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EFFECTS OF BENCH HEIGHT OVER-ESTIMATION ON FRAGMENTATION

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ABSTRACT

Auchi-Igarra Mineral District and Okene-Lokoja Mineral District are two mineral districts in Nigeria with a lot of quarries for the exploitation of granite and marble for road construction, buildings, paint and chemical industries. However, most quarries in these districts have been having very high percentage boulders (80% - 90%) after blasting, as against 5% maximum for effectively blasted rounds. Our observations show that the boulders range in sizes from 1-2m. In this paper, we have deciphered the reasons for this boulder formation: mainly high benches when compared to hole diameters. Samples were collected for strength tests and maximum bench height for each hole diameter was recommended.The recommendations were tried in the field and have yielded effective fragmentation with fragment sizes from 10cm to 25cm.

Keywords: *Bench height, Boulders, Fragmentation, Secondary blasting, Hole diameters*

INTRODUCTION

Cost-effective mining operations cannot be achieved without proper fragmentation. Good fragmentation must provide fragment sizes in the neighbourhood of 20cm, and fragments in the neighbourhood of 1m are considered as boulders. Boulders must not constitute more than 5% of the total material blasted in one round (Tomakov, 1994). Bad blasting has a ripple effect on cost of loading and haulage. Boulders present problems in loading operations causing much dynamic load on haulage vehicles both at loading points, haulage routes and dumping operations. When blasting operation produces much boulders (plates 1-6), the bucket of the loading equipment cannot be filled, leading to a fall in the productivity of the loading equipment. When secondary blasting is applied to reduce the size of boulders, the blasting becomes much more expensive than would have been if the primary blasting were optimum.

Various authors have tried to study the causes of bad fragmentation in mines with the intention of developing models that help to optimize the fragmentation. Salient among the causes often advanced include:

- higher benches compared to the diameter of blasthole
- over-estimated burden and spacing for the blasthole
- inadequate charge quantity per hole
- inappropriate firing sequences

Adeev and Baron (1986), recognised the role of appropriate bench height estimation for a given diameter of blasthole and established a statistical model relating hole diameter to bench height, swell factor and rock class factor. Nitro Nobel (1987), also showed the effect of rock type (rock factor) and rock fractures on fragmentation.

The field photographs below speak volume of current fragmentation problems in the quarries.

Plate1: Field photograph of granitic boulders at Igue-Oke after primary blasting (site No. 1)

Plate 2: Field photograph showing boulders at Igue-Oke after primary blasting (Site No. 2)

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Plate 3: Field photograph of calc gneiss boulders after primary blasting at Igue-Oke (site No. 3)

Plate 4: Granite boulders at a quarry in Kporoko Village (site No. 1)

Plate 5: Field Photograph showing a driller on top, these granite boulders will require re-blasting before transporting to crushing plant at a quarry in Kporoko Village, Nigeria (site No. 2)

Plate 6: Showing boulder at a quarry inKporoko Village (site No. 3)

SAMPLE COLLECTION AND STRENGTH ANALYSIS

Nine quarries were visited which include

1. Quarry 1: Granite quarrying for chippings production
2. Quarry 2: Marble quarrying for paint and chemical industries.
3. Quarry 3: Granite quarrying chippings production
4. Quarry4: Marble quarrying for paint and chemical industries.
5. Quarry 5: Gneiss quarrying for dimension stone production
6. Quarry 6: Marble quarrying for paint and chemical industries.
7. Quarry 7: Granite quarrying for chippings production
8. Quarry 8: Marble quarrying for paint and chemical industries.

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Samples were collected from each of the quarries. Also average boulder sizes were measured in each of the quarries and vary between 1m to 2m. Efforts were made to get some drilling and blasting information such as diameter of blast holes, spacing and burden, bench height. Definite order of drilling the holes which would have specified spacing and burden were non - existent.The distance between holes varied from 5 to 8m, bench heights varied from 8m to 16 meters.

