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Cost Implication of Explosive Consumption in Selected Quarries in Ondo and Ekiti State

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ABSTRACT

The study involves the use of Langefors formula and other general blasting formulas to design suitable and optimized blasting parameters which will ensure minimal environmental problems and reduced production cost. Blasting data were collected from four different quarries in Ekiti and Ondo states which were used in conjunction with the recommended formulas to obtain the actual total cost of explosives consumed per blast and the ideal total cost of explosives required per blast at the quarries. On comparing the results, it was observed that the four quarries are consuming more explosive than required, with Stonework Industries Limited recording the highest cost of excess explosive per blast and Samchase Nigeria Limited had the lowest cost of excess explosive per blast. This trend translates to higher cost of production which can be minimized by adopting ideal blasting design.

Keywords: *Explosive, Quarries, Langefors formula, Environmental problems, Blasting*

1. INTRODUCTION

Quarrying is the process of obtaining quarry resources, usually rocks, found on or below the land surface (Banez, 2010). Rock blasting at quarries represents multiple challenges not easy to see at first sight. Aggregate industries face similar or superior prices for explosives while extracting a material that usually is of less value of metal mining operations. Therefore, learning to optimize a quarry operation can be a perfect training for a position in blasting at larger metal mining operations. In 2004, U.S. explosives production was 2.52 million metric tons (Mt), a 10% increase from that in 2003; sales of explosives were reported in all States. Coal mining, with 67% of total consumption, continued to be the dominant use for explosives in the United States. Quarrying and non-metal mining, the second ranked consuming industry, accounted for 13% of total explosives sales; construction, 9%; metal mining, 8%; and miscellaneous uses, 3% (Deborah, 2004). In an age where globalization exerts great influence on the world economy, making most developing economies market driven, it becomes imperative for mining companies to adopt innovative and cost effective method to enhance mineral production. It therefore rest on the management of these companies to use recent scientific methods to evaluate the cost implication of production blasting to achieve optimum fragmentation and make favourable decision in order to ensure that they withstand the competition in the industry and stay in production (Robert, 2002).

Quarrying as a process comprises a number of consecutive subprocesses: drilling, blasting, secondary breaking, loading, hauling, crushing, screening, stockpiling and delivery of saleable products. Each quarry is unique and needs to be planned carefully in terms of both working practices and the selection of equipment in order to maximize the profitability of the operation. A typical cost distribution for operations in granitic rocks is presented in figure 1. (QM, 2002).

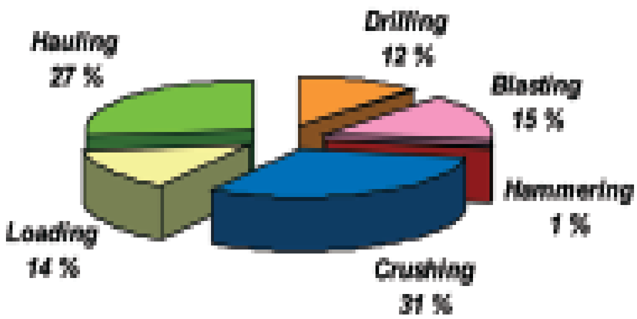

Fig.1: Typical distribution of crushed aggregate production costs for operations in granitic rocks

Since blasting represents about 15% of the total cost per tonne of aggregates produced. Owing to technical and economical consequences in this stage of the excavation process, thorough attention must be paid to the quantity of explosive consumed to fragment a specific rock volume.

Powder factor is a necessary calculation for cost accounting purposes. Powder factor is a function of type of explosive, rock density, and geology. Powder factor for a volume of rock blasted can be calculated by the formula:

$$\textbf{Powder factor (Kg/m}^3\textbf{)} = \frac{\textbf{Total weight of explosives in the blast}}{\textbf{Blast volume}}$$

Table 1: Typical powder factors used in mass blasts

Rock type	PF(kg/m³)
Hard	0.7 – 0.8
Medium	0.4 -0.5
Soft	0.25 – 0.35
Very soft	0.15 – 0.25

(Dyno Nobel, 2010)

The objective of this work is to compare the actual cost of explosives consumed for blasting a volume of rock to the ideal cost of explosives required for blasting the same volume of rock taking quarries in Ondo and Ekiti states as case studies.

