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Effects of controllable blasting variables on number of boulders generated after blasting in Ratcon and NSCE quarries, Ibadan, Oyo State, Nigeria

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Abstract

The research work examines the effects of controllable blasting variables on number of boulders generated after blasting. The objective of the research was achieved through collection of data related to blasting which are drill hole depth, drill hole diameter, burden, spacing, average charge per hole, and specific charge. The collected data were analysed statistically using both Microsoft Excel Software and SPSS Software. The result of the analysis reveals that all the input controllable blasting variables which are drill hole diameter (X_1), drill hole depth (X_2), hole spacing (X_3), burden (X_4), average charge per hole (X_5), specific charge(X_6) that participated as independent variables in the models are found to be significant and the R^2 values obtained from the graph show a very strong correlation between the number of boulders generated after blasting and the input variables except that of drill hole diameter which shows a very weak correlation. The equation generated using the SPSS could be used to determine number of boulders generated after blasting.

***Keywords**: Controllable blasting parameters, Blast-hole diameter, Blast-hole depth, Spacing, Burden, Number of boulders generated after blasting, Specific charge, SPSS.*

1 Introduction

Basically, four stages are involved in surface mining of hard rock which is drilling, blasting, loading and hauling. The overall cost of production is highly dependent on the cost of drilling and blasting.

Excavation in competent rock demands considerable amounts of energy. Whether the rock is to be extracted to obtain its minerals, to serve as a construction material, or as part of a construction work, the process of rock excavation necessarily implies breaking the target rock to desired fragments. This is the part of the excavation process where the use of explosives plays a fundamental role [1]. The large amount of energy that relatively small quantities of explosives can liberate has made blasting the most universal method to excavate in almost any kind of rock. Energy liberated from the chemical reactions of explosives in the form of high temperature and high pressure gases is partly utilized to create fractures, fragmentation, and move the rock.

In the traditional approach blasting is viewed as a sub-process in mining and its main objective is to fracture the in situ rock mass and prepare it for efficient digging and hauling. Hence, blasting results are often evaluated and optimised based on the needs of its subsequent mining operations such as loading and hauling while maintaining pit slope stability and safety standards. Blast results are often considered good when they ensure good digging and loading operations while maintaining the safety and environmental standards [2].

A blasted rock muckpile and the fragment sizes within it are very important for the mining industry since they affect the downstream processes from hauling to crushing. The size distribution of the blasted muckpile can be predicted by a variety of semi empirical models which are based on blast design parameters, such as burden, spacing, drill-hole diameter, bench height and explosives consumption. Despite their few limitations, models are commonly used, since they provide reasonable trends to evaluate changes in blast design parameters. The optimization of the final fragment on a cost basis must result in the minimum total cost that the drilling and blasting design parameters can generate. Generally, the cost of drilling is the sum of two major components, capital and operational cost, while the blasting cost consists of mostly the cost of explosives, blasting accessories and labour. It is common for mine operators to seek the optimum drilling and blasting cost. However, when no fragment specifications are provided, this is a vague target. Similarly, it is quite common for mine operators to be concerned with fragmentation only when difficulties in drilling and loading are encountered, or when a large amount of oversize is produced, resulting in a general loss of productivity in the crusher and/or secondary blasting. It is desirable to have a uniform fragment size distribution, avoiding both fines and oversizes. To achieve this controllable blasting design variables have to be properly taken care of. This research work was carried out to determine effects of controllable blasting variables on number of boulders generated after blasting by generating statistical model.

1.1 Description of the study areas

The study areas are located at Ibadan, Oyo State, Nigeria. The two quarries used for this research are NSCE quarry and Ratcon quarry. These two quarries produce granite aggregates of various sizes such as 1", ½", ¾", lumps and quarry dust. The two quarries are in full operation.

1.2 Geology of the study area

Basement complex underlines virtually every part of the country this was recognized by using radiometric dating in the West African craton to which the Nigerian Basement complex belongs but the basement occur mainly in the South-Western and North Central part of Nigeria. It also extends Western-wards and is apparently continuous with the Precambrian rocks of Dahomey [3]. The basement complex rocks of Nigeria, based on their petrology are composed predominantly of five classes namely: Migmatite gneiss, Schist, Charnockitic rocks, older granites and non-metamorphosed dolerite dykes.

Sedimentary rocks predominantly compose of sands, sandstones and limestone; cover about half of the surface of Nigeria. Crystalline igneous and metamorphic rocks generally referred to as the basement rock cover the rest of the country.

