Optimization of Blasting Geometry for Different Rock Types

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Abstract: Sri Lankan quarries observe their own blasting parameters and standards mainly based on experience gained over the years. Some of them are not the optimum values, due to the fact most of the quarries encounter a lot of environmental and economical problems.

In this research an attempt has been made to find the optimum burden and spacing for different rocks in Sri Lanka using a graphical relationship with spacing or burden vs cost per unit production while keeping drilling parameters such as drill hole diameter, drill hole depth, angle of drilling, bench height and explosive quantity per drill hole constant. Optimum burden and spacing means the burden or spacing which gives more production with lower cost with the ground vibration and air blast at permissible limits. To determine the ground vibration and the air blast over pressure of the optimum values at particular distances, a neural network was computed by training the data we gathered.

Key Words: Optimum spacing and burden, Unit production cost, Air blast, Ground vibration, Artificial neural network.

1. Introduction

Rock aggregates are used as a construction material for decades for road, building and bridge construction in Sri Lanka from small scale to large scale operations. Quarry operation is the major rock aggregate supplying industry in Sri Lanka. Among the areas where the rock aggregates originate, Kaluthara, Athurugiriya and Anuradhapura plays a major role. Normally rock types in these areas are deviations of Garnet Biotitic Gneisses (http://library.wur.nl/WebQuery/isric/20944).

Quarrying is a highly profitable industry in Sri Lanka. Due, lack of optimum blasting parameters and equipment, quarry owners profits suffer. Both of these should be carried out in correct way to get optimum outcome.

Drilling and blasting of rock has several stages from drilling to blasting of rock. In drilling the interrelationship of burden, Spacing and depth should be observed as indicated in imperial relationships (Jimeno et al., 1995).

Using these equations and conditions an attempt has been made to optimize blasting parameters for spacing and burden for different rock types in Sri Lanka. This will reduce the cost in different ways, mainly reducing cost of secondary breaking, optimizing powder factor and reducing environmental impacts.

This research is specially designed as a guide to mining engineers and blasting practitioners engaged in

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mining applications by givin g them optimum parameters for spacing and burden. Two quarry sites were chosen from Kaluthara and Galgamuva for this analysis with different rock types to basically revise blasting geometry specially spacing and burden along with explosives selection criteria.

2. Methodology

2.1 Site selection and data collection

Two quarries with different rock types were selected, one from Kaluthara and the other from Galgamuva. The rock type at Kaluthara quarry is Garnet Biotitic Gneiss where in Galgamuva it is charnokite. During the site visits relevant data for the optimization was collected. This consist of number of drill holes, drill hole diameter, drill hole depth, spacing, burden, charge height, charge per delay, stemming height, theoretical production from the blast, actual monthly production, drilling cost per meter, cost of explosives and Secondary cost. Together with above data, the ground vibration and air blast over pressure of blasts were also recorded along the GPS location of the point of observation. Site rock sample testing was carried out at Moratuwa university rock mechanics laboratory for specific gravity, point load and tensile strength.

2.2 Data preparation and analysis

Collected data was subjected to graphical analysis to obtain an idea of data behaviour. Graphical analysis was for actual production, cost (drilling cost + blasting cost + secondary breakage cost), max.charge per delay, base charge and column charge against burden and spacing. By analysing these graphs, the conclusion was made to draw the optimizing graph second order polynomial. The optimizing graph is drawn as cost per unit production and burden/spacing.

2.3 Ground vibration and Air blast check of the optimum values

Developed back propagation neural network is used to check the ground vibration and air blast for the optimum burden and spacing (Monjezi et al., 2011). Inputs for the neural network were burden, spacing, max. charge per delay, distance to the monitoring point from the face, point load, tensile strength, averaged specific gravity, and the outputs were ground vibration and air blast over pressure.

1. No. of input neurons: 7
2. No. of output neurons: 2
3. No. of hidden layers: 1
4. No. of hidden neurons: 18
5. No. of training epochs: 4000
6. No. of training datasets: 200
7. No. of testing datasets: 20
8. Error goal: 0.005

3. Results and Discussions

Optimum burden and spacing were calculated for Kaluthara quarry site of C.A & Co. Civil Engineering Contractors, using the graphs given below. As different diameters (64 mm, 76 mm) have been used, the optimization is done for the two diameters separately. They are shown in Figure 1,2,3,4.

The graphs are drawn as burden, spacing against the cost per unit volume. By examining the graphs the burden and spacing for the lowest cost per unit production is determined.