2. LOCATION OF THE STUDY AREAS

The primary data were collected from four different quarries as mentioned below:

1. Mac Engineering Construction Limited, situated at Km20, Ado-Akure road in Ikere-Ekiti, Ekiti State.
2. Kopek Construction Limited, situated at Km5, Ise road in Ikere-Ekiti, Ekiti State.
3. Samchase Nigeria Limited situated at Km3, Akure road, Itaogbolu, Ondo State.
4. Stonework Industries Limited, situated at Km8, Akure-Owo road in Akure, Ondo State.

3. GEOLOGY OF THE STUDY AREAS

i) Ikere-Ekiti (Ekiti state)

One of the study areas (Ikere-Ekiti) is underlain by the Pan-African older granite series (NGSA, 2006) of the Precambrian Basement Complex rocks of Southwestern Nigeria (Figure 2 shows the geological map of Ekiti state). Field observations at the survey site revealed that the lithology is the coarse porphyritic granite and the undifferentiated porphyritic granite and granite, gneiss and migmatite rocks types. A characteristic feature of the Basement Complex tectonics is the widespread occurrence of fractures (Oluyide, 1988). Thus, varieties of structural features such as foliations, folds, faults, joints, fractures and fissures exist in the Basement Complex environment. Ikere Local Government area lies within latitudes 6° 18[1]N and 6° 29[1]N and longitudes 5° 20[1]E and 5° 30[1]E.

