Influence of Geotechnical Conditions on Explosive Specific Charge in Sri Lankan Quarrying and Tunnelling Practices

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Abstract: Quarrying and underground excavations carried out by drilling-and-blasting is the most common technique used in Sri Lankan mining practice. Although only a small amount of the explosive energy is efficiently utilized in rock blasting, the economics of subsequent processes such as loading, hauling and crushing are governed by the initial explosive impact on breakage of hard rock. Explosive consumption in the initial stage of rock breakage from the mass is expressed in terms of explosive specific charge or powder factor. Variations in geological and geo-technical parameters such as rock joint characteristics; strength of rock and rock mass rating (RMR) with varying geological characteristics is reflected in the variation of the specific charge of the explosive. Even though there is a large variation in geology over the Sri Lankan land mass only the metamorphic rock terrain has been considered, in studying the influence of geological and geotechnical properties on the determination of the explosive specific charge as an important parameter in blast planning and estimation. The paper emphasises the relationship of rock strength parameters and rock mass rating when estimating optimum explosive specific charge for economical quarrying and tunnelling practices in Sri Lankan conditions.

Key words: Specific charge, Geology, Geotechnical parameters, Fragmentation, RMR, Point load strength, Brazilian tensile strength.

1. Introduction

Blasting is one of the most challenging areas in the mining and excavation industry. Explosive specific charge is one of the key performance indicators in rock blasting, especially in the quarrying and tunnelling. The explosive specific charge shows the relationship between the volume of rock broken by the blasting and the weight of the explosives required for that particular breakage. Indirectly, it is very good indicator of the strength of the particular rock which was expressed in the form of amount of explosives required.

Blasting of rock is complicated in nature because it depends on a multitude of controllable and uncontrollable factors. Among those factors, geological and explosive characteristics are the most critical. Generally, attention has been paid to the explosive characteristics as well as only a few researches have linked geological characteristics of the rock in relation to regarding optimizing the usage of explosives. However, in this research, some major geotechnical parameters of rock such as Uniaxial Compressive Strength (UCS), Brazilian Tensile strength and Point Load strength index as well as major geological variations of Sri Lankan metamorphic terrain have been taken into consideration in relation to the explosive specific charge variation. The difficulty encountered in field work is due to the fact that the rock is neither homogeneous nor isotropic. The structural properties in the rock mass may even when the rock type is the same, changed from one part to another throughout the country. Rock jointing system in the rock exercises a dominant influence on blasting results.(S.Strelec*at el.*, 2000). To address the difficulty, Rock Mass Rating (RMR) variations also has to subject to analysis along with the explosive specific charge.

There isa large number of active quarries and few tunnelling operations in Sri Lanka located throughout the country with varying geology. Despite the varying nature of geology, in expressing and documenting the consumption of explosives, one common value(s) of explosive specific charge has been used. Thus, this has been a draw-back in achieving optimum blasting performance in rock blasting. The main objective of the present study is to derive a model showing the influence of major geotechnical parameters and Rock Mass Rating on explosive specific charge variation in Sri Lankan quarrying and tunnelling practice.

2. Methodology

In order to study the influence of Point load strength (PLS), Uniaxial compressive strength (UCS), Brazilian tensile strength (BTS) and RMR value on the variation of Explosive Specific Charge (SC) an extensive programme of visits was carried out covering a number of metal quarries. At each location, quarry bench joint systems were mapped with the collection of rock samples for further laboratory analysis. Tunnel mapping was carried out at Bogala Underground. For the purpose of studying explosive consumption pattern in relation production output, past six months production statistics were collected. Then data were subjected to following analysis procedures.

2.1 Identification of locations

Major concern about the geological variation especially the Sri Lankan metamorphic terrain had been taken into consideration while selecting the locations. All the locations are currently operating metal quarries covering different regions of the country and one tunnelling operation at BogalaGraphitemines.In addition Aruwakkalu limestone quarry was also selected as one of the locations.

The selected areas were;Horowpathana, Oddusudan, Mirijjawila, Mirigama, Galpatha, Dodangoda, Mawathagama, Pannala and Aruwakkalu.

