Journal of Mining and Earth Sciences

Website: http://tapchi.humg.edu.vn

Applying single hole test blast for determining optimum burden in low bench blasting

Hoa Van Pham*

Faculty of Mining, Hanoi University of Mining and Geology, Vietnam

ARTICLE INFO

Article history:
Received 12 Oct. 2016
Accepted 15 Mar. 2017
Available online 30 June 2017

Keywords:
Single hole blasting
Optimal burden
Low bench blasting

ABSTRACT

The low bench blasting is usually used in the blasting works on the surface during the specific conditions at the working sites. This case study was carried out at KT2 construction site, Huoi Quang hydro-electric project in Vietnam with the aim to define optimum burden for the blasts in 2.5 m bench height. In this study, due to the ratio of bench height to borehole diameter K/d is 32,9 (for normal bench blasting K/d ≥ 60, the value of burden cannot be determined by traditional equation for normal bench blasting. Therefore, a series of single hole test blasts was used the same bench height and the charge weight was kept unchanged for defining the optimum burden. This method brings many encouraging results when the maximum value of burden was obtained with maximum broken volume, minimum specific charge and even good fragmentation and acceptable toe condition.

1. Introduction

Single hole blasts have been used by many researchers to define specific charge, critical burden for the purpose of determining the blast ability of rocks. The method was firstly approached by Fraenkel (Fraenkel, 1954 ; Langefors and Kihlström, 1963) and it was also used to test rock constant *c* in Langefors formula. The rock constant c is determined by Fraenkel in the following way:

"For practical use, the blast ability of rock, c(kg/m^3), can be determined by test blasting with one single vertical hole with 33mm bottom diameter, hole deep 1.33m and with that charge which is needed to give a 1m high vertical bench and 1m burden a breakage and throw of maximum 1m".

Rustan and Vutukuri (1983) used the single hole blasting methods to establish the relationship between specific charge, burden, geometrical scale and physical properties of rock and rocklike materials with fragmentation, burden, volume broken, and angle of breakage. From these encouraging results, Rustan and Nie (1992) carried out similar experiments in full scale at Nordkalk AB's limestone quarry in Sweden and compared the results with their test model in the same rock. In their results, a comparison between full scale and model blast tests shows that a good

*Corresponding author
E-mail: phamvanhoa@humg.edu.vn

correlation exists between burden and other parameters such as angle of breakage and the mean fragment size k_{50} (the mesh size where 50% of the mass passes) versus burden. Another research by Bilgin (Bilgin, 1991) also provided some very interesting results from single hole test blasting in full scale. After analyzing the relations between burden versus angle of breakage, broken volume, throw, and backbreak, his conclusions is that the maximum broken volume had been obtained when the burden was optimum, even though the specific charge was minimum and the fragmentation and toe conditions were still good and acceptable.

The results and method introduced from single hole blasts suggests that the more frequent application of this method for determining the optimum burden when changing the bench height in the blasting works in specific civil engineering in Vietnam

2. Problem

With the requirement of industrialization process in Vietnam, many hydroelectric projects are building. The surface blasting works carrying out at these projects usually deal with the difficulties due to the mountainous terrain and the working conditions in the construction sites. The experimental blasts were carried out at the KT2 construction sites of Huoi Quang hydroelectric project which located in Son La province. The bench cut method was applied and blasted rocks in benches which cannot access by trucks will be shoveled by backhoe excavators and it will fall down by gravity to the dump at the foot of the mountain (Figure 1,2). The old drilling machine used at this construction site can only drill well with only one rod of 3m. When it drills with two rods, the drilling rod usually sticks into the borehole due to the weakness of the machine and the drilling productivity is decreased. Other reason was the limitation in the volume of explosive using in one blast by authorities and the moving method, so the bench height of 2.5m was used.

It is well known that the rock will be fragmented better if the bench height is increased (Rustan, 1990). However, in this actual case, low benches will lead to the decrease of charge length. According to Langefors & Kihlström (Langefors and Kihlström, 1963), if the ratio of bench height to maximum burden $K/B_{max} \leq 2$, there is not enough room for full bottom charge and this part of borehole should only use for the bottom charge, so it is classified as low bench blasting. Because the full bottom charge will not be used, therefore the burden has to be reduced in order to get the appropriate breakage with shorter charge length.