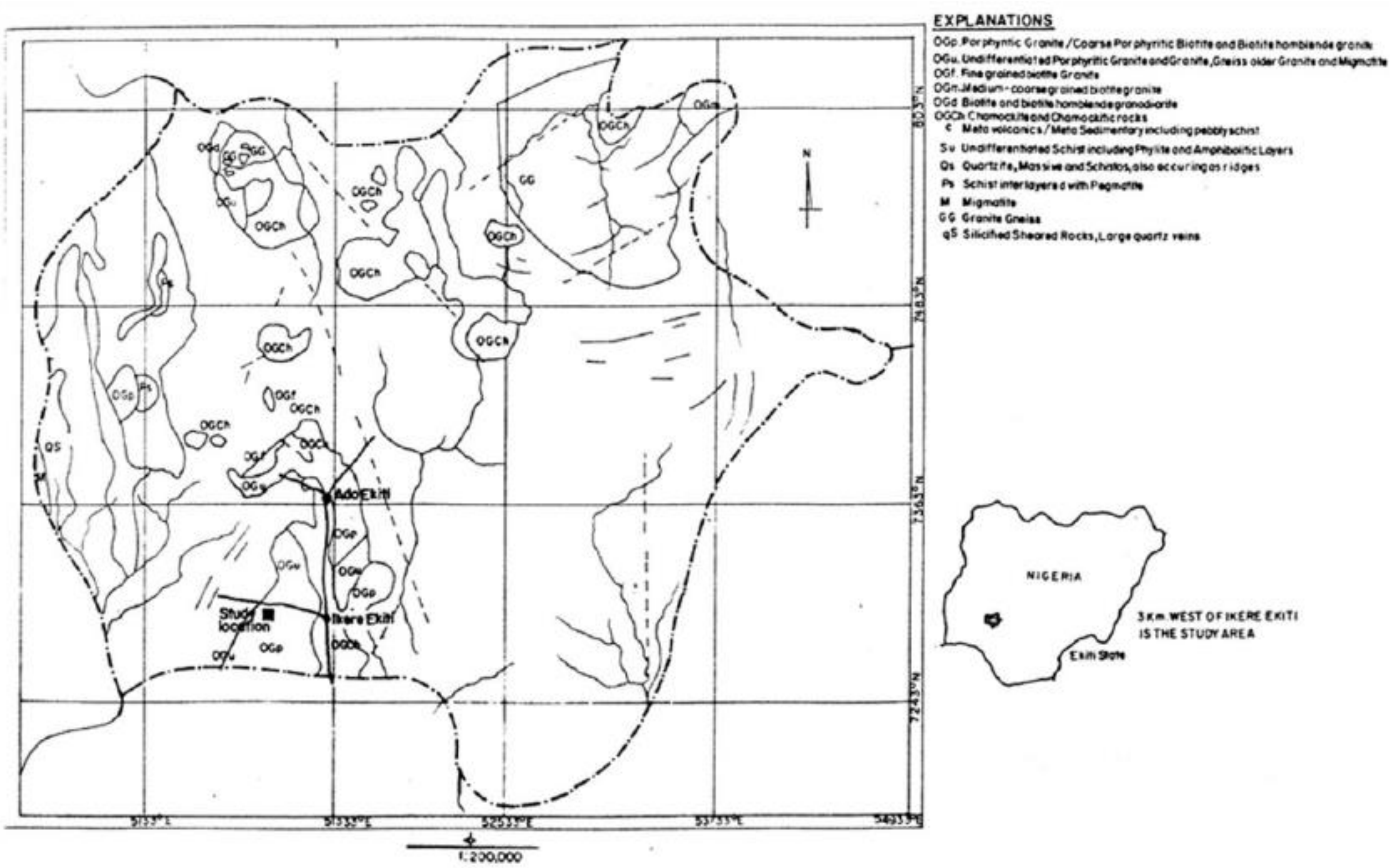

Fig 2: Map of Ekiti state showing the general geology

ii) Itaogbolu (Ondo state)

Itaogbolu is located within Akure North Local Government Area of Ondo State, South-Western Nigeria. The town is a fast growing agrarian community apart from having a potential for booming business. The study area has a land mass of 2940.109 km^2. The area has a relatively high relief of between 950 to 1500 cm above sea level. Sociopolitical divisions bound Itaogbolu on the North by Ikere local Government in Ekiti State, on the West and East by Akure South and Owo local Government, respectively, on the South by Idanre local Government (Adefemi and Awokunmi, 2010).

iii) Akure (Ondo state)

Akure is underlain by the Precambrian Basement complex rocks of Southwestern Nigeria. The charnockitic rocks of Akure intruded into the gneiss-migmatite-quartzite complex and the older granite suite. This study area lies within longitudes 5° 00'E and 5° 17'E and latitudes 7° 10'N and 7° 20'N in the south-western part of Nigeria. The major rock types in the area as classified by Adekoya *et al*. (2003) are (a) The gneiss-migmatite-quartzite complex; (b) The schist belts which are low to medium grade supracrustal and meta-igneous rocks; (c) The Pan African granitoids (Older Granites) and other related rocks such as charnockitic rocks and syenites; and (d) Minor felsic and mafic intrusive. (Figure 3 presents the geological map of Akure).

