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DEVELOPMENT OF QUARRY SOLUTION VERSION 1.0 FOR QUICK COMPUTATION OF DRILLING AND BLASTING PARAMETERS

B. ADEBAYO*, A. W. BELLO

Department of Mining Engineering, Federal University of Technology,
Akure, P.M.B. 704, Akure, Ondo State, Nigeria
*Corresponding Author: baayoakinola@yahoo.com

Abstract

Computation of drilling cost, quantity of explosives and blasting cost are routine procedure in Quarry and all these parameters are estimated manually in most of the quarries in Nigeria. This paper deals with the development of application package QUARRY SOLUTION Version 1.0 for quarries using Visual Basic 6.0. In order to achieve this data were obtained from the quarry such as drilling and blasting activities. Also, empirical formulae developed by different researchers were used for computation of the required parameters viz: practical burden, spacing, length of hole, cost of drilling consumables, drilling cost, powder factor, quantity of column charge, total quantity of explosives, volume of blast and blasting cost. The output obtained from the software QUARRY SOLUTION Version 1.0 for length of drilling, drilling cost, total quantity of explosives, volume of blast and blasting cost were compared with the results manually computed for these routine parameters estimated during drilling and blasting operation in quarry, it was then discovered that they followed the same trend. The computation from the application package revealed that 611 blast-holes require 3326.71 kg of high explosives (166 cartons of explosives) and 20147.2 kg of low explosives (806 bags of explosives). The total cost was computed to be ₦ 5133999:50 ($ 32087.49). Moreover, the output showed that these routine parameters estimated during drilling and blasting could be computed within a short time frame using this QUARRY SOLUTION, therefore, improving productivity and efficiency. This application package is recommended for use in open-pit and quarries when all necessary inputs are supplied.

Keywords: Parameters, Rocks, Explosive, Drill hole, Quarry, Blasting.

Nomenclatures

B	Burden, m
B_{CW}	Bottom charge weight, kg/m
B_H	Bench height, m
C_A	Cost of accessories, ₦
C_B	Cost of blasting, ₦
$C_{BW(AVE)}$	Average bottom charge weight, kg/hole
C_C	Cost of drilling consumables used during the drilling period, ₦
C_{CW}	Column charge weight, kg/m
$C_{CW(AVE)}$	Average column charge weight, kg/hole
C_E	Cost of explosive, ₦
C_F	Cost of fuel, ₦
C_L	Cost of lubricant, ₦
C_P	Cost of personnel, ₦
D	Body diameter, m
D_{ANFO}	Density of ANFO, kg/m^3
D_C	Drill cost, ₦/m
D_H	Drill hole depth, m
$D_{H(AVE)}$	Average drill hole depth, m
H_I	Instrument height, m
L	Total length drilled, m
L_R	Level reading, m
L'	Cumulative length of drill hole depth, m
M_C	Maintenance cost, ₦
N	Number of drill hole
S	Spacing, m
U	Sub-drill, m
V_B	Volume of blast, m^3

1. Introduction

The rocks are aggregates of naturally occurring solid material consisting of one or more minerals. In other word, rocks are heterogeneous aggregates of grains varying in shape, size and strength with varying contact relationships between the grains in either the distribution, size or quality of the contact, with various binding agents between the grains whose properties are often largely different from those of the grains and with planar or triaxial discontinuities as stated by Bell [1]. According to Encyclopedia Britannica [2], granite is the most common type of intrusive igneous rock at the Earth's surface. Since, granite forms deep within the Earth. Mottana et al. [3] described natural granite as a typically white, light gray, pink, yellow, dark gray, and green.

Top hammer drill is designed for drilling vertical or horizontal primary or secondary blast holes, and is recommended for road construction work, pre-slit drilling, quarry work, open pit mining, line hole drilling, trench work, sewer constructions, etc. with a detached compressor extracted from Atlas Copco Instructional Manual [4].

Naval Ordinance System Command [5] defined an explosive as a material that either is chemically or otherwise energetically unstable or produces sudden expansion of the material usually accompanied by the production of heat and large changes in pressure (and typically also a flash and/or load noise) upon initiation. Encyclopedia Britannica [6] state that blasting is the process of reducing a solid body, such as rock, to fragments by using an explosive. During blasting, the energy released by the detonation of explosives produces some basic effects which are: rock fragmentation, displacement, ground vibration and air blasts. The cost of blasting as defined by the type and amount of explosive to be used cannot be separated from the cost of drilling when the objective is to minimise total costs as proposed by Jimeno et al. [7].