(Ash, 1990) has mentioned in his report that the ratio between charge length and borehole diameter $l/d < 60$ can be classified as low bench blasting. Within the ratio $l/d < 60$, the values of burdens should be increased if the charge length increases. From all of the above reasons, we have carried out a series of single hole test blasts at the KT2 construction site to determine the optimal burden when blasting in low benches.

Fig. 1. Moving blasted rock to the dump to the foot of the mountain by an excavator at the KT2 construction site.

3. Experimental Procedures

The rock at the KT2 construction site is basalt with gray color and fine-grained crystal. Single hole test blasts were carried out at the bench where the rock was similar in order to define the best results of optimum burden in the same rock type condition. The mechanical properties of rock are given in Table 1.

The boreholes were drilled sufficiently apart from each other so that the angles of breakage would not overlap one another. In these test blasts, a borehole diameter of 76mm was used. This makes the charge length longer when using the smaller borehole diameter. In order to ensure the confinement of a blast, the stemming length (T) should be used in the range of T=(0.6÷0.8)B (B is the burden) [2, (Adhikari, 1999) or $T = (25 \div 40)d$, or the stemming length should be equal to the burden (T = B). The charge length l was kept constant and it was calculated so that it should be longest possible to enhance the breaking power by elongated charge, but the space of borehole for stemming length must ensure the confinement of the blasts. The blasting parameter used in the full-scale tests are shown in Table 2. The values of proposed burdens of the test blasts are 1.9m; 2.3m; 2.5m and 2.9m. The proposed burdens were chosen base on the reference the burden of normal bench blasting as a ceiling value.

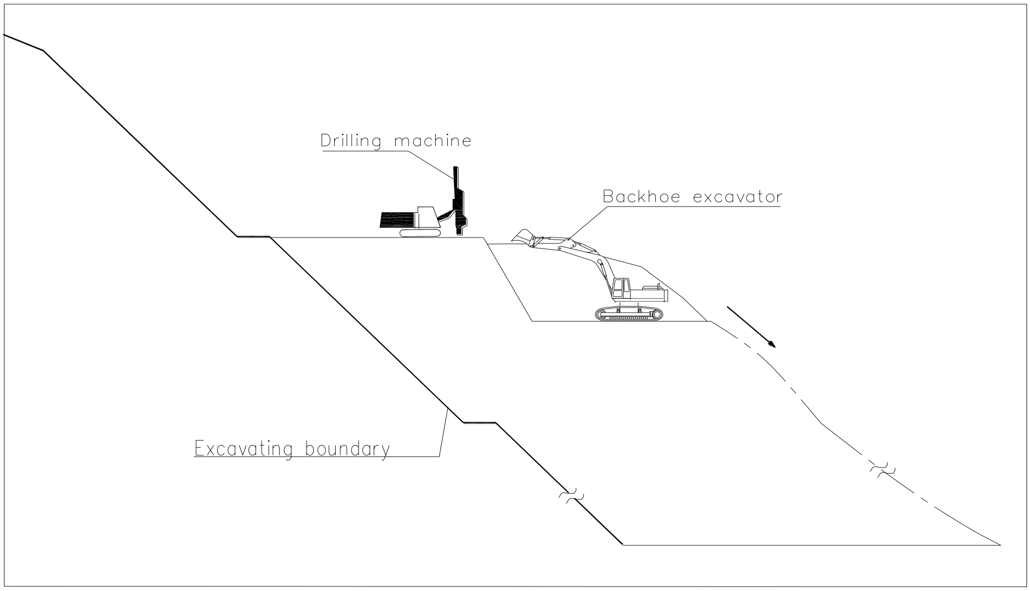

Fig. 2. The arrangement of mining machines on the bench when moving blasted rocks to the foot of the mountain describing the bench height on in-site construction site.

Table 1. Mechanical properties of basalt at the KT2 construction site.

Uniaxial compressive strength (MPa)	Uniaxial tensile strength (MPa)	Density (g/cm^3)
117	12.50	2.77

Table 2. Blasting parameter for the full-scale test blasts at the KT2 construction site.