Table 1: Average rock strength for each quarry as established by Total Quality Nigeria Ltd at Effurun Delta State

QUARRY	TYPE OF ROCK	ROCK STRENGHT (MPA)	ROCK CLASS FACTOR	SWELL FACTOR
QUARRY 1	GRANITE	23	5	1.2
QUARRY 2	MARBLE	16	4	1.12
QUARRY 3	GRANITE	24	5	1.2
QUARRY 4	MARBLE	20	4	1.12
QUARRY 5	GNEISS	36	7	1.25
QUARRY 6	MARBLE	16	4	1.12
QUARRY 7	GRANITE	26	5	1.2
QUARRY 8	MARBLE	16	4	1.12

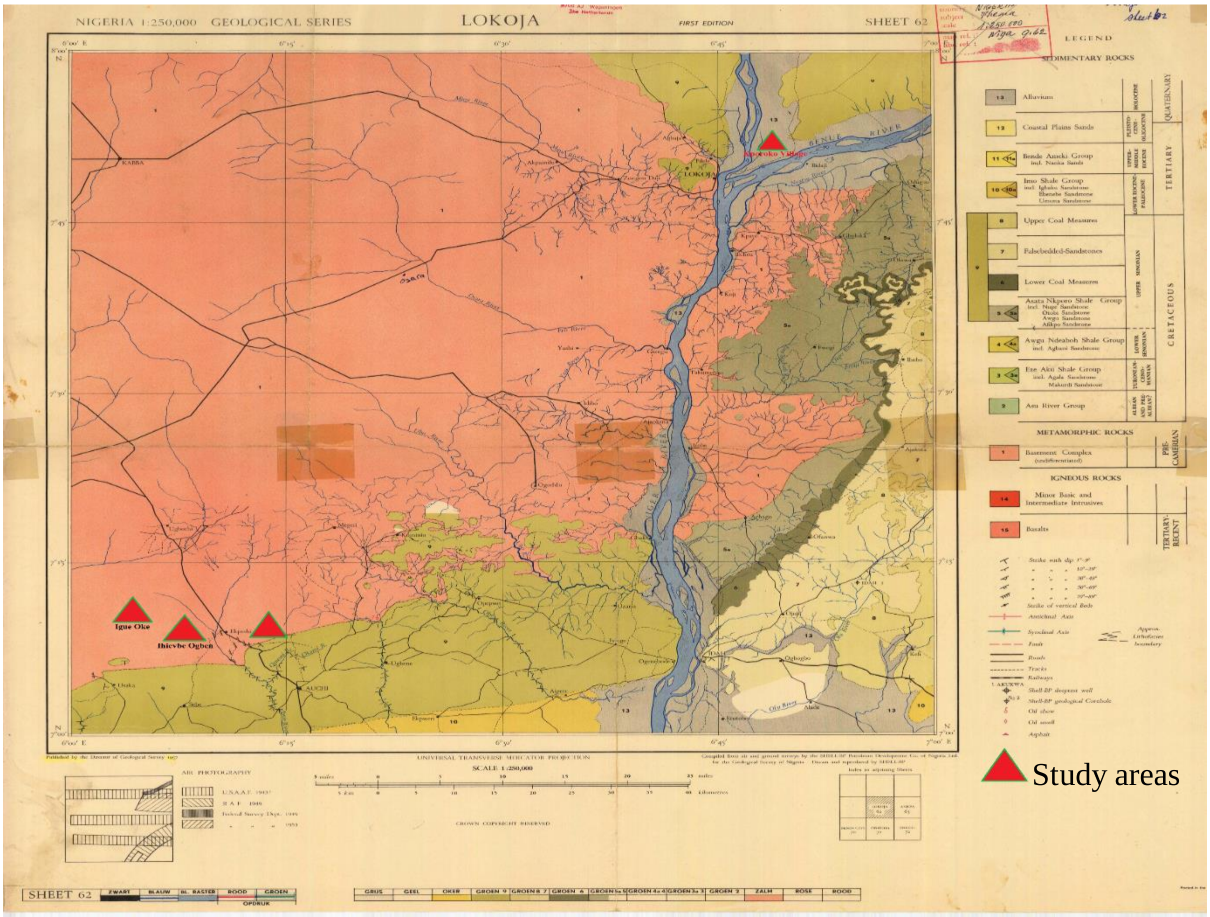

Figure 1: Map of Auchi-Igarra and Okene-Lokoja Mineral Districts Showing the Study areas

ESTIMATION OF MAXIMUM BENCH HEIGHT FOR OPTIMUM BLASTING

Adeev and Baron (1986), having studied factors affecting fragmentation have developed a mathematical model relating diameter of the blasthole to bench height, swell factor, rock factor and some constants, ie

$$D = 9H + 35.5Sw + 33.5F - 195 \qquad \text{equ (1)}$$

Where;

D = diameter of blasthole
Sw = swell factor
F = rock factor

From equu (1) $H = \frac{D - 35.5Sw - 33.5F + 195}{9}$

For instance, for quarry No. 8 with diameter of blasthole 79mm, swell factor of 1.2 and rock factor of 5 (granite), the maximum bench height should be

$$H = \frac{79 - (35.5 \text{ x } 1.2) - (33.5 \text{ x } 5) + 195}{9}$$

$= 7.1m$

Hence, using the rock drill to drill on bench height higher than 7m will lead to bad fragmentation since this will create toe burden greater than what the blasthole charge can move. It is worthy of note that quarry No. 8 has been using this same rock drill on a 15m bench height. The diagram below illustrates this problem (Fig. 2).