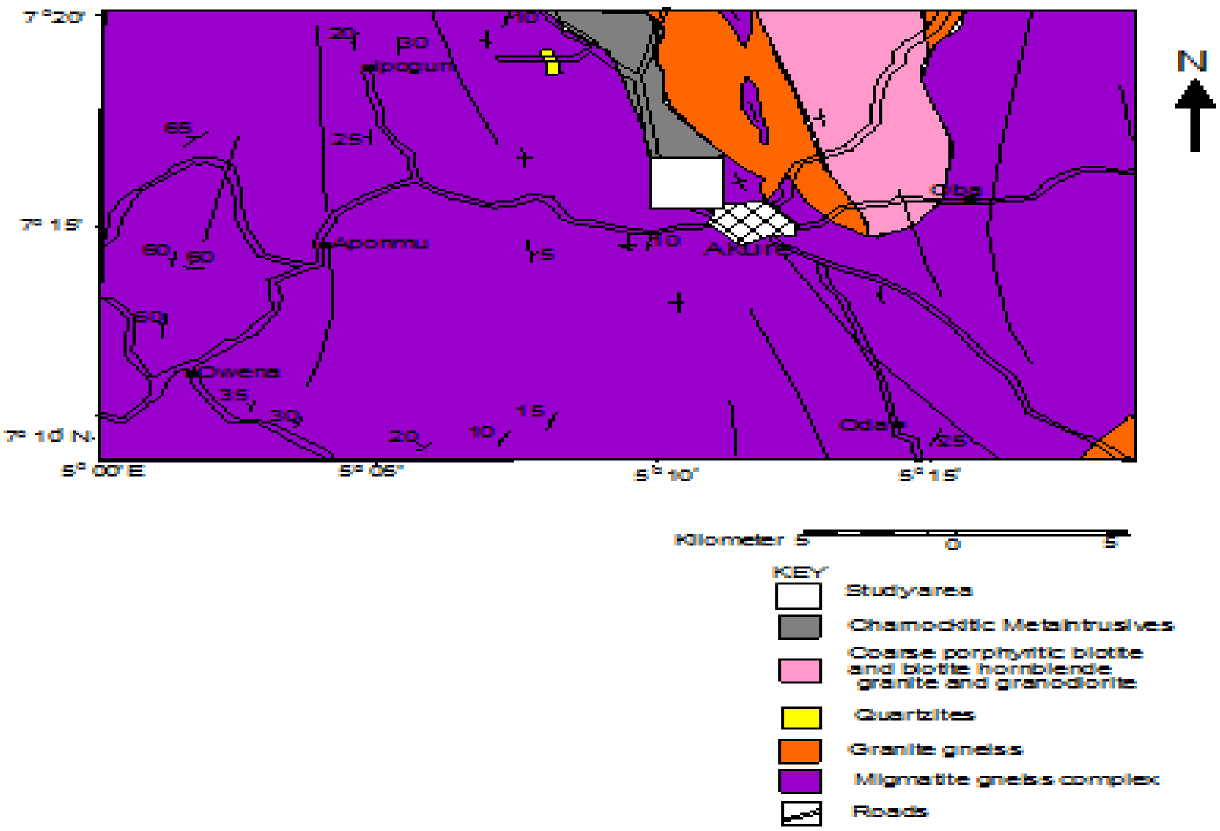

Fig.3: Geological Map of Akure showing study Area (Adapted from Ademeso, 2009)

4. METHODOLOGY

The method used for carrying out this work basically involved site visits to the selected quarries, collection and evaluation of information on the blast parameters and design at the quarries. Data collected at the quarries included: burden, spacing, bench height, blast hole diameter, total number of holes drilled per blast, total weight of explosive in the bottom and column charge per blast, current cost of the explosives used for bottom and column charges. The following parameters were determined by using Langefors formula (Equation 1 – 11) and other appropriate formula (Equation 12 &13): Subdrilling, hole depth, drilling error, maximum burden, concentration of bottom charge, height of bottom charge, total weight of explosive required per blast, ideal weight of explosive required per hole, weight of bottom charge per hole, weight of column charge per hole, total weight of explosive required for bottom charge per blast, total weight of explosive required for column charge per blast, powder factor and blast volume.

The actual cost of explosives currently consumed at the quarries and the ideal cost of the explosives that is expected to be used at the quarries were obtained by computation using the data collected during the study and applying equation 14 -16, the results were then used to calculate the cost of excess explosives consumed at the quarries (Equation 17).