Jimeno et al. [7] stated that the success and economics of drilling operation depends majorly on the condition of the bit. The bit dictates the pace of the drilling operation through its penetration rate. A high penetration rate will cause reduction in the time for drilling a particular hole which has corresponding effect on the cost of the drilling. Plinninger et al. [8] also indicated that the rate of penetration denotes the depth penetrated per unit time while the wear rate describes the velocity of material removal from the bit and it a basic factor for the calculation of bit consumption and wear costs.

A computer program QUARRY SOLUTION version 1.0 incorporated to handle field data, design and plan both drilling and blasting activities. David [9] is of the view that the first step in writing instructions to carry out a task is to determine what the *output* should be - that is, exactly what the task should produce. The second step is to identify the data, or *input*, necessary to obtain the output. The last step is to determine how to *process* the input to obtain the desired output, that is, to determine what formulas or ways of doing things can be used to obtain the output. The objectives of this research are to compute levelling reading reduction, average drill hole depth, volume of blast, quantity of explosive, cost of blasting, cost of drilling, as well generate their reports**.**

2. Location of Study Area

Analytical Associated Granite Industries (AGI) Limited deposit is located on the co-ordinate (latitude 3^0 18' 25" E and longitude 7^0 15' 15" N). The quarry is situated in Sekere Village, Igbo-Ora, Oyo State as shown in Fig. 1.

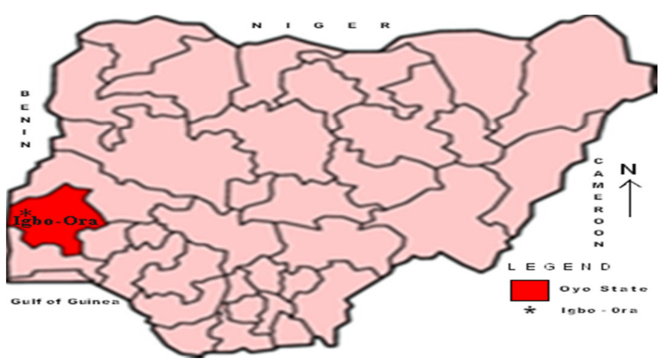


Fig. 1. Map of Nigeria Locating the Study Area (Igbo-Ora, Oyo State).

3. Methods

3.1. Determination of drill hole depth

A level and staff are required in the determination of drill hole depth prior to drill activities. This is to give a well leveled undulating platform to ease the movement of quarry machinery during extraction loading. The level is stationed at a convenient position while the staff is placed at various points high-marked for drilling. Figure 2 show best how the result is displayed. Equation (1) is proposed by Allan [10]:

$$D_H = [(H_I) + (B_H) + U] - (L_R)] \quad (1)$$

where D_H is the drill hole depth (m), H_I is the instrument height (m), B_H is the bench height (m), U is the sub-drill (m), and L_R is the level reading (m).

The computation of main average drill hole depth which assists drillers during drilling and blasting operations was determined using Eq. (2):

$$D_{H(AVE)} = \frac{L^I}{n} \quad (2)$$

where $D_{H(Ave)}$ is the average drill hole depth (m), n is the no. of drill hole, and L^I is the cumulative length of drill hole depth (m).

3.2. Determination of volume of blast

Prior to blasting, the likely quantity of the blast could be evaluated using Eq. (3) proposed by Gustafsson [11]. Figure 2 show best how the result is displayed.

$$V_B = S \times B \times L^I \quad (3)$$

where V_B is the volume of blast (m^3), S is the spacing (m), B is the burden (m), and L^I is the cumulative length of drill hole (m).

3.3. Determination of quantity of explosive

The average drill hole depth is adopted due to varied depth of blast hole. There are several parameters involved, the major equation. The column charge weight and bottom charge weight was determined using the Eqs. (4) and (5) proposed by Gustafsson [11]:

$$C_{CW} = \frac{D_{ANFO} \times d^2}{1273} \quad (4)$$

where C_{CW} is the column charge weight (kg/m), D_{ANFO} is the density of ANFO (kg/m^3), and d is the hole diameter (m)

$$B_{CW} = \frac{D_{HE} \times d^2}{1273} \quad (5)$$

where B_{CW} is the bottom charge weight (kg/m), D_{HE} is the density of high explosive (kg/m^3), and d is the hole diameter (m).