Bench height (K)	2.5m
Burden (B) proposed at	1.9, 2.3, 2.5, 2.7, 2.9m
Borehole diameter (d)	76mm
Blast hole inclination	Vertical
Inclination of benches	80 – 850
Subdrilling length	0.3B
Main charge, Ammonite AD-1	4.15kg/hole
Charge length (l)	1.22m
Ratio of charge length/borehole diameter (l/d)	16
Primer, VE-05A (TNT)	175g
Initiation	Electrical blasting caps

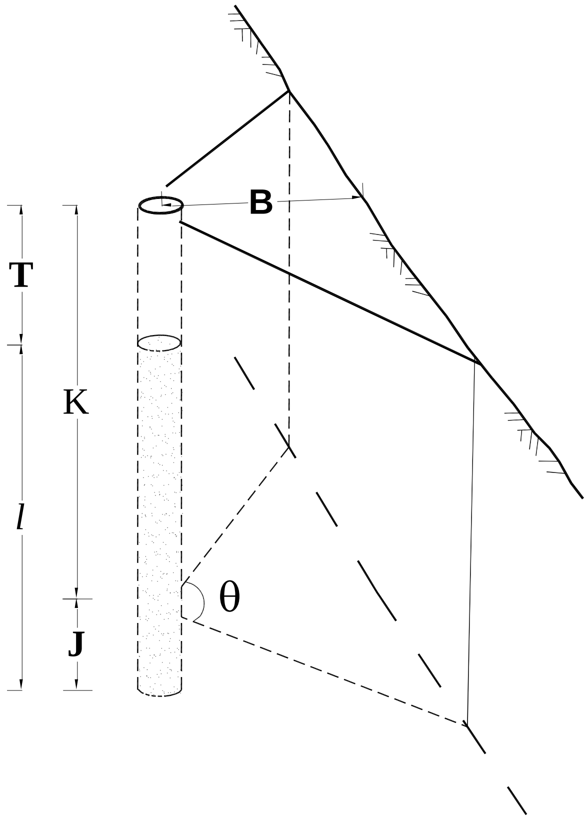

Fig. 3: The illustration of a single hole test blast (θ is the angle of breakage).

In order to prevent the AD-1 cartridges stuck on borehole wall, the cartridge diameter of 60 mm was chosen, and it was charged in combination with loose AD1 explosive to couple explosive with the borehole.

Before the test, all piece of blasted rocks spreading around were removed and then the bench face was inspected. The actual burdens were precisely measured together with the actual bench heights. The charging procedure was carefully carried out by placing the primer at the bench floor level and tamping the explosive by a wood stick. After the test, the angle of breakage (θ), the backbreak for each blasthole was measured (Figure 3). The photos of blasted rocks were also taken in order to inspect the fragmentation of the blasts. The blasted rock volumes were calculated using the angle of breakage, burden and bench height.

4. Results and discussion

The purpose of this test blasts was to define the optimum burden, the burden at which the maximal broken volume and minimum specific charge was obtained, for the bench height of 2.5m. The results of the single hole test blasts are presented in Table 3

4.1. Angle of breakage versus burden

In these tests, the angle of breakage is an important parameter when it is used to define the broken volume of rocks and the specific charge. After blasting, the fragmented rocks were removed by excavator out of the crater, and then the protractor was used to measure the breakage angle. The measured angles of breakage were given in Table 3, and the relation between angle of breakage and burden is described in Figure 4. The regression analysis was applied in order to find the correlation between breakage angle and burden. As in Figure 4, the best fit was obtained in the form of an inversely proportional linear relationship and the value the angle of breakage decreases following further increase of burden. This trend is also observed in the model tests or full scale tests of (Rustan and Nie, 1992; Bilgin, 1991). According to these authors, the sudden reduction in the breakage angle was believed to be the sign for critical burden B_c (B_c is the smallest burden without breakage). However, in our test blasts we only focused on the determination of optimal burden in this series of single hole test blasts.

