng lượng nổ để phá vỡ đất đá ở dưới nước đã được áp dụng từ lâu và khá rộng rãi, cả ở Việt Nam và trên thế giới, nhưng hiện chưa có các nghiên cứu đầy đủ về tính toán các thông số khoan nổ mìn phá đá dưới nước trong các điều kiện địa chất và thủy văn khác nhau. Bài báo đã lựa chọn và tiến hành nghiên cứu phân tích cơ sở lý thuyết và thực nghiệm về ảnh hưởng của chiều sâu nước đến kích thước trung bình của cục đá sau nổ bằng lượng nổ đặt trong lỗ khoan, để góp phần hoàn thiện việc nghiên cứu tính toán các thông số khoan nổ phá dưới nước.*

Từ khóa: Phá hủy đất đá; mức độ đập vỡ đất đá; nổ dưới nước.

Received: 06/4/2020; *Revised:* 24/5/2020; *Accepted for publication:* 17/6/2020

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