Langefors formula as used in the study is stated below (Equation 1 – 11):

$U = 0.3B_{max}$ ……………………………………………….1

$H = 1.05\ (K+U)$ ………………………………………………. 2

$F = 0.05 + 0.03H$ ……………………………………………….3

$B_{max} = B + F$ ……………………………………………….4

$l_b = (B_{max}/1.47)^2$ ………………………………………………. 5

$h_b = 1.3B_{max}$ ………………………………………………. .6

$q_t = Q_t/N$ ……………………………………………….7

$q_b = h_b.l_b$ ………………………………………………. 8

$q_c = q_t – q_b$ ………………………………………………. 9

$Q_b = q_b \times N$ ………………………………………………. 10

$Q_c = q_c \times N$ ………………………………………………. 11

(Matti, 1999)

Other blasting formulas used are as follows (Equation 12 – 17):

$Q_t = PF \times V$ ……………………………………………….12

$V = B \times S \times H \times N$ ……………………………………………….13

(Dyno Nobel, 2010)

$C_b = C_{dynamite} \times Q_b$ ………………………………………………. 14

$C_c = C_{ANFO} \times Q_c$ ………………………………………………. 15

$C_t = C_b + C_c$ ……………………………………………….16

Cost of excess explosive consumed per blast = Actual cost of explosive consumed per blast – Ideal cost of explosive required per blast ……………………………………………….17

The ideal powder factor for the blast was obtained from recommended standard (Table 1). The rock type at the quarries is hard, therefore from Table 1, the maximum ideal powder factor for hard formation is $0.8 kg/m^3$ which was applied. The current prices of the explosives based on findings as at April, 2014 are stated below:

Dynamite was purchased at the rate of one thousand naira per kilogramme (N1000/kg) while ANFO costed two hundred and thirty naira per kilogramme (N230/kg).

Nomenclature

Subdrilling, U
Practical burden, B
Maximum burden, B_{max}
Spacing, S
Hole depth, H
Bench height, K
Blast volume, V
Total number of holes per blast, N
Drilling error, F
Bottom charge concentration, l_b
Height of bottom charge, h_b
Powder factor, PF
Ideal weight of explosive required per blast, Q_t
Ideal weight of explosive required per hole, q_t
Weight of bottom charge per hole, q_b
Weight of column charge per hole, q_c
Weight of the bottom charge per blast, Q_b
Weight of the column charge per blast, Q_c
Cost of explosive in the bottom charge per blast, C_b
Cost of explosive in the column charge per blast, C_c
Total cost of explosive per blast, C_t
Cost of dynamite per kilogramme, $C_{dynamite}$
Cost of ANFO per kilogramme, C_{ANFO}

5. RESULTS AND DISCUSSION

The summary of the information obtained from the four quarries is presented in Table 2 which includes: burden, spacing, bench height, hole diameter, total number of holes, weight of explosives in the bottom and column charge per blast. Table 3 is a presentation of the actual cost of explosives used for the bottom and column charge for all the four quarries per blast while Table 5 presents the ideal cost of explosives required for charging the bottom and column holes per blast. Table 4 is the summary of the results obtained when the ideal blast parameters were computed for the four quarries using equation 1 - 13. The results presented by Table 6 is the summary of the actual and ideal cost of the explosive for the quarries and the cost of the excess explosive consumed per blast for each quarry. Figure 4 is a bar chart comparing the cost of the excess explosive consumed at the four quarries.

From the information collected, the rock type blasted in the four quarries is granitic rock and the mining method adopted is surface mining method with a burden and spacing dimension that varies from 1.5m - 2m. The bench height varies from 9m – 12m and the hole diameter varies from 80mm – 100mm. The total number of holes ranged from 120 – 150 holes. The blasting method used is non-electric (Nonel), ANFO was used as the column charge while dynamite was used as the bottom charge, sand-dust or gravel was the stemming material used. The total weight of explosive consumed per blast by the quarries ranged between 5130 – 6825kg, the weight of dynamite is between 1980 – 3075kg while that of ANFO is between 3000 – 3750kg.