Oyo State is underlain by Pre-Cambrian rocks which forms part of the Basement complex of South Western Nigeria [4], [6], [7]. Fig. 1 shows the geological map of Nigeria.

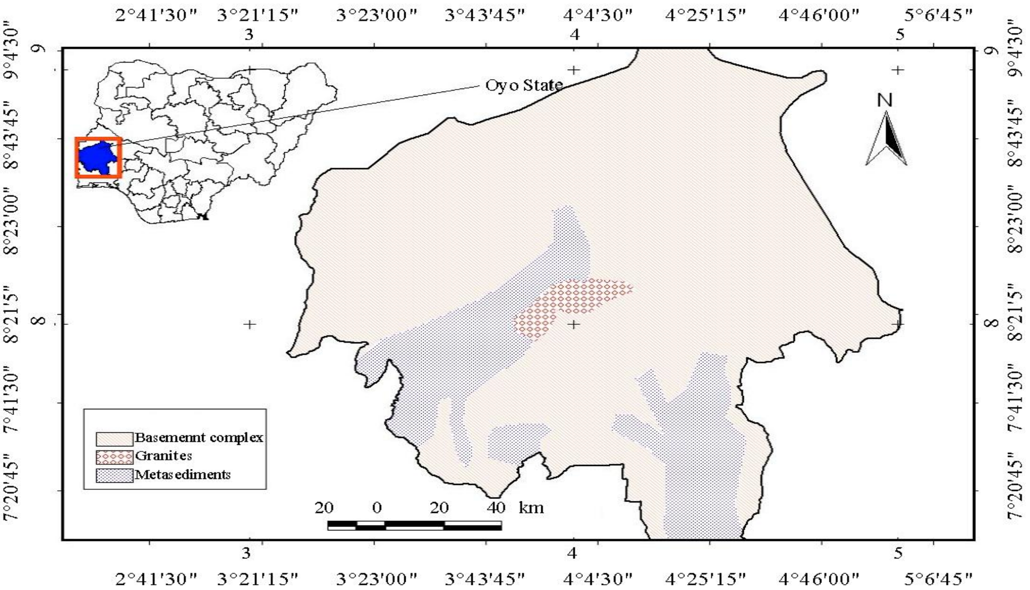

Fig. 1: Geological Setting of Oyo State (After [7])

2 Materials and methods

2.1 Data collection and analysis

Data that is blasting parameters (blast-hole diameter, blast-hole depth, spacing which defined as the distance between holes in any given row [8], and burden which is defined as the distance between the individual rows of holes [8] among others) were obtained from the study areas by collection of both past blasting records and direct recording during the witnessed blasting operations and the data were analysed using statistical tools. Thirty blasting records from the study areas were obtained.

3 Results and discussion

Table 1 shows the result of blasting variables obtained from the field. This result was used in correlating the blasting variables with number of boulders generated after blasting and in generating the model.

Table 1: Blasting Variables Obtained from Ratcon and NSRC

X_1	X_2	X_3	X_4	X_5	X_6	Y_1
76.2	9	2.3	2.2	20.50	0.32	20
76.2	10	2.3	2.3	22.50	0.43	25
88.9	12	2.6	2.5	24.17	0.31	25
76.2	12	2.6	2.4	23.20	0.31	30
88.9	15	2.6	2.4	27.20	0.29	30
88.9	15	2.6	2.6	27.20	0.27	30
76.2	9	2.3	2.1	20.50	0.47	20
76.2	10	2.3	2.3	22.50	0.43	20
76.2	10	2.3	2.3	22.50	0.43	25
76.2	9	2.3	2.3	20.50	0.43	20
76.2	9	2.3	2.2	20.50	0.45	25
76.2	9	2.3	2.1	20.50	0.47	20
88.9	15	2.6	2.1	27.20	0.33	20
88.9	12	2.6	2.2	24.17	0.35	25
76.2	9	2.3	2.3	20.50	0.43	20
76.2	9	2.3	2.3	20.50	0.43	25
76.2	10	2.3	2.3	22.50	0.43	25
88.9	12	2.6	2.4	24.17	0.32	20
88.9	12	2.6	2.5	24.17	0.31	20
88.9	15	2.6	2.6	27.20	0.27	20
76.2	3	1.5	1.1	5.94	1.20	10
76.2	3	2.0	1.8	6.00	0.56	10
76.2	3	1.5	1.5	5.94	0.88	10
76.2	3	1.5	1.5	5.94	0.88	6
76.2	3	2.0	2.0	6.00	0.50	6
76.2	3	2.0	1.8	6.00	0.56	10
76.2	3	1.5	1.4	5.94	0.94	10
76.2	3	1.5	1.5	5.94	0.88	10
76.2	3	2.0	2.0	5.94	0.50	6
76.2	3	1.5	1.5	6.00	0.89	6