The formula for the bench height of 2.5m at KT2 construction site has the form as follows:

$$\theta = 204.36 - 45.27 \times B; \quad (1)$$

$R^2 = 0.958$

Where:

θ = angle of breakage (degree)

B = burden (m)

R = correlation coefficient

This formula has the same form as the results from single hole blasts of other researchers (Bilgin, 1991; Rustan and Nie, 1992) but it should be used as a reference only for the same testing conditions like the KT2 construction site.

4.2. Backbreak versus burden

The backbreaks were detected and measured at the top surface of the bench. The relation between burden and backbreaks is presented in Figure 5.

Table 3. Results of single hole test blasts.

Blast No.	Actual Burden (m)	Bench height (m)	Angle of breakage (degree)	Backbreak (m)	Breakage volume (m3)	Specific charge (kg/m3)
1	1.9	2.5	115	0.65	14.17	0.33
2	2.3	2.5	103	0.80	16.63	0.28
3	2.5	2.5	96	1.1	17.35	0.27
4	2.7	2.5	81	1	15.57	0.30
5	2.9	2.5	70	1.2	14.72	0.32

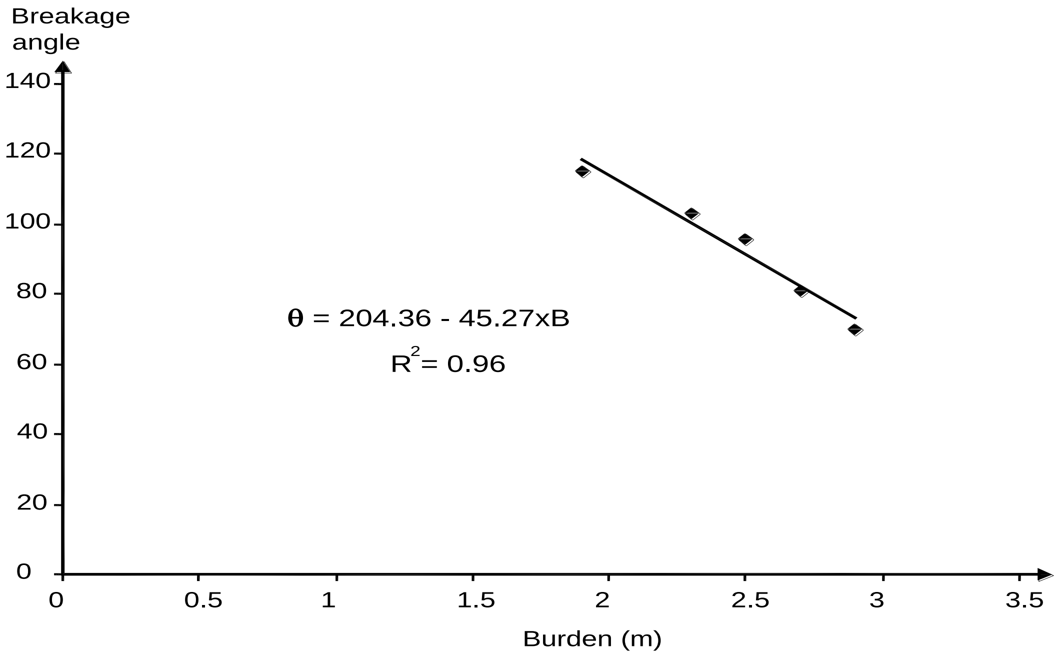

Fig. 4. Measured angle of breakage versus burden in test blasts.