Table 2: Blast parameters collected from the four selected quarries

Parameters	Mac	Kopek	Samchase	Stonework
Burden (m), B	1.5	2	2	1.8
Spacing (m), S	1.5	2	2	1.8
Bench height (m), K	9	10	10	12
Hole diameter(mm), d	88.9	95	80	100
Total number of holes, N	126	150	120	140
Actual total weight of explosive in bottom charge per blast (kg)	1980	3075	2460	2870
Actual total weight of explosive in column charge per blast (kg)	3150	3750	3000	3500
Actual total weight of explosive consumed per blast (kg)	5130	6825	5460	6370

Table 3: Cost implication of the actual quantity of explosive consumed at the selected quarries (Figures are quoted in Nigerian Naira)

Parameters	Mac	Kopek	Samchase	Stonework
Actual cost of explosive(Dynamite) for the bottom charge (N)	1, 980, 000	3, 075, 000	2, 460, 000	2, 870, 000
Actual cost of explosive (ANFO) for the column charge (N)	724, 500	862, 500	690, 000	805, 000
Actual total cost of explosive consumed per blast (N)	2,704, 500	3, 937, 500	3, 150, 000	3, 675, 000

Table 4: Blast parameters computed for the four selected quarries

Parameters	Mac	Kopek	Samchase	Stonework
Blast volume, V (m^3)	2551.50	6000.00	5760.00	5443.20
Subdrilling, U (m)	0.5	0.6	0.6	0.5
Hole depth, H(m)	10	11	11	13
Maximum burden, B_{max} (m)	1.9	2.4	2.4	2.2
Concentration of bottom charge,l_b (kg/m)	1.67	2.67	2,67	2.24
Height of bottom charge, h_b (m)	2.4	3.1	3.1	2.9
Ideal weight of explosive required per hole,q_t	16.2	32.0	38.4	31.1
Ideal weight of bottom charge per hole, q_b (kg)	4.0	8.0	8.3	6.5
Ideal weight of column charge per hole, q_c (kg)	12.2	24	30.1	24.6
Ideal total weight of explosive required for bottom charge per blast, Q_b (kg)	504	1200	996	910
Ideal total weight of explosive required for column charge per blast, Q_c (kg)	1537.2	3600	3612	3444
Ideal total weight of explosive required per blast, Q_t (kg)	2041.20	4800.00	4608.00	4354.00

Table 5: Cost implication of the ideal quantity of explosive required at the selected quarries (Figures are quoted in Nigerian Naira)

Parameters	Mac	Kopek	Samchase	Stonework
Ideal cost of explosive requires for bottom charge per blast (N)	504, 000	1, 200, 000	996, 000	910, 000
Ideal cost of explosive required for column charge per blast (N)	353, 556	828, 000	830, 760	792, 120
Ideal total cost of explosive required per blast (N)	857, 556	2, 028, 000	1, 826, 760	1, 702, 120

Table 6: Summary of cost implication of the explosive consumption for the four selected quarries (Figures are quoted in Nigerian Naira)

Name of quarry	Actual total cost of explosive consumed per blast (N)	Ideal total cost of explosive required per blast (N)	Cost of excess explosive consumed per blast (N)
Mac	2, 704, 500	857, 556	1, 846, 944
Kopek	3, 937, 500	2, 028, 000	1, 909, 500
Samchase	3, 150, 000	1, 826, 760	1, 323, 240
Stonework	3, 675, 000	1, 702, 120	1, 972, 880