Fig. 2 shows the plot of number of boulders generated against drill-hole diameter, coefficient of correlation between them is 0.198 indicating very weak correlation between them. The equation of the graph is shown in Equation 1.

$$N_{BG} = 0.7542e^{0.0388\varnothing} \quad (1)$$

where N_{BG} is the number of boulders generated after blasting, e is the exponential function and $\varnothing$ is the blast-hole diameter in mm.

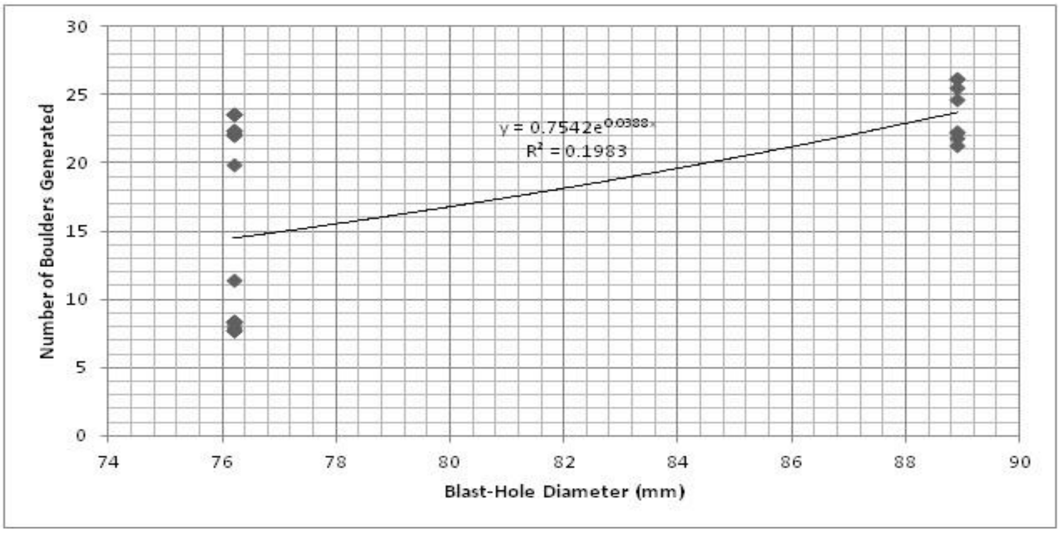

Fig. 2: Number of Boulders Generated against Blast-hole Diameter

Fig. 3 shows the result of correlation between the number of boulders generated and drill-hole depth, coefficient of correlation is 0.8545 indicating strong correlation between them.
The equation of the graph is shown in Equation 2.

$$N_{BG} = 6.7429e^{0.1062H} \quad (2)$$

where N_{BG} is the number of boulders generated after blasting and H is the blast-hole depth in m.