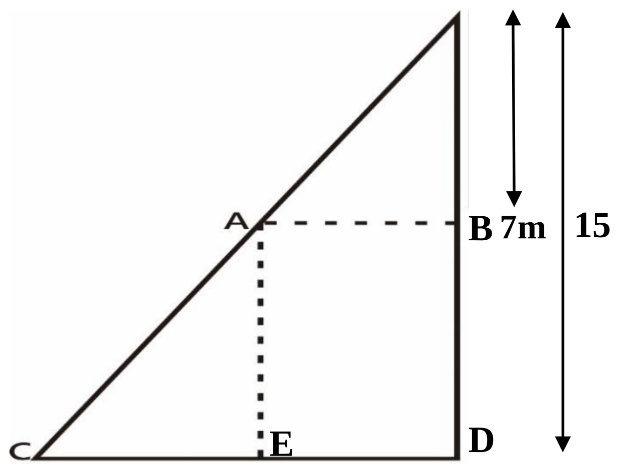

Figure 2: Illustrating how over-estimated bench height can create excess burden and bad fragmentation

AB is the burden created by a 7meter bench height, which is the appropriate bench height for a 79mm diameter blasthole. However, because the rock drill was used to drill a 15m bench, the burden increases to CD which is higher than AB by CE. Thus, CE is the excess load over and above the capacity of the charge concentration of a 79mm diameter blasthole. The inability of the charge to move the bench burden due to the excess burden CE is the reason why much boulders occur any time a round is blasted by Quarry No. 7.

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Using the above model, the maximum allowable bench heights for given diameters of blastholes have been calculated for both granite and marble quarries as recommended in table 3.

Figures 2 and 3 also show the graphic representation of these estimates.

Table 2: Showing maximum bench heights for given diameters of blasthole in the granite quarries.

Blasthole diameter(mm)	60	70	80	90	100	110	120	130	140	150
Bench height (m)	5	6	7.2	8.3	9.4	10.7	12.72	14.93	17.31	19.87

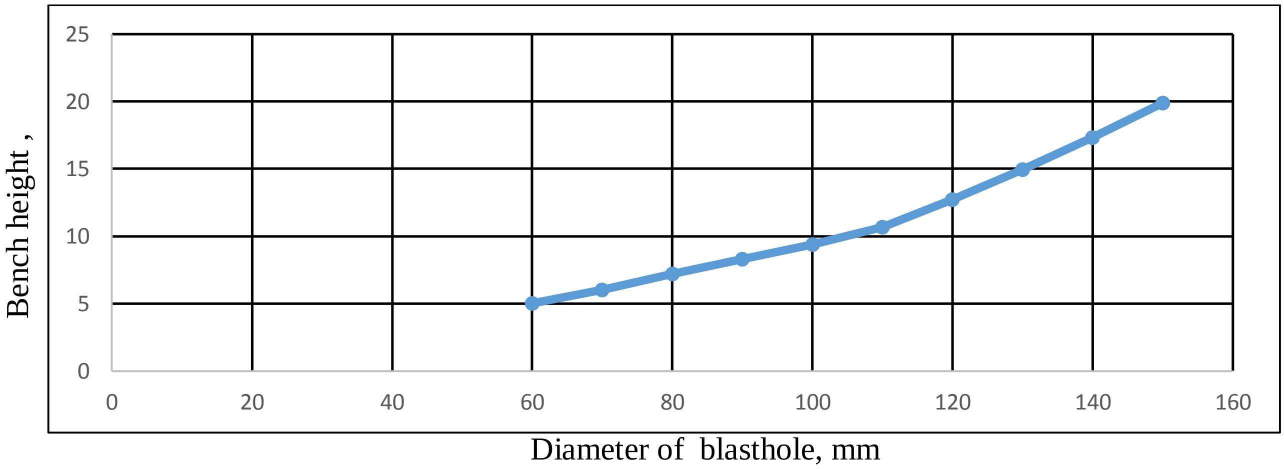

Figure 3: Graph showing blasthole diameter vs maximum bench height for granite quarries

Table 3: Showing hole diameter vs maximum bench height for marble quarries.