The average column charge weight and average bottom charge weight was determined using the Eqs. (6) and (7)

$$C_{CW(Ave)} = C_{CW} \times D_{H(Ave)} \tag{6}$$

where $C_{CW(Ave)}$ is the average column charge weight (kg/hole), C_{CW} is the column charge weight (kg/m), and $D_{H(Ave)}$ is the average drill hole depth (m)

$$C_{BW(Ave)} = B_{CW} \times D_{H(Ave)} \tag{7}$$

where $C_{BW(ave)}$ is the average bottom charge weight (kg/hole), B_{CW} is the bottom charge weight (kg/m), and $D_{H(Ave)}$ is the average drill hole depth (m).

3.4. Determination of drill cost

It is the total cost incurred in drilling a unit metre of a rock. Equation (8) proposed by Gustafsson [11] is used to compute the drill cost

$$D_C = \frac{C_C + C_L + M_C + C_F + C_P}{L} \tag{8}$$

where, M_C is the maintenance cost (₦), C_P is the cost of personnel (₦), L is the total length drilled (m), D_C is the drill cost (₦ /m), C_C is the cost of drilling consumables used during the drilling period (₦), C_L is the cost of lubricant (₦), and C_F is the cost of fuel (₦).

3.5. Determination of blasting cost

The cost of blasting involves several parameters. Equation (9) proposed by Gustafsson [11] is used to determine the total cost blasting.

$$C_B = C_E + C_F + C_A \tag{9}$$

where C_B is the cost of blasting (₦), C_E is the cost of explosive (₦), C_F is the cost of fuelling (₦), and C_A is the cost of accessories (₦).

4. Results and Discussion

Table 1 presents the results of average drill hole depth, volume of blast and tonnage; the values of the five (5) set of drilling activities arranged according to serial number.

Table 1. Field Data Processing Results.

S/N	No. of Drilled hole	Total Length Drilled (m)	Ave. drill depth (m)	Vol. of Blast (m^3)	Tonnage (Tons)
1	127	1,092.9	8.61	5,650.30	15,255.8
2	128	994.80	7.77	5,143.12	13,886.4
3	114	1,373.6	12.04	7,101.51	19,174.1
4	138	1,608.8	11.65	8,317.50	22,457.3
5	104	1,072.5	10.31	5,544.82	14,971.0
Cum.	611	6,142.6	50.38	31,757.3	85,744.6

Table 2 presents the results of quantity of explosive required and simplified number of high explosive cartons and low explosive bags needed; the values of the five (5) set of drill activities arranged according to their serial number.

Table 2. Quantity of Explosive Required.

S/N	No. of Drilled hole	Qty of High Explosive (Kg)	Qty of Low Explosive (Kg)	No. of High Explosive Cartons	No. of Low Explosives Bags
1	127	691.47	3482.40	34.5	139.2
2	128	696.92	3095.16	34.8	123.8
3	114	620.69	4633.98	31.0	185.3
4	138	751.36	5402.00	37.5	216.0
5	104	566.24	3533.60	28.3	141.3
Cum.	611	3,326.68	20,147.14	166.1	805.6

Table 3 presents the results of cost of explosive, cost of fuel, cost of blasting accessories and cost of blasting; the values of the five (5) set of drill activities arranged according to serial number.

Table 3. Cost of Blasting.

S/N	No. of Drilled hole	Cost of Explosive consumed (₦)	Cost of Fuel consumed (₦)	Cost of Blast accessories (₦)	Cost of Blasting (₦)
1	127	902,668	24,000	32,540	959,208
2	128	847,580	24,000	32,560	904,140
3	114	1,036,477	24,000	32,280	1,092,757
4	138	1,223,548	24,000	32,760	1,280,308
5	104	841,472	24,000	32,080	897,552
Cum.	611	4,851,745	120,000	162,220	5,133,965

4.1. Development of QUARRY SOLUTION software

The software is Microsoft Windows compatible and works on personal computers with sizable microprocessor (e.g. 80386), 4MB of RAM and at least 10MB of free hard disk space. The program has several interfaces but some of QUARRY SOLUTION SOFTWARE are shown in Figs. 2 to 6. The computation of variable within the form: field data, drill cost management, blasting cost management, and quantity of explosive are each interfaces display in Figs. 2 to 5. The report generator for field data is displayed in Fig. 6. A sample of the print preview of quantity of explosive report is presented in Fig. 7.

