Determination of the Specific Charge in Sri Lankan Quarrying Industry and Tunnelling Practice

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Abstract: At present, Sri Lanka is investheavily on the development of the country's infrastructure., facilitating the vast demand for construction materials particularly, aggregate metals. Blast fragmentation is one of the most important aspects in open pit blasting. Blasted rock should be easily loaded and transported and the rock fragments should be adequately pre-conditioned (i.e. weakened) in order to reduce the energy requirements in down-stream processes such as, crushing and grinding. In Sri Lanka, the geological parameters of rocks vary throughout the island. Currently, there is a large number of metal quarries and mining activities operating all over the country, but the lack of optimum blasting practice and specific charge selection is a drawback to achieve the optimum benefits.

In this research, an investigation on specific charge values have been carried out for the required level of fragmentation in quarrying industry and tunneling practice throughout Sri Lanka depending on geological parameters varying from region to region. Rock sample collection from various geological locations, determination of rock strength and hence, building-up a relationship between rock strength and specific charge values, experimentation of a fragmentation model have been carried out.

Keywords: Specific charge, Geology, Blasting Geometry, Fragmentation, Rock mass parameters, Fragmentation Models

1. Introduction

Specific charge shows the relationship between the volume of rock broken and the amount of explosives required for breakage. It is an indication of the strength of the rock and the energy input required for breaking, expressed in the form of amount of explosive. Specific charge varies with explosive and rock mass characteristics.

The strength of rock can be expressd by various parameters, e.g. compressive and tensile strength. Wide variance between intact rock strength and rock mass strength causes many uncertainties in large-scale mining activities. Mechanical behaviour of rock mass is highly affected by rock discontinuities changing in a wide range from microscopic cracks to regional faults.

Specific charge can be used to estimate the cost of a blasting operation and in turn to optimize the cost of down-stream operations such as loading, hauling and crushing, reducing negative effects on the environment and the cost of explosives as well. At presnt, there are a number of active quarrying and tunneling operations in Sri Lanka.

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In the Sri Lankan context, one common value is used for the specific charge as a guideline. This does not reflect the specific charge variation with geo-technical parameters. Therfore,the measured values are different in various geological regions of the country.

In this research, a comparision of specific charge values for different geological settings in Sri Lanka was made using statistical information acquired from regional quarries. A correlation was made between the specific charges and the uniaxial compressive strength for various rock types obtained from a particular geological location.

Field studies dealing with different levels of rock fragmentation under different geological settings provided an opportunity to validate a number of widely-used blast fragmentation models and predict the level of fragmentation in the SriLankan context. Most of these models make provisions to calculate the mean fragment size (x50) as well as the entire fragment size distribution. Some them are the Kuz-Ram, KCO nd JKMRC models.

2. Methodology.

For the purpose of determination of explosive specific charge in Sri Lankan quarrying and tunneling practices, initially it is required to identify the appropriate locations.

2.1 Identification of locations, data collection and determination of specific charge.

It is also important to obtain accurate information on the consumption of explosives from regions with varying geology throughout the island. It was planned to obtain rock samples representing the following areas in the island with varying geological features. Areas selected were namely, Horowpathana, Thunukkar, Vavuniya, Mihinthale, Kanthalai, Kekirawa (Ganewalpola), Thonigala, Anamaduwa, Nikaweratiya, Ambanpola, Siripura, Welikande, Karadiyatenna, Damana, Piyangala, Hirigurawa, Sangamankanda, Medawachchiya, Oddusudan, Nedunkarni, Kahalagala (Polonnaruwa), Mutur, Kaduwela, Meepe, Arangala, Padukka, Kotadeniyawa, Meerigama, Yakkala/Ambaspitiya, Kaluthara, Meegahatenna, Neboda, Thebuwana, Batepola, Hiyare, Unawatuna, Seenimodara (Tangalle), Hambantota, Walasmulla and were marked in the 1:100,000 scale Sri Lanka Geological Map.