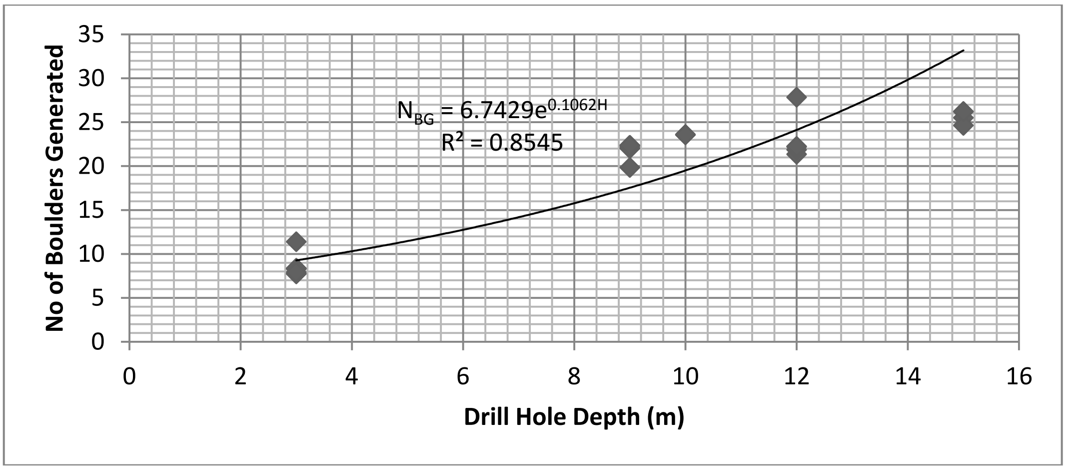

Fig. 3: Number of Boulders Generated against Drill Hole Depth

Fig. 4 shows the relationship between number of boulders generated and spacing, the coefficient of correlation between them is 0.7795 indicating strong correlation between them.
The equation of the graph is shown in Equation 3.

$$N_{BG} = 1.4942e^{1.0972S} \quad (3)$$

where N_{BG} is the number of boulders generated after blasting and S is the blast-hole spacing in m.

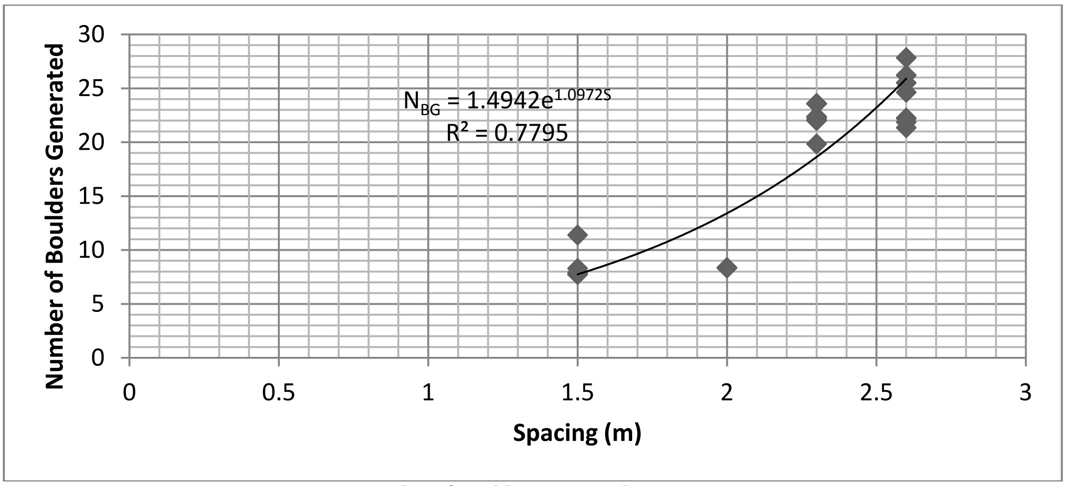

Fig. 4: Number of Boulders Generated against Spacing

Fig. 5 shows the relationship between number of boulders generated and burden, coefficient of correlation between them is 0.61 indicating slightly strong correlation between them. The equation of the graph is shown in Equation 4.

$$N_{BG} = 2.6481e^{0.9025B} \quad (4)$$

where N_{BG} is the number of boulders generated after blasting and B is the drill-hole diameter in m.