The interface displayed in Fig. 2 will compute average hole depth (m), volume of blast (m^3) and tonnage of rock blast (tonnes) once the field parameter are supplied.

The interface displayed in Fig. 3 will compute quantity of both high and low explosive required for a single blast once necessary parameter are supplied. Also, the number of low explosive bags and high explosive cartons determined which is useful for stock keeping.

The interface displayed in Fig. 4 will compute total cost of blasting once the necessary input are supplied. The interface displayed in Fig. 5 will compute drill cost when several variables are supplied.

The interface displayed in Fig. 6 will process the field data report using crystal report 9.0 once the button (report processing) is clicked upon. Select the appropriate date of entry before processing report. Then print preview using crystal report 9.0 before printing out as hard copies.

The interface displayed in Fig. 7 will present a print preview of quantity of explosive report using crystal report 9.0. Then, print button is clicked upon to effect hard copies output.

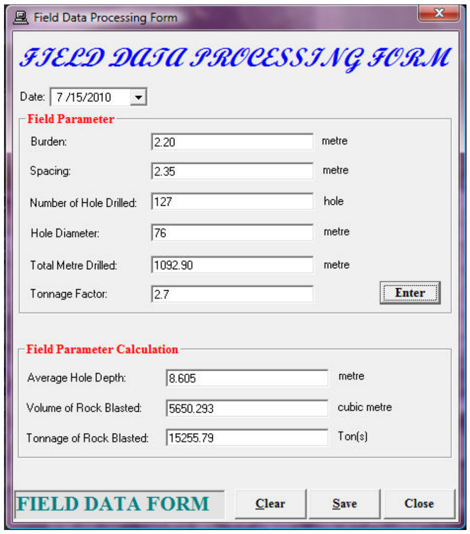


Fig. 2. Field Data Processing Form.

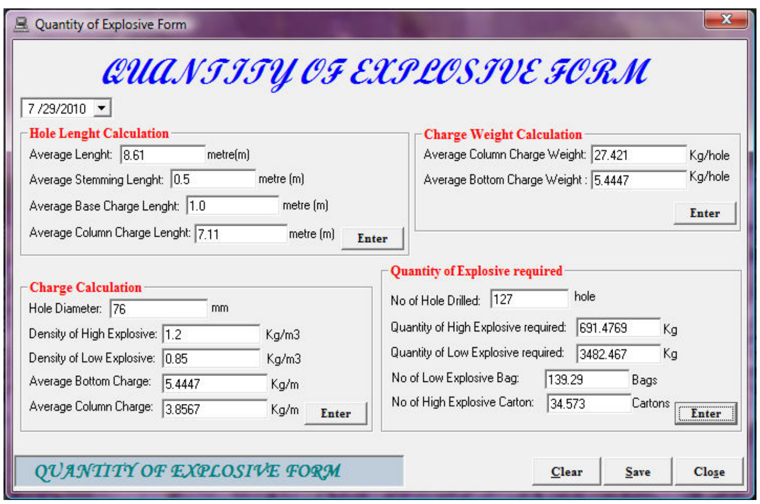


Fig. 3. Quantity of Explosive Form.

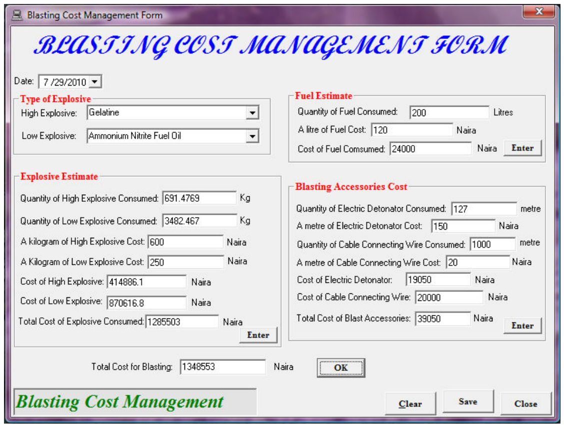


Fig. 4. Blasting Cost Management Form.