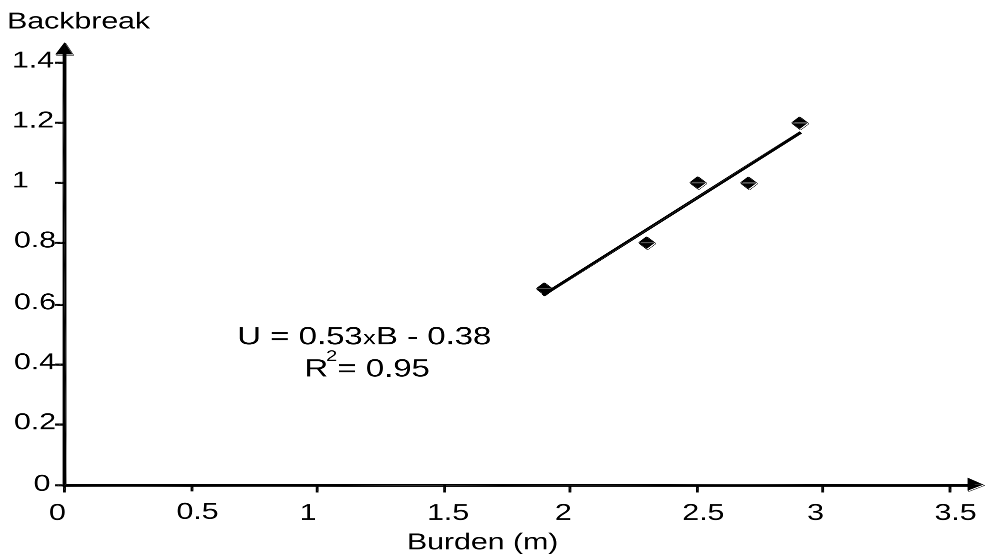

Fig. 4. Backbreak (U) versus burden in test blasts.

From the Figure 5, it is possible to see the direct proportional relation between burden and backbreaks. As stated by Bilgin (Bilgin, 1991) that when the burden gets greater, the detonation gases are retained for a longer periods of time within the blasthole, so the gases have more time to penetrate into the newly created and natural cracks causing them to open and extend. For this reason, burden should not be selected bigger than the optimum burden, this will help to reduce backbreak and the damage of the remaining bench face for the next blasts is minimum.

4.3. Broken volume versus burden

The relation between calculated broken volumes from angle of breakage, burden and bench height is plotted in Figure 6 (equation 1):

$$V = K.B^2.tg\left(\frac{\theta}{2}\right) \quad (2)$$

In the regression analysis, the best fit is obtained in form of polynomial curve fitting. The shape of the curve shows that the broken volume increases when the burden increases to a certain value. Beyond this value the broken volume decreases with further increase in the burden. In this case, the curve gets its maximum at 2.4m burden value. As stated by Hagan (Hagan, 1983) that : "for a given set of blast conditions, there is an optimum burden (B_o) for which the volume of suitably fragmented and loosened rock is maximum and toe conditions are acceptable". This state was proven in the single hole test blast by some researchers such as Bilgin (1991), Rustan and Nie (1992) and it is also true for the test blasts at KT2 construction site. Visual inspection carried out after the tests showed that the fragmentation and toe condition were acceptable. From above-calculation, the optimum burden can be accepted with the value of 2.4m.

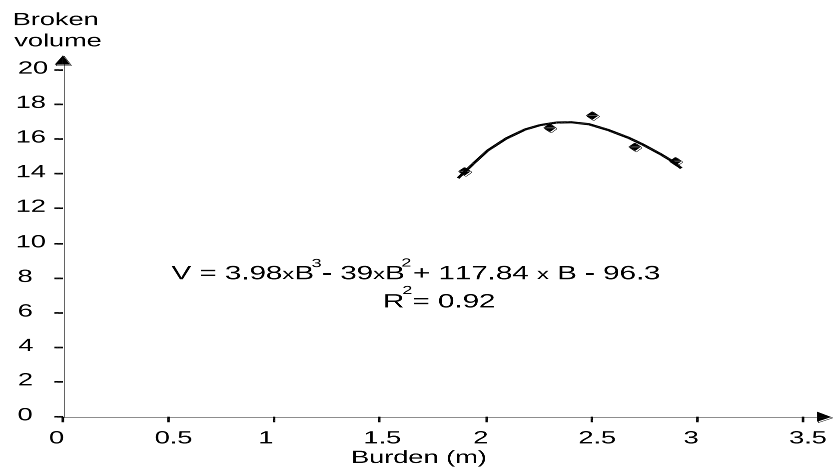

Fig. 6. Broken volume versus burden in test blasts.