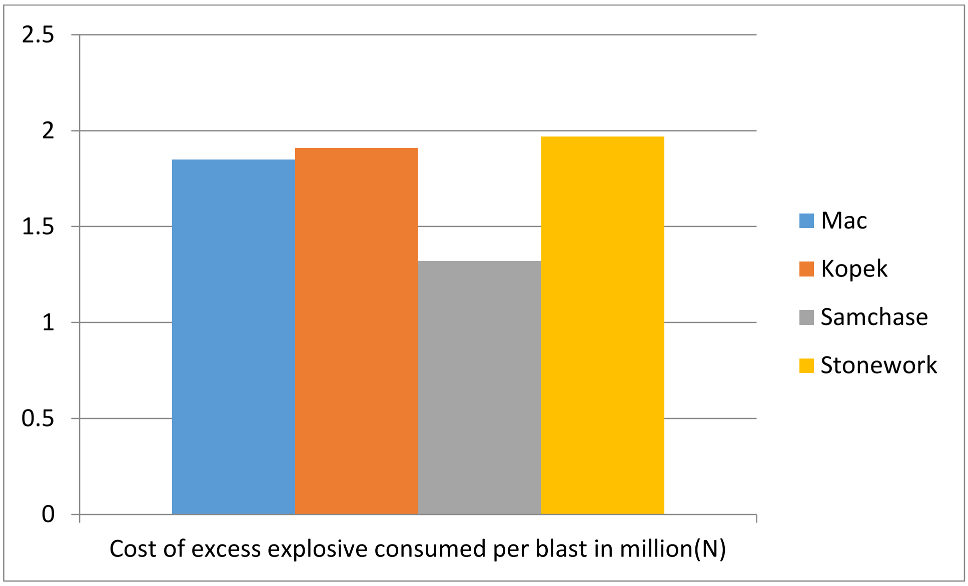

Fig. 4: Bar chart showing the cost of excess explosive consumed per blast (in million naira)

From Table 4, the volume of rock blasted at the quarries is between 2551.5 – 6000m^3, the value of the subdrilling ranges between 0.5 – 0.6m while the hole depth is between 10 – 13m. A maximum ideal powder factor of 0.8kg/m^3 was applied (from Table 1) to compute the ideal total weight of explosive required per blast for all the quarries. The concentration of bottom charge is between 1.67 – 2.67kg/m, height of bottom charge is between 2.4 – 3.1m. The ideal total weight of dynamite required for bottom charge per blast is between 504 – 1200kg while the ideal total weight of ANFO required for the column charge per blast is between 1537.2 – 3612kg. The ideal total weight of explosive required per blast is between 2041.2 – 4800kg.

Mac Engineering Company Limited: From Table 6, the actual total cost of explosive consumed to blast a rock volume of 2551.5m^3 at Mac Engineering Company Limited is N2,704,500 while the ideal total cost of explosive required to blast the same volume of rock by computation is N857, 556, thereby recording an excess explosive cost of N1,846, 944.

Kopek Construction Limited: Table 6 also revealed that the actual total cost of explosive consumed to blast a rock volume of 6000m^3 at Kopek Construction Limited is N3, 937, 500 while ideally the required total cost is N2, 028, 000, this led to an excess explosive cost of N1, 909, 500.

Samchase Nigeria Limited: Table 6 also showed that the total cost of explosive consumed to blast 5760m^3 volume of rock at Samchase Nigeria Limited is N3, 150, 000 while the ideal total cost of explosive required to blast an equal volume of rock is N1, 826, 760, this resulted into an excess explosive cost of N1, 323, 240.

Stonework Industries Limited: At Stonework Industries Limited, to blast 5443.2m^3 volume of rock, the ideal total cost of explosive required is N1,702, 120, but an actual total cost of N3, 675, 000 was recorded which represented an excess cost of explosive of N1, 972, 880.

6. CONCLUSION

It was observed that all the four quarries are consuming more explosive than required which will also translates to higher cost of production. Relatively, the highest cost of excess explosive per blast was recorded by Stonework Industries Limited with value of N1, 972, 880, this is immediately followed by Kopek Construction Limited with value of N1, 909, 500, Mac Engineering Construction Limited is placed third in descending order with value of N1, 846, 944 while Samchase Nigeria Limited recorded the lowest cost of excess explosive per blast with value of N1, 323, 240. Although, the excess cost of production will eventually be transferred to the customers, the production cost could be minimized by adopting ideal blasting parameters and design. The excess explosive consumed however, represents wasted energy which will make the blasting operation to be associated with environmental problems like high ground vibration, excess flyrocks and undesirable air blast. Additionally, their operations will be associated with production of excess fines and dust. Part of the explosive energy that was intended to give the proper amount of rock fragmentation and displacement is lost to the surrounding rock and atmosphere.

It is recommended that all the quarries selected for this study should optimize their production by minimizing the total amount of explosive used to carry out their blasting operation. Quarry engineers and supervisors should consider the effects of using excess explosive on the environment and its implication on production cost, they should also maintain standard and ensure best practices in all their quarry activities.

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