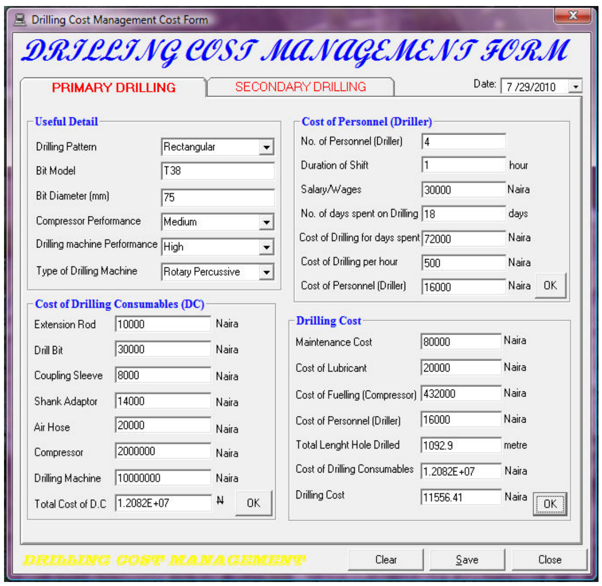


Fig. 5. Drilling Cost Management Form.

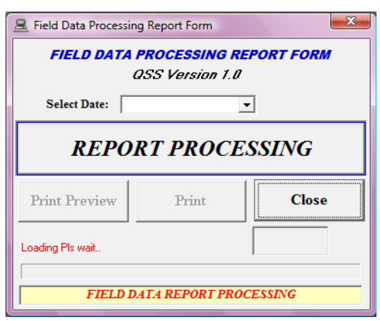
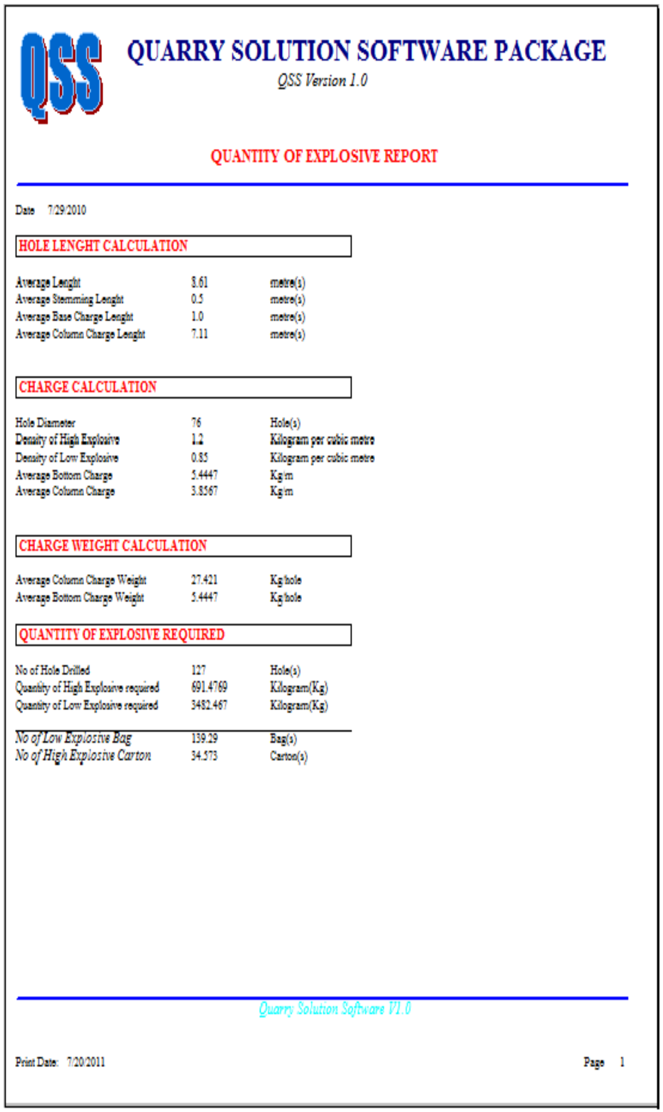


Fig. 6. Field Data Report Generator



QSS

QUARRY SOLUTION SOFTWARE PACKAGE

QSS Version 1.0

QUANTITY OF EXPLOSIVE REPORT

Date 7/29/2010

HOLE LENGHT CALCULATION

Average Lenght	8.61	metre(s)
Average Stemming Lenght	0.5	metre(s)
Average Base Charge Lenght	1.0	metre(s)
Average Column Charge Lenght	7.11	metre(s)

CHARGE CALCULATION

Hole Diameter	76	Hole(s)
Density of High Explosive	1.2	Kilogram per cubic metre
Density of Low Explosive	0.85	Kilogram per cubic metre
Average Bottom Charge	5.4447	Kg/m
Average Column Charge	3.8567	Kg/m