The required information was collected from representative quarries, underground tunneling at Bogala, from the Geological Survey and Mines Bureau data base and the network of regional engineers. With the input of blast information obtained, the specific charge value adopted in metal quarries was calculated using the following equation.

$$q = \frac{Q}{B * S * H}$$

Where:

q: Specific charge (kg/m^3)
B: Burden (m)
S: Spacing (m)
H: Bench height (m)
Q: Total amount of explosive material in blast hole (kg).

For the purpose, rock samples were obtained from seven regions in Sri Lanka with different geological conditions, namely, Medawachchiya, Kaduwela, Oddusudan, Hambantota, Damana and KudaOya - NuwaraEliya.

Samples were subjected to UCS and Point Load tests at the university laboratory and uniaxial compressive strength values were calculated. The analyzed data were tabulated to show region - wise variations.

2.2 Fragment Size Prediction Using Models.

A number of engineering models have been developed to relate fragment distribution to blast design. Data from five industrial blasts from quarries with varying geological conditions located at Oddusudan, Mirijawala, Padukka, Welimada and Dodangoda were used. In this exercise fragmentation analysis was carried out using the KCO model, an extended version of Kuz-Ram Model being a widely used model in the blasting industry. Following data relating to each blast was obtained.

- Burden,
- Drill hole diameter,
- Spacing,
- bottom charge length,
- column charge length,
- Bench height,
- Blasting pattern (Staggered / rectangular),
- Type of explosive,
- Rock joint spacing,
- Dip of joint(dip out of the face/ dip into face/ strike perpendicular to face)

Standard deviation of drilling accuracy (Track drill or jack hammer), Rock density, Uniaxial Compressive Strength(UCS) and Young's Modulus were calculated.

The 50% passing particle size (X_{50}) and 80% passing size(X_{80}) were predicted by using above information and th efollowing equations.

$$X50 = AK^{-0.8}Q^{\frac{1}{6}}\left(\frac{115}{RWS(ANFO)}\right)^{\frac{19}{30}}$$

Where:

X50: Average Fragment size (cm),
A: Rock mass factor,
K: Specific charge (kg/m³),
Q: Total amount of explosive material in blast hole (kg)
RWS (ANFO): Strength of explosive used, % ANFO equivalent

$$P(x) = \frac{1}{\left(1 + \left(\frac{\ln\left(\frac{Xmax}{x}\right)}{\ln\left(\frac{Xmax}{X50}\right)}\right)^{b}\right)}$$

$$b = \left(2 * \ln 2 * \ln\left(\frac{Xmax}{X50}\right)\right) * n$$

Where:

P(x): Percent of material passing sieve size (cm)
b: curve undulation parameter
x: sieve size (cm)
x50: 50 % passing size (cm)
Xmax: Maximum in situ block size(cm)
n: Uniformity index

$$n = \left(2.2 - \frac{14B}{D}\right) \times \sqrt{\left(1 + \frac{S}{B}\right)/2} \times \left(1 - \frac{SD}{B}\right) \times \left\{\left|\frac{BCL - CCL}{L}\right| + 0.1\right)^{0.1} \quad L$$

Where:

B: Burden (m)
D: Drill hole diameter (mm)
SD: Standard deviation of drilling accuracy(m)
S: Spacing (m)
BCL: Length of bottom charge (m)
CCL: Length of column charge (m)
L: Total charge length (m)
H: Bench height (m)
P: Staggered pattern- 1.1 / Rectangular pattern – 1.0

3.Results.

3.1 Specific charge with UCS results.

The average Uniaxial Compressive Strength and average Specific Charge values for selected regions calculated after analysis are presented in table 3.1 below.

Table 3.1 - Average Compressive Strength with Average Specific Charge.