Hole diameter(mm)	60	70	80	90	100	110	120	130	140	150
Bench height (m)	9	10	11.2	12.3	13.4	14.6	15.7	16.8	18	19

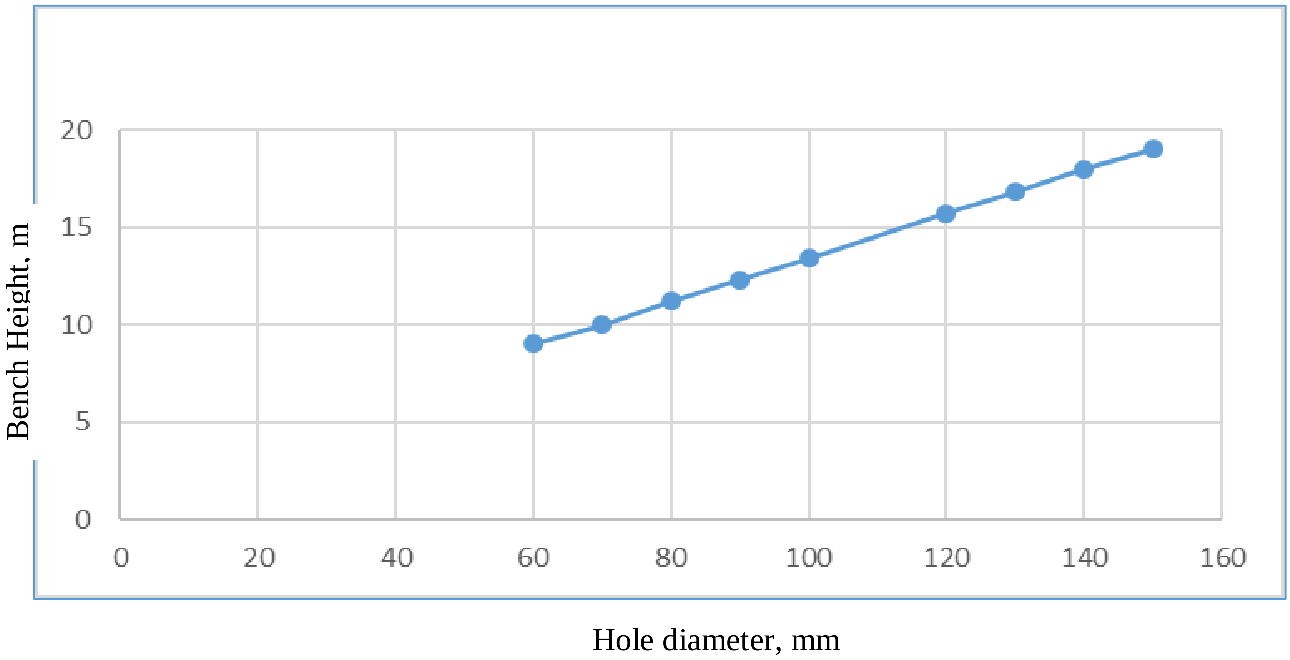

Figure 4: Graph showing blast hole diameter for maximum bench height for marble.

The field photographs in plate 7, 8 and 9 shows the fragmentation on quarries with the parameters as recommended above

Plate 7

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Plate 8

Plate 9

Plate 7, 8 and 9: Results of fragmentation with the recommended parameters

DISCUSSION

The bench heights estimated using equation (1) and shown in Tables 2&3 above are the maximum bench heights allowable in order to avoid bad fragmentation i.e creation of boulders. However, bench heights less than the recommended maximum can be allowed provided they are not so small as to cause over-blasting and fly rocks. It is also worthy of note that insignificantly low bench heights can increase cost per unit of production since access roads have to be created each time from one bench to another and productivity of both drilling, loading and haulage equipment may be lower as a result of downtime during construction and bench preparation period. In any case, it is somehow better to over blast than to operate with increased bench heights that will lead to bad fragmentation. So, as much as possible, lower bench height is more advantageous or cost effective provided the allowable maximum bench heights are not exceeded.

CONCLUSION

The result of the test blasting has shown that the major factor affecting bad fragmentation in Auchi-Igarra and Okene-Lokoja mineral districts as in many other mineral districts in Nigeria is over-estimated bench heights compared to the diameter of the blasthole. It is therefore very important for these quarries to operate within the recommended bench heights.

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