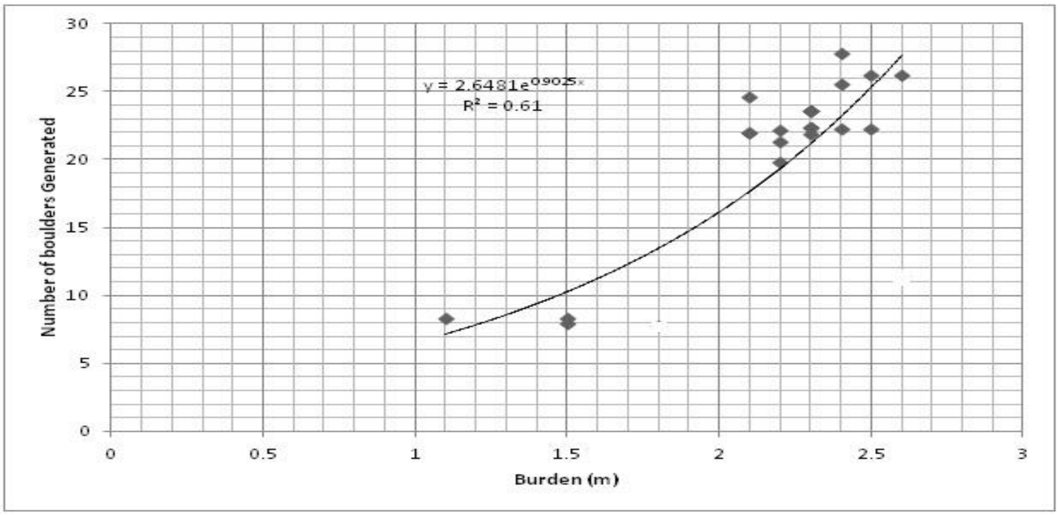

Fig. 5: Number of Boulders Generated against Burden

Fig. 6 shows the graph of number of boulders generated and average charge per hole, the coefficient of correlation between them is 0.9371 indicating very strong correlation between them. The equation of the graph is shown in Equation 5.

$$N_{BG} = 6.3717e^{0.0554A_{CH}} \quad (5)$$

where N_{BG} is the number of boulders generated after blasting and A_{CH} is the blast-hole diameter in kg/m.

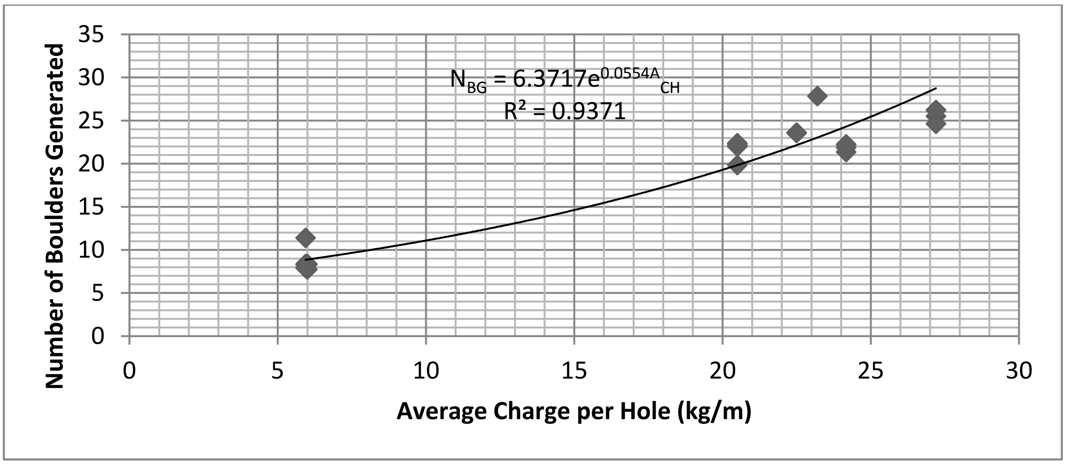

Fig. 6: Number of Boulders Generated against Average charge per Hole

Fig. 7 shows the plot of geometric volume of blast and specific charge, the coefficient of correlation between them is 0.6016 indicating slightly strong correlation between them and they are negatively correlated. The equation of the graph is shown in Equation 6.

$$NBG = 37.339e^{-1.601S_C} \quad (6)$$

where N_{BG} is the number of boulders generated after blasting and S_C is the blast-hole diameter in kg/m^3.

