Flyrock Generation and Social Impact Mitigation in Local Quarrying

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Abstract

Quarrying industry in Sri Lanka has expanded widely due to the rapid increase in the demand for basic raw material in the construction industry. Thus, large number of quarries are operating throughout the country. Major concerns related to these activities are the social impact and the impact on workers' health and safety. While blasting is carried out, blasted rock fragments could be projected out of the set boundaries (flyrock) and is a threat to human safety. Although precautionary measures and mitigation techniques have been in use for many years, impacts on worker's safety and health have not shown any resulting reduction. This study focusses on many strategies to control flyrock and introducing controllable parameters (e.g. powder factor) based on past reports of accidents and related engineering parameters. Three different areas were selected based on the availability of data, considering consequences, distances and the powder factor for the study. Accordingly, collected data was tabulated for ease of analysis and buffer the distance for focused area was calculated statistically. Relationship of area of hazardous zones with different explosive charge was determined using statistical tools correlation co-efficient and R square and allowable powder factor for calculated buffer zone was determined based on statistical data. Recommendations and conclusions were made based on the calculated data.

Keywords: Consequences, Powder factor, Rock blasting, Statistical analysis

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1 Introduction

During mining and construction activities in Sri Lanka such as road construction, tunnelling projects, irrigation channels and rock aggregate requirement are totally achieved by rock blasting. Although mechanical excavators can be used to remove the top soil, blasting is considered as inevitable method to fragment hard rock. In local quarry blasting, radial cracks inside the blasthole are made by electric detonators and eventually expanded by explosive gases releasing its chemical pressure under high pressure [1]. In many blasting activities a large portion of energy is wasted [2] bringing about several environmental impacts such as air blast, vibration, flyrock [3,1]. Among these impacts, flyrock is the main cause of accidents ranging from small to fatal injuries [10]. Formation of flyrock is unpredictable and several factors such as the geology, blast pattern, burden, spacing, stemming length, blasthole diameter, hole angle, explosive charge, blaster experience are affected for flyrock formation [1]. Among them, except geology others are amenable to engineering solution (mitigation techniques). Due to the rapid increase in demand for aggregates in Sri Lanka, issuing metal quarry licenses have increased during past years. [6]. Therefore, several environmental issues are encountered at quarries. However, only a limited number of concerns towards health of the workers and surrounding people, have been addressed. Thus, recognition, evaluation and control of consequences from flyrock around quarries have a vital aspect in avoiding such issues and to speed up the industrialization process without delays. In Sri Lankan mining industry, flyrock mitigation techniques, erection of wire mesh, heavy covering using blasting mats and tarpaulin are common methods. Despite the application method, significant number of accidents have been reported. Hence, demarcating a zone of flyrock hazard in quarrying activities will act as an initial step in risk convey by potentially improving workers safety.

2 Methodology

2.1 Site Selection

Two provinces; Western and Uva representing an urbanized area and a rural area respectively were the focus of the study.

According to the Census 2012 [5], population of Western province and Uva province were respectively 5,851,130 and 1,266,463. The provinces were selected to make ease of comparison of flyrock accidents under urbanized and rural categories.

2.2 Data Collection

Relevant data related to flyrock accidents were collected from the GSMB (Geological Survey and Mines Bureau) and from a number of quarries though a questionnaire. The data obtained further narrowed down the research area to B grade quarrying activities (License issued by GSMB is categorized into three grades according to the monthly production, machinery used and blasting type). From the data obtained, fields of interests namely flyrock distance, explosive quantity and consequences were chosen for further analysis. The data which have been chosen were used to fill the interested field and subjected to analyse under three categories namely the consequences, distance of flyrock and specific charge vs distance.

2.3 Data Analyzing

Under the three categories; the consequences, flyrock distance and powder factor was analysed.

2.3.1 Analysis of the Consequences

All consequences from the reported accidents are identified. It was narrow down to six main categories; house damage, fatal accidents, property damage, vehicle damage, small injury, in order to identify majority consequences with region specified. Accordingly, method for mitigation majority of consequences was identified.

2.3.2 Flyrock Distance Analysis

All given data was tabulated according in ascending or descending order so as to tabulate the frequency table. Data to be statistically analysed were from year 2015-2018. Frequency diagram for given data set was tabulated to get the highest frequency and to anticipate sample distribution. Based on the availability of distances, non- parametric test for urban and rural areas was adopted making relevant background for analysis. Statistical Software "SPSS" was used for all analysis and based on the results, calculation was done.

Considering the maximum flyrock distances, safe distances to conduct blasting can be predicted though the statistical analysis. Furthermore, the engineering parameter; powder factor can be predicted for predicted safe boundary.

2.3.3 Powder Factor Analysis

Powder factor is defined as the amount of explosives needed to blast one cubic meter volume of rock (kg/m^3). For the analysis of powder factor, rural area was only selected based on availability of data. Considering the relationship (linear) of powder factor vs flyrock distance, allowable powder factor for such area was calculated.

3 Results and Discussion

3.1 Consequences Results

According to the categorized accidents happened due to flyrock, more prone is related to house damages. Figure 1 shows the percentages for each category.

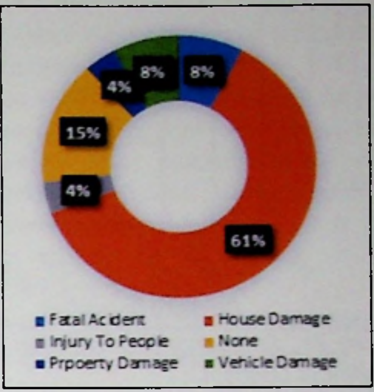

Figure 1: Graphical Representation of Consequences.