CHARGE WEIGHT CALCULATION

Average Column Charge Weight	27.421	Kg/hole
Average Bottom Charge Weight	5.4447	Kg/hole

QUANTITY OF EXPLOSIVE REQUIRED

No of Hole Drilled	127	Hole(s)
Quantity of High Explosive required	691.4769	Kilogram(Kg)
Quantity of Low Explosive required	3482.467	Kilogram(Kg)
No of Low Explosive Bag	139.29	Bag(s)
No of High Explosive Carton	34.573	Carton(s)

Quarry Solution Software V1.0

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Fig. 7. A Print Preview of Quantity of Explosive Report.

4.2. Model implementation

The implementation of the empirical application model consists of the design of the system, the sampling procedure and analysis of the system. The software developed had been noted to adopt drilling and blasting parameters obtained from quarry operations for the computation of length of drilling, drilling cost, total quantity of explosives, volume of blast and blasting cost. The collation, retrieval and analysis of these data can be done either manually or on a computer. It was observed in the course of developing the software programme that software applications have becomes veritable tools for developing practical solutions to problems which are usually tedious when handled manually. In this research, the Quarry Solution software developed was implemented using Microsoft Visual Basic application language as the front end. Visual basic which was adopted as the front end in the research is an event-driven programming language which has evolved as a result of Graphical User Interface (GUI) provided by the windows operating system. The report can be viewed on the screen, saved in a file or sent to the printer to obtain hard copy as presented in Fig. 7.

The Quarry Solution software has a user-friendly interface and interactive for computation of drilling and blasting parameters such as length of drilling, drilling cost, total quantity of explosives, volume of blast and blasting cost when appropriate input parameters are supplied. The software was designed in such a way that errors are detected if data was wrongly entered. The speed of the programme is very high, and it produces design solutions to problems considered and its accuracy is very high.

5. Conclusions

The computer program QUARRY SOLUTION Version 1.0 was developed using Visual Basic 6.0 to compute levelling readings reduction, quantity of explosive, cost of blasting, drilling cost, penetration rate, volume of blast and tonnage when necessary drilling and blasting parameters are supplied. The following conclusions are drawn:

- The generated reports (field data processing, blasting cost management, drilling cost management, quantity of explosive) are retrieved by selecting the appropriate date of entry from the database (Microsoft Access at the backend).
- The report generated is printed out as hard copies which portray vital information for quarry operator to select appropriate explosives, and drill string.
- The report would improve productivity and save running cost.

References

1. Bell, F.G. (1992). *Engineering properties of rocks and soils*. Butterworth Heineman, Oxford, England.
2. Encyclopedia Britannica (2009). Granite. Retrieved July 5, 2009, from http://www.britannica.com/EBchecked/topic/241660/granite.
3. Clement, M.A.; Crespi, R.; and Liborio, G. (1977). *Guide to rocks and minerals*. Simon and Schuster Inc, New York, 20-25.
4. Atlas (2001). *Instructional manual for crawliar drilling machine model CM348*. Atlas Copco Ghana Ltd, Ghana, 3-78.
5. Naval Ordinance System Command (1972). *Safety and performance tests for qualification of explosives*. Washington, D.C., NAVORD OD 44811.
6. Encyclopedia Britannica (2009). Blasting. Retrieved July 5, 2009, from www.britannica.com/EBchecked/topic/69050/blasting.
7. Jimeno, C.L.; Jimeno, E.L.; Francisco, J.; Ayala, C.; and De Ramiro, Y.V. (1995). *Drilling and blasting of rocks*. Taylor and Francis Publisher, 1-70.

8. Plinninger, R.J.; Spaun, G.; and Thuro, K. (2002). Predicting tool wear in drill and blast. *Technical Review on Drill Bit Wear*, Tunnels and Tunnelling International Magazine, 38-41.
9. David, I.S. (1999). *An introduction to programming using visual basic 6.0.* (4^{th} Ed.). University of Phoenix, College of Information System and Technology. Upper Saddle River, New Jersey, 3.
10. Allan, A.L. (1997). *Practical Surveying and Computation*. 2nd Ed. Laxton's, Oxford, England.
11. Gustafsson, R. (1981). *Blasting technique*. Austrian Edition, Dynamite Nobel Wien. Vienna, Austria, 1-327.