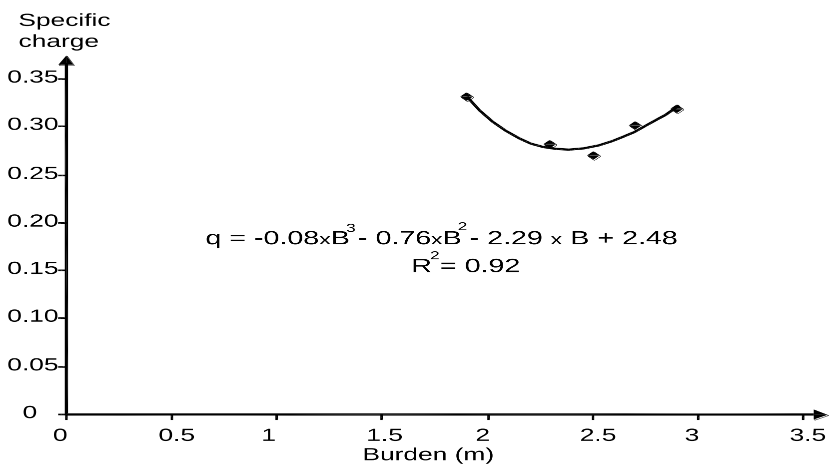

Fig. 5. Relation between specific charge and burden in test blasts.

4.4. Specific charge versus burden

The results from Table 3 also showed that the calculated specific charge is minimum when the burden is optimum. The explosive seems to expose the most useful energy with the value of optimum burden. That means the more useful energy is used to break the rock, and the less harmful effects such as vibration, flyrock on the environment. If the optimum burden is chosen for each blast design, it will be a very important step to get good fragmentation at lowest possible explosive cost (Figure 7).

4.5. Optimum burden

By solving the regression equation presented in Figure 6 to find the maximal value of burden, the optimum burden was found with the value of 2.4m corresponding with ratio of $B_0 = 31.6d$, and at this value the maximal broken volume was obtained.

5. Conclusions

The optimum burden was determined with the value equal to the bench height, and it can be classified into low bench blasting. That means, in low bench blasting, the blasthole has space for only bottom charge, and the explosive should load with maximum density in order to get maximum breaking effect.

The determination of optimum burden also leads to many advantages when it brings the maximum broken volume, minimum specific charge, and the fragmentation and toe conditions was good and acceptable. Other factors such as backbreak, specific charge will be also decreased if the optimum burden is selected, this also leads to the useful use of explosive energy in rock breaking.

This result is also useful for the specific condition at construction site when most of explosive energy will be used for breaking rock with optimum burden, and it will reduce blasting cost to the constructor.

Acknowledgement

The author would like to thank the engineers and staffs working at the KT2 construction site, Huoi Quang hydroelectric project supported us in carrying out the experiments.

References

Adhikari, G. R., 1999. Studies on Flyrock at Limestone quarries. *Rock Mechanics and Rock Engineering* 32(4). 291-301.

Ash, R. L., 1990. Design of blasting rounds. Surface Mining, ed. M. *Society for Mining, and Exploration* 2. B. A. Kennedy.

Bilgin, A., 1991. Single hole test blasting at an open pit mine in full scale: A case study. *International journal of Mining, Reclamation adn Environment* 5(4). 191-194

Fraenkel, K. H., 1954. *Handbook in rock blasting technique. Part I*. Esselte AB, Stockholm

Hagan, T. N., 1983. The influence of controllable blast parameters on fragmentation and mining costs. *Int. Symp. on rock fragmentation by blasting, Lulea, Sweden* 1. 31-51.

Langefors, U. and Kihlström, B., 1963. *The modern technique of rock blasting, ed.* 1., New York: John Wiley & Sons, Inc. 405.

Rustan, A. and Nie, S. L., 1992. New method to test the rock breaking properties of explosives in full scale. *International Journal of Surface Mining and Reclamation* 6. 191-200.

Rustan, A. and Nie, S. L., 1992. New method to test the rock breaking properties of explsives in full scale. *International journal of Mining, Reclamation adn Environment* 6(4). 191-200.

Rustan, A. and Vutukuri, V. S., 1983. The influence from specific charge, geometric scale and physical properties of homogeneous rock on fragmentation. *Int. Symp. on rock fragmentation by blasting, Lulea, Sweden* 1. 115-142.

Rustan, P. A., 1990. Burden, Spacing and Borehole Diameter at Rock Blasting. *Third International Symposium on Rock Fragmentation by Blasting*. 303-310.