2.2 Tests and analysis carried out

Prepared rock core samples were subjected to two laboratory tests at the university laboratory according to ISRM suggested methods such as Point load strength (PLS) index test; ISRM (1985) and Brazilian tensile strength (BTS) test; ISRM (1977). Calculation of both Point load strength & Brazilian tensile strength also followed the same ISRM methods mentioned above. Indirect calculation of Uniaxial Compressive Strength (UCS) of each specimen was calculated by multiplying the corrected point load strength index ($I_{s(50)}$) by 17 as suggested by Jayawardena (2011).

Rock Mass Rating (RMR) of each site was calculated using field-gathered data and information through joint/fracture survey of each site according to method proposed by Bieniawski (1989).

2.3 Analysis of results

Finalised data and information were analysed to build up the relationship between the explosive specific charge and the geotechnical parameters which were tested or calculated such as point load strength index ($I_{s(50)}$), unconfined compressive strength (UCS), Brazilian tensile strength (σ_t) and rock mass rating (RMR).

3. Results

Summary of final test results were tabulated as shown in following table 3.1. Then thorough statistical and regression analysis of the data set was carried out to build up the model for Explosive Specific Charge (SC) variation with the above tested factors.

Statistical and regression analysis of data using 'MINITAB' software showed a good relationship (R^2 = 0.99) among SC, PLT/UCS, BTS and RMR. However, this is valid only for the Explosive Specific Charge calculated by test blast data and not for the SC calculated from six month blasting data. The developed regression model is expressed in Eqn. 3.1below.

Table 3.1: Summery of Test results

Area	Location	Avg. Point load strength index, $I_{s(50)}$ [MPa]	Avg. UCS [MPa]	Avg. Brazilian tensile strength, σ [MPa]	Avg. Specific charge [kg/m^3]	Specific charge from test blast report [kg/m^3]	RMR rating
Mullaitivu	Oddusudan	9.07	154.11	6.77	0.16	_	78
	Thathayamalei	5.14	87.38	6.07	0.23	0.411	73
Anuradhapura	Horowpatana	9.03	153.5	7.64	0.21	0.38	92
Kaluthara	Dodangoda	7.88	133.9	10.12	0.15	0.306	84
	Galpatha	7.92	134.7	12.74	0.27	0.293	70
Hambantota	Mirijjawila	10.89	185.0	13.31	0.14	0.313	73
Kurunegala	Mawatagama	9.39	159.6	9.30	0.18	_	92
	Pannala	5.99	101.7	8.72	0.28	0.343	75
Gampaha	Mirigama	7.83	133.1	10.22	0.19	_	78
Puttalam	Aruwakkalu (Limestone)	2.46	41.82	3.52	0.34	0.337	_

Developed model is; S.C = 0.735 + 0.0191 P.L - 0.0282 B.T.S - 0.00344 R.M.R.(Equation 3.1).

Where;

S.C; Explosive Specific Charge
P.L; Point load strength (or UCS x 17)
B.T.S; Brazilian tensile strength
R.M.R; Rock Mass Rating

4. Discussion

This study was carried out to check whether there is a relationship among specific charge, rock strength (including UCS, Point load strength index and Brazilian tensile strength) and RMR rating.

As shown in the statistical and regression analysis, the research would be able to model a good relationship of explosive specific charge variation with geotechnical parameters as expressed in Eqn 3.1 above. However, this model holds valid for those explosive specific charge values calculated from test blast data and not to the values which had been calculated from six month blasting data.

According to developed regression model, the influence of Point load strength (or UCS) and Brazilian tensile strength on Explosive specific charge is more than that of RMR.

5. Conclusion

Two models have been built through the comprehensive statistical and regression analysis of laboratory test data (such as point load strength, Brazilian tensile strength and UCS), joint/fracture survey data (RMR value), actual site blasting data and test blasting data. First model based on the actual site blasting data reveals the significant influence of point load strength or UCS on the explosive specific charge whereas second model which was derived based on the test blasting data reveals the significant influence of all the factors (i.e. Point load strength/UCS, Brazilian tensile strength and RMR) on explosive specific charge. In addition to this main findings related to hard rock (metamorphic rock) quarrying, inadequacy of data with possible number of sites related to limestone quarrying and hard rock tunnelling (only one location had been found for each case such as Aruwakkalu limestone quarry of Holcim Quarry and crosscut tunnelling of Bogala mines respectively) had been a limiting factor restricting the derivation of models for limestone quarrying and hard rock tunnelling practices.

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