3.2 Flyrock Results

For the analysis of distance, general background was generated.

3.2.1 General Background

- All the flyrock accidents could happen any time and there is no significant relationship with time. Time is independent of the maximum flyrock distance.
- Same scale blasts and blasting techniques were adopted for every blast due to considering "B" grade quarrying only.
- There is no influence from geological intersections such as faults, joints and cavities.
- For urban areas, Colombo, Gampaha were considered, whereas Badulla and Monaragala were considered as rural areas.

Table 1 shows the cumulative percentages for Western province and Table 2 shows the overall analysis considering the accident happened in both Uva and Western provinces.

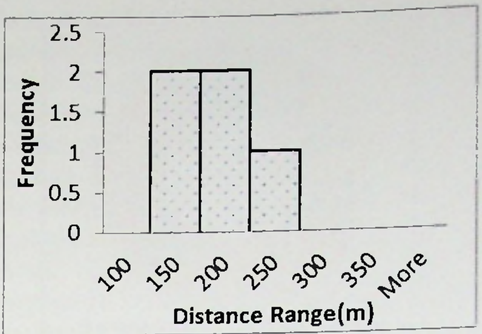

Figure 2: Frequency Distribution for Gampaha District.

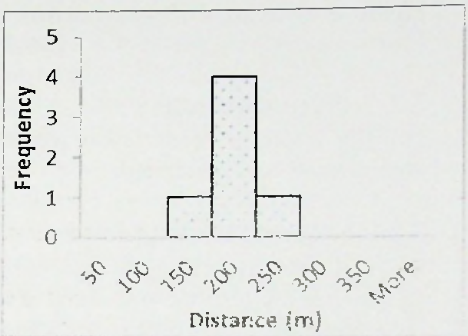

Figure 3: Frequency Distribution for Colombo District.

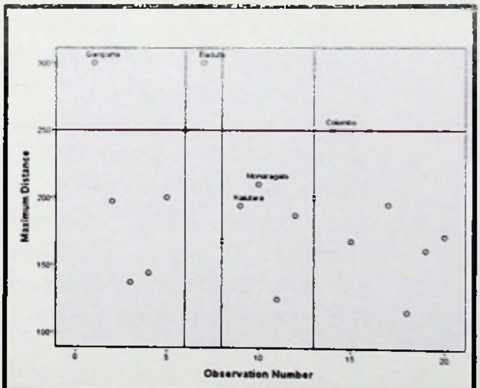

Figure 4: Overall Analysis of Distance

Table 1: Analysis of Distance for Western Province.

Overall Distances		
Distance Range (m)	Frequency (%)	Cumulative Frequency (%)
0-50	0	0
50-100	0	0
100-150	23	23
150-200	38	61
200-250	08	69
250-300	23	92
300-350	08	100

Table 2: Overall Analysis for Western and Uva Provinces.

Overall Distances		
Distance Range (m)	Frequency (%)	Cumulative Frequency (%)
0-50	0	0
50-100	0	0
100-150	20	20
150-200	40	60
200-250	15	75
250-300	15	90
300-350	10	100

3.2.2 Discussion of Results

According to the plot shown in Figure 4, 250m was taken as the buffer distance. Here the number of accidents occurred at the given distance was taken as factor of interest.

Considering the plot, two accidents have taken place at 300 m whereas 250 m shows 3 accidents. However, 250 m was chosen allowing 10 % of marginal probability based on cumulative frequency analysis mentioned in the Table 2 and Table 3.

Based on the urbanization of Colombo and Gampaha, this buffer distance can be further reduced to the range of

200-250 m (Figure 3 and 4). However, specific low margins cannot be recommended due to the uncertainty of accidents.

3.3 Powder Factor

Powder factor vs Maximum flyrock distance is plotted to calculate allowable powderfacor for safe distance.

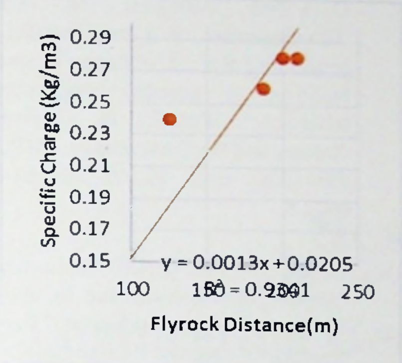

Figure 5: Powder Factor vs Flyrock Distance.

R square	0.9341
District	Monaragala
Buffer distance	250 m
Allowable powder factor	0.30 Kgm^{-3}

3.4 Limitation

Based on the availability of data, marginal probability for buffer distance was taken as 10%.

In this study, powder factor analysis was only done for Monaragala based on available accident data.

Engineering parameter considered was limited due to availability of data and time constraints.

3.5 Further Direction

This study can be extended to other provinces to increase significance of the study.

Other engineering parameters such as burden, spacing ratio, delay pattern and hole diameter with flyrock distance can be analyzed concurrent to this study.

The study can be simulated for other special area of study such as vibration and air blast pressure to demarcate overall analyzed buffer zone for quarrying industry.

4 Conclusion

House damage can be considered as frequently occurring damage, and allowable powder factor for 250 m buffer distance should be slightly less than 0.3.

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