Prediction of Air Over Pressure due to Blasting in Tropically Weathered Granite Quarries in Malaysia with Multi-Variable Regression Analysis

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Abstract

World class infrastructure is developed at Johor Bahru city of Malaysia. Granite is the most commonly available rock for production of aggregates. Blasting is essential for breaking of rocks. Environmental effects due to blasting are associated with flyrock, ground vibration, air over pressure and dust. Some of the aggregate quarries are proximate to human habitation. Many complaints are received by quarry management from different quarries by nearby habitants for (noise) air over pressure due to the blasting. This study was undertaken to investigate different parameters which contribute to air over pressure. At the end of study, multi variable regression analysis used for correlating with air over pressure (AOp) developed. Tropically weathered granite can be classified as fresh, slightly weathered, moderately weathered, highly weathered and completely weathered. Data were collected for 110 blasts from three quarries consisting of hole diameter (mm), burden(m), stemming length(m), charge per meter(kg/m), powder factor(kg/m^3), joint aperture (mm), maximum charger per delay (kg), distance of blast from monitoring point (m) and measured AOp. Sensitivity analysis varies from 0.82 to 0.98. The data is analysed with multi variable regression analysis (MVRA) and equation was developed for predicting AOp with 8 input parameters. R^2 with predictor equation and measured value shows 0.66.

Keywords: Charge per meter, Joint aperture, Maximum charge per delay, Powder factor, Sensitivity analysis.

1 Introduction

Malaysia shall achieve shortly status of developed nation from developing nation status. Various infrastructure activities are planned in Selangor, Perak, Sarawak, Terengganu, Johor, Negeri Sembilan which is resulting in socioeconomic impact. Industrial and economic activities depend on construction sector. Construction sector is a back bone of which contributes for basic infrastructure in Malaysia. Demand for housing is increasing in urban areas due to increase in per capita income of Malaysian population. Concrete is manufactured in bulk for which requires aggregates and manufactured sand are required. Granite aggregates play important role in the development of Johor Bahru, Kuala Lumpur, Penang and Selangor region. Several geotechnical studies have been carried out on regional as well as local faults in granite [1-4]. Aggregate quarries need blasting for breaking granitic rock. Due to the tropical climate there is weathering effect where rock mass properties are affected [5-7]. Quarry management must deal with complaints received from surrounding aggregate quarries due to environmental adverse effects created by blasting which include air overpressure, ground vibration and flyrock [8-10]. This study was carried out at three aggregate quarries situated near Johor Bahru focused on air over pressure due to rock blasting.

2 Methodology

2.1 Selection of Input Parameters

Input parameters were selected based on former research work [10-16] and sensitivity analysis. The maximum charge per delay (*C*) in kg, and distance between monitoring point and blasting face (*D*) in m, and hole diameter (*d*) in mm has direct impact on AOp. With increase in hole diameter AOP is increased. In three granite quarries as hole diameter is different, there is a variation in blast geometry as well as Charge Per Meter (*CPM*) and hence the same is selected. Burden (*B*) in m has direct impact on air over pressure. Lower the burden higher is air over pressure (*AOp*) Stemming height (*ST*) in m has indirect correlation with air over pressure. With increase in stemming height, AOp is reduced to suppressing effect of gas pressure wave. The *CPM* in kg/m has direct relationship with AOp such that when CPM is increased, AOp is also increased. Powder Factor (*PF*) in kg/ m^3 is selected as it is known from various researchers that with increase in (*PF*) there is increase in AOp. The Joint Aperture (*JA*) is measured in mm which is the shortest distance between joint surfaces. Weathered granite is found to have variable joint aperture [17].

2.2 Sensitivity Analysis

A sensitivity analysis was carried out to identify the relative influence of each parameter in the neural network system by the cosine amplitude method [18]. To apply this method, all data pairs were expressed in common X-space. The data pairs used to construct a data array *X* are defined by Equation 1:

$X=\{x_1, x_2, x_3..., x_i,..., x_n\}$. $X=\{X_1, X_2, X_3 ..., X_i, ..., X_n\}$ ....Eq.(1)

The elements x_i in the array *X* are a vector of length *m*, that as Equation 2:

$xi=\{xi_1,xi_2,xi_3...,xi_m\}$.$xi=\{xi_1,xi_2,xi_3...,xi_m\}$.......................................Eq.(2)

Each of these data pairs can be trained as a point in *m*-dimensional space, where each point requires *m*-coordinates for a full description. Thus, in the space pair, all the points are associated with the achieved results. The following equation illustrates the strength of the relation (r_{ij}) between the dataset X_i and X_j (Equation 3).

$$r_{ij} = \frac{\sum_{k=1}^{m} x_{ik} \cdot x_{jk}}{\sqrt{\sum_{k=1}^{m} x_{ik}^2 \sum_{k=1}^{m} x_{jk}^2}} \quad \text{Eq.(3)}$$

Figure 1 shows sensitivity analysis of each input parameter with respect to measured AOp and sensitivity analysis varied from 0.82 to 0.98. Each input parameter shows substantial sensitivity with AOp.