Region	UCS Value (MPa)	Average UCS (MPa)	Average Specific charge (kg/m^3)
Colombo	38.64 36.19	37.42	0.25
	38.32	38.32	0.26
Kurunegala	36.19	36.19	0.28
Oddusudan	44.28	44.28	0.32
Hambantota	56.84	56.84	0.40
Welimada	49.71	49.71	0.26
Hambantota	41.72	41.72	0.30

3.2 Relationship between Rock Strength versus Specific Charge.

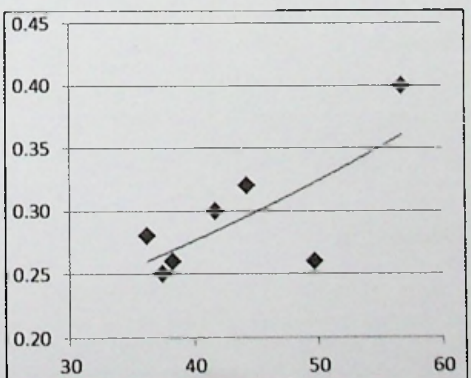

Figure 3.1 -Variation between Compressive Strength and Specific Charge

3.3 Tunnel blasting results:

Table 3.2- Specific charge for -476 m Cross Cut tunnel at Bogala Underground.

Explosive Used (kg)	Advance length (m)	Tunnel volume (m^3)	Specific charge (kg/m^3)
2593.6	83.05	423.11	6.13

3.4 KCO fragmentation model results:

The average particle size prediction using blasting and geotechnical information is presented in table 3.3 below.

Table 3.3 - KCO Model Results.

Location	Average Particle Size(cm)	Passing fraction of 50 cm sieve
Dodangoda	14.98	0.88
Mirijjawila	17.97	0.94
Oddusuddan	15.00	0.86
Welimada	16.35	0.82
Padukka	14.37	0.89

4. Discussion.

The study shows that at the identified locations with varying geoelogical features in Sri lanka rock type, hardness, joints, dip, strike, etc. of the area considerably affect the blasting results. The specific charge values, calculated by using test blast information acquired from different aggregate quarries with the assistance of GSMB were correlated with different geological locations. For quarry blasting, specific charge values varied in the range 0.2- 0.5 kg/m^3 and, for tunnelling, it was calculated as 6.0 kg/m^3 due constricted tunnel area and finer fragmentation neede to facilitate mucking. The specific charge value for Welimada region was lower than the predicted value, because control blasting had been adopted with low explosive charges due to public concern.

ANFO is the widely used explosive in Sri Lankan quarry blasting practice and, Water Gel the priming charge. The specific charge values calculated for ANFO and for a mix of ANFO with the addition of amounts of Water Gel was taken as the same, as the relative weight strength of ANFO to Water Gel was almost equal to one.

The relationships between various geo-technical factors to specific charge and blasting geometry for various locations in Sri Lanka will be highly valuable for blasting professionals in decision making when optimizing productivity. The KCO model is widely used as a fragmentation model to predict particle size and particle distribution for a particular blast. The existence of a number of software packages based on the basic concept of fragmentation models produced by the Sweden-based Swebrec Research Centre being in the forefront of rock blasting related software engineering facilitates future research in this area.

5. Conclusion

In the research, as was expected, clear geological variations were identified in different geographical locations in Sri Lanka. The average specific charge values were calculated for these different geological conditions. It was possible to build up numerical relationships of rock strength with specific charge values. It was found that higher the rock strength, higher was the specific charge required for optimum fragmentation. The results obtained in the research project will be of great significance to the Geological Survey and Mines Bureau (GSMB), the mining regulatory body of Sri Lanka as well as mining professionals. The results provide a clear guideline to better plan and organize blast rounds. It is highly recommebded to use the fragmentation model in the Sri Lankan context in oreder to achieve optimum blast design and optimum fragmentation.

Research conducted to identify the specific charges for different geological rocks was performed mainly based on the Uniaxial Compressive Strength(UCS) of rocks. However, this may cause several discrepancies in the results as UCS is only a single factor amongst a number of several geo-technical parameters. It is suggested to continue the research incorporating the influence of Rock Mass Rating (RMR) on the specific charge as an additional parameter to build up a better set of guide lines for quarry blasting as well as tunneling practice.

Hence, it will enable producing an improved computer-aided programme (Models and Software) for optimizing Sri Lankan quarrying and blasting practice.

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