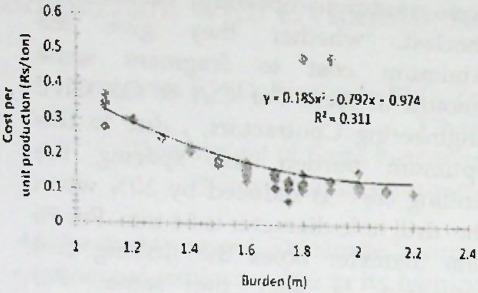

Figure 1 – Burden optimized graph for 64 mm drill hole

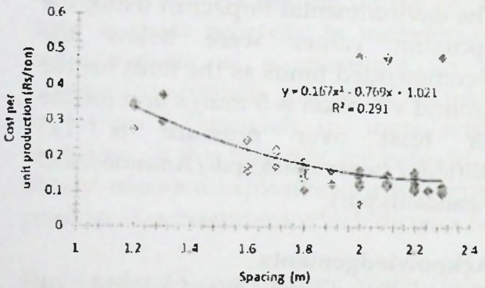

Figure 2 – Spacing optimized graph for 64 mm drill hole

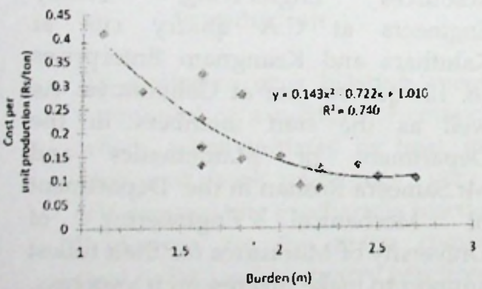

Figure 3 – Burden optimized graph for 76 mm drill hole

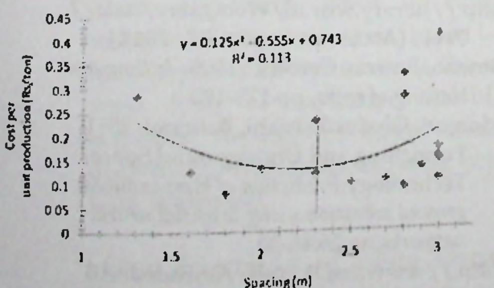

Figure 4 – Spacing optimized graph for 76 mm drill hole

The optimum geometry for Galgamuva quarry site of Keangnam Enterprises Co. Ltd shows in Figure 5 and 6

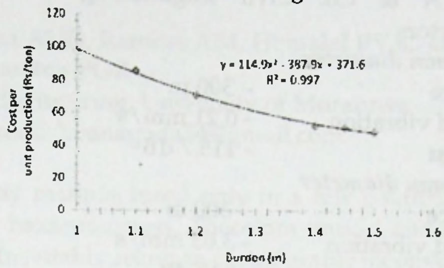

Figure 5 – Burden optimized graph for 40 mm drill hole

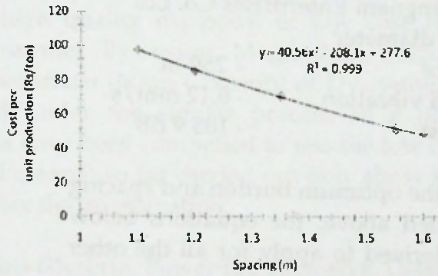

Figure 6 – Spacing optimized graph for 40 mm drill hole

When considering the accuracy of the graphs, it is at a good position as the R^2 value is very much closer to 1 in each graph. The cost comparison of the optimum burden and spacing with the ordinary values showed a great reduction in drilling cost. For C.A & Co. Civil Engineering Contractors it was reduced by 30% and for Keangnam Enterprises Co. Ltd it was reduced by 50%. The drilling cost is calculated by required drill holes in optimum geometry to produce the same production as in ordinary blasting geometry.

It is important to know about the ground vibration and the air blast induced due to this optimum burden and spacing. Using the artificial neural network, the ground vibration and the air blast generated by the optimum burden and spacing was predicted at

the closest building at the site. They are as follows.
For C.A & Co. Civil Engineering Contractors
For 64 mm diameter

Distance	- 300 m
Ground vibration	- 0.21 mm/s
Air blast	- 115.7 dB

For 76 mm diameter

Distance	- 300 m
Ground vibration	- 3.03 mm/s
Air blast	- 115 dB

For Keangnam Enterprises Co. Ltd
40 mm diameter

Distance	- 250 m
Ground vibration	- 0.12 mm/s
Air blast	- 105.9 dB

Using the optimum burden and spacing calculated above, the equations below were derived to apply for all the other rock types.

$$B_{opt} = 0.025d + 0.6 \quad (1)$$
$$B_{opt} = -2.6\rho + 9.688 \quad (2)$$

$$S_{opt} = -0.012d + 3.2 \quad (4)$$
$$S_{opt} = -8\rho + 25.44 \quad (5)$$

Where,
B_{opt} = Optimum burden (m)
S_{opt} = Optimum spacing (m)
d = Drill hole diameter (mm)
ρ = Rock density (kg/m^3)

4. Conclusions

For C.A & Co. Civil Engineering Contractors the optimum burden and spacing for 64 mm diameter are respectively 2.2 m and 2.4 m and for 76 mm diameter holes the optimum burden and spacing was respectively 2.5 m and 2.25 m. For Keangnam Enterprises Co. Ltd the optimum burden and spacing for 40 mm diameter drill holes are respectively 1.7 m and 2.5 m. Above optimum values were taken by keeping number of drill holes, and hole depth constant. With same conditions optimum values were checked, whether they give the minimum cost to fragment same amount of rock. For C.A & Co. Civil Engineering Contractors, , due to this optimum burden and spacing the drilling cost is reduced by 30% when the drill hole diameter is 64 mm. For 76 mm diameter holes the drilling cost reduction is also the same. For Keangnam Enterprises Co. Ltd that was 50%.

The environmental impact in using the optimum values were below the recommended limits as the limit for the ground vibration is 5 mm/s and for the air blast over pressure is 115 dB(http://www.cea.lk/pdf/AmendedABOPstandards.pdf).

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