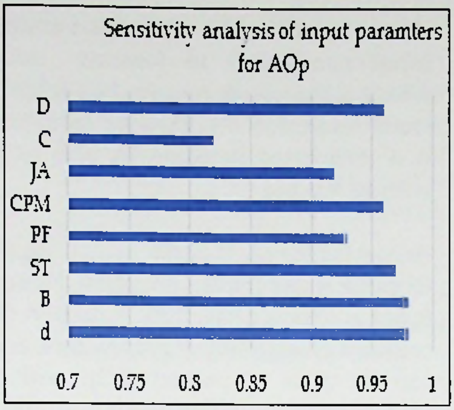

Figure 1: Sensitivity Analysis of Input Parameters for AOp.

2.3 Measurement of AOp

Seismographs are placed at safer distance in front of direction of blasting face and placed at monitoring point as shown in Figure 2. GPS reading of monitoring point and blasting face is noted to calculate distance between monitoring point and blasting face.

Figure 2: Seismograph at Monitoring Point.

2.4 Measured Input Parameters

From three quarries, total of 110 data were collected. Table 1 shows minimum, maximum and average values for each parameter. There are 8 input parameters and one output AOp.

Input Parameters:

The minimum, maximum and average Hole diameter (*d*) are 76, 102, 86.9 mm respectively.

The minimum, maximum and average Burden (*B*) are 2.1, 3.9, 2.8 m respectively.

The minimum, maximum and average Stemming length (*ST*) are 1.5, 4.5, 3.10 m respectively.

The minimum, maximum and average Powder Factor (*PF*) are 0.22, 0.86, 0.46 kg/m^3 respectively.

The minimum, maximum and average charge / m (*CPM*) are 3.66, 9.81, 5.88 (kg/m) respectively.

The minimum, maximum and average Joint aperture (*JA*) are 2, 38, 17.63 (mm) respectively.

The minimum, maximum and average Maximum charge per delay (*C*) are 19, 512, 152.08 (kg) respectively.

The minimum, maximum and average Distance (*D*) are 200, 450, 279.91 (m) respectively.

Coefficents for d, B, ST, PF, CPM, JA, C and D are dB/mm, dB/m, dB/m, dB/(kg/m^3), dB/(kg/m), dB/mm, dB/kg and dB/m respectively for developing linear equation for prediction of AOp.

2.5 Output Parameter:

The minimum, maximum and average Air Over pressure (AOp) are 93.8, 142.3, 128 (dB) respectively.

3 Results and Discussion

3.1 Multi Variable Regression Analysis:

The Multiple Variable Regression Analysis (MVRA) technique can be applied to obtain the best-fit equation when there is more than one input parameter. In general, the objective of the MR method is to produce a relationship between input and output parameters. Ceryan et al. (2012) stated that as long as inputs have acceptable correlations or determinations with output(s), they can be used as inputs in predictive models.

Following linear equation was developed with MVRA based on Table 1.

AOp = -0.07524*d*+ 1.563742 *B*+ 0.322136 *ST* -2.13345 *PF* -1.78046 *CPM* -0.0501 *JA* + 0.40.1652 C + 0.045811 *D* ....Eq.(4)

Table1: The Variation Parameters and Coefficient.

Variable parameters	Coefficients	Unit for coefficient
d	-0.07524	dB/mm
B	1.563742	dB/m
ST	0.322136	dB/m
PF	-2.13345	dB/(kg/m^3)
CPM	-1.78046	dB/(kg/m)
JA	-0.0501	dB/mm
C	0.401652	dB/kg
D	0.045811	dB/m

R^2 is 0.66 with respect to measured value.

Table 1 shows eight input parameters viz *d, B, ST, PF, CPM, JA,* C and *D*. Measured AOp with seismograph is the output. Minimum, maximum and average value of each input and output parameters are given. Sensitivity analysis is given in Figure 1. Table 1 shows coefficients of each variable input parameters to forecast AOp which is the result required to achieve study objective. Following equation was developed between JA and AOp with R^2 = 0.144

AOp = 0.1365 JA +122.62 ....Eq.(5)

R^2 value is low for this equation. Hence, it not a strong corelation. Equation (4) contains all eight input parameters, and can be used to predict AOp with a higher accuracy (R^2 = 0.66).

4 Conclusion

1. *d, B, ST, PF, CPM* are blast design parameters. *JA* is indicates degree of weathered granite and was evaluated with respect to AOp.
2. Sensitivity analysis of each parameter was carried out varying from 0.82 to 0.98. *d* shows a maximum sensitivity of 0.98.
3. The empirical linear relationship was developed with coefficients and input variable parameter.
4. Further analysis can be done with artificial intelligence.
5. Following linear equations were developed:

AOp = 0.1365 JA +122.62 and R^2= 0.144

AOp = -0.07524d+ 1.563742 B+ 0.322136 ST -2.13345 PF -1.78046 -0.0501 JA + 0.401652 C + 0.045811 D and R^2= 0.66 indicating all combined paramters provides better result for prediction of AOp.

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