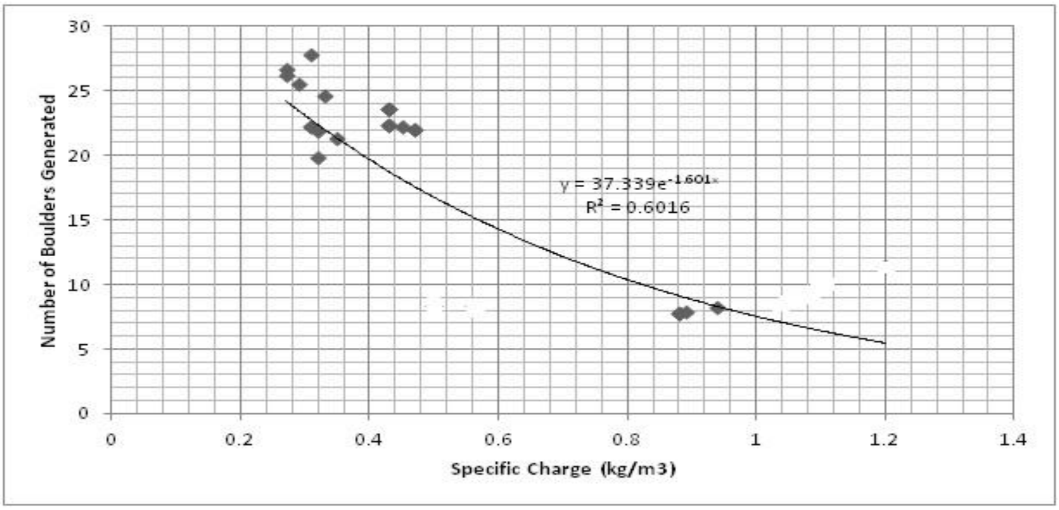

Fig. 7: Number of Boulders Generated against Specific Charge

3.1 Model

The value of R^2 is 0.876 showing that the six predictors entered in the regression analysis account for 87.6% of the variation in the number of boulders generated after blasting and F associated with this value is 26.996 this is greater than one, this show that the generated model is better at predicting number of boulders generated after blasting rather than using means as the best guess. All the input controllable blasting variables which are drill hole diameter (X_1), drill hole depth (X_2), hole spacing (X_3), burden (X_4), average charge per hole (X_5), specific charge(X_6) that participated as independent variables in the models are found to be significant. Table 2 shows the computation for the model.

$$Y_1 = 1.466 - 0.492X_1 + 1.157X_2 + 10.076X_3 + 5.124X_4 + 0.246X_5 + 18.167X_6 \quad (7)$$

Table 2: Model Computation

Model	Unstandardized Coefficients		Standardized Coefficients			Correlations		
	B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1(Constant)	1.466	27.218		.054	.958			
X_1	-.492	.216	-.360	-2.283	.032	.428	-.430	-.168
X_2	1.157	1.062	.641	1.090	.287	.879	.222	.080
X_3	10.076	7.886	.516	1.278	.214	.829	.257	.094
X_4	5.124	6.290	.259	.815	.424	.802	.167	.060
X_5	.246	.531	.266	.462	.648	.914	.096	.034
X_6	18.167	12.442	.560	1.460	.158	-.735	.291	.107

a. Dependent Variable: Y_1

3.2 Model explanation

Drill-hole Diameter (-0.492): This value indicates that as the drill-hole diameter increases by one unit, number of boulders generated increases by 0.492 units. This interpretation is possible if the effects of other variables in the model are kept constant. The t-test (-2.283) associated with this value shows that it is significant. The drill-hole diameter is making significant effect on number of boulders generated after blasting.
Drill-hole Depth (1.157): The value is an indication that as the drill-hole depth increases by one unit, number of boulders generated increases by 1.157 units. This interpretation is possible if the effects of other variables in the model are kept constant. The t-test (1.090) associated with this value shows that it is significant. The drill-hole depth has significant effect on number of boulders generated after blasting.
Spacing (10.076): The value is an indication that as the hole spacing increases by one unit, number of boulders generated after blasting increases by 10.076 units. This interpretation is possible if the effects of other variables in the model are kept constant. The t-test associated with this value is 1.278 which shows that it is significant.
Burden (5.124): The value is an indication that as the burden increases by one unit, number of boulders generated after blasting increases by 5.124 units. This interpretation is possible if the effects of other variables in the model are kept constant. The t-test (0.815) associated with this value indicates that it is having significant effect on the number of boulders generated after blasting.
Average Charge per Hole (0.246): The value is an indication that as the average charge per hole increases by one unit, number of boulders generated after blasting increases by 0.246 units. This interpretation is possible if the effects of other variables in the model are kept constant. The t-test (.462) associated with this value indicates that it is having significant effect on the number of boulders generated after blasting.
Specific Charge (18.167): The value is an indication that as the specific charge increases by one unit, number of boulders generated after blasting increases by 18.167 units. This interpretation is possible if the effects of other variables in the model are kept constant. The t-test (1.460) associated with this value indicates that it is having significant effect on the number of boulders generated after blasting.

4 Conclusion

From the results of the research the following conclusions were drawn:
Out of all the controllable parameters obtained from the field only the specific charge per drill-hole has a negative correlation with the number of boulders generated after blasting while others that are blast-hole diameter, blast-hole depth, spacing, burden and average charge per hole have positive effects as shown in Figures 2 to 7.

Equations 1 to 6 generated can be used to determine either of the two variables in each of the equations.
The equation generated using SPSS (Equation 7) is useful for the determination of number of boulders generated after blasting.

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