

Correlation of Blast-hole Deviation and Area of Block with Fragment Size and Fragmentation Cost

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Abstract - Blast-hole deviation and fragment size were correlated with powder factor and fragmentation cost. Six scenarios were adopted for blast-hole parameters, bit diameter and explosives. The explosives for scenarios A-B, C-D and E-F are ANFO, heavy ANFO, and emulsion respectively. The blast-hole diameter employed for six scenarios are 191 mm and 311 mm. Blast-hole deviations were recorded by taken the length of displacement of the beam of the drill away from vertical. Also, the mean fragment size was determined using existing equations developed by researchers and extra fragmentation cost (mechanical and chemical) were estimated. The result obtained revealed that blast-hole deviation varied from 0.1 - 0.5 m for the six scenarios. The mean fragment size varied from 332 mm for 0.1 m blast-hole deviation to 289 mm for blast-hole deviation of 0.5 m. This trend was experienced in (B -F) scenarios that as blast-hole deviation increases the mean fragment size reduces and cost of drilling and blasting increase on the other hand. Larger mean fragment size was achieved with the use of ANFO than mean fragment size distribution experience when heavy ANFO was applied. Furthermore, with larger blast-hole diameter of 311 mm there is reduction in size of fragments when compared to blast-hole diameter of 191 mm. Extra fragmentation cost incurred in scenarios A, B, C, D, E and F are: \$10,631.39, \$23,769.34, \$15, 274.49, \$36, 093.07, \$16,392.46 and \$36,093.07 respectively. Finally, strong correlation exist among, blast-hole deviation, area of block, fragment size and fragmentation cost.

Key Words: Fragmentation, Cost, Deviation, Blast-hole, Explosives, Scenarios

1. INTRODUCTION

The main aim of mine operator is to exploit the mineral or ore deposit in the most economical way that gives maximum profit. Good rock fragmentation is a concern to many researchers because it is considered as the most important aspect of ore or mineral production. The level of

fragmentation achieved will ultimately affect costs of drilling, blasting and the efficiency of all the subsequent mining operations [1]; [2]; [3] and [4]. Suitable results of blasting can only be obtained when the rock is properly understood [5].

The drilling phase is the most expensive production, requiring a sizable capital investment and experience. Blast-hole deviation is frequently experienced in mine as the bit advance deep into the rock mass. Blasting operation will not be effective if the blast-holes are poorly placed or aligned. Therefore, there is possibility that this condition will give rise to excessive burden or reduced burden which will yield undesirable fragmentation size distribution. It was observed that when a drill hole is off target (due to pegs moving, poor collaring, and re-drilling) the effective spacing is increased in one area and decreased in another [6]. This will definitely alter the drilling and then influence fragmentation with fragment size distribution. However, if a hole is misplaced by 0.4 m, it could reduce the explosive power at a certain point of about 28%. It was noted that cost of drilling and blasting increases as collar hole deviation increases [7]. In addition inappropriate planning, design and field operational errors of blasts including unpredictable site conditions, variability of rock mass properties and characteristics of explosives and accessories may aggravate blast-hole deviations which will invariably lead to environmental disturbance after the detonation of explosives charged inside the blast-holes. The quantity of explosive required to fragment 1 m³ or 1tonne of rock is known as powder factor [8]. Blast-hole deviation may have up 97% influence on the area of block and mean fragment size as blast-hole deviation increase the area of block will shrink.

2. MATERIALS AND METHOD

This study was conducted at Hwange Colliery Mine and scenarios adopted for the paper are presented in Table 1.

Table -1: The Scenarios Adopted for Blasting Parameter and Explosives

Scenario	Design Burden	Design Spacing	Explosive	Bit diameter
A	5.6	6.5	ANFO	191
B	5.6	6.5	ANFO	311
C	5.6	6.5	Heavy ANFO	191
D	5.6	6.5	Heavy ANFO	311
E	5.6	6.5	Emulsion	191
F	5.6	6.5	Emulsion	311

2.1 Blast-hole deviation

The length of the horizontal displacement drill beam away from vertical was measured measuring tape.

2.2 Determination of Mean Fragmentation Size

The equations for determination of mean fragment size are expressed in Equations 1-2 [9]; [10]:

$$A = 0.06(RMD + RDI + HF) \tag{1}$$

$$X = A \times \left(\frac{V}{Q}\right)^{0.8} \times (Q)^{0.167} \times \left(\frac{E}{115}\right)^{-0.633} \tag{2}$$

Where,

The rock characteristic factor A is calculated to correct the mean fragment size, it is made up of 3 factors which are the rock mass description (RMD), rock density influence (RDI) and the hardness factor (HF) [11].

X is Mean fragment size (mm), V is volume of blasted rock (m³), Q is mass of explosive charge per hole (kg), E is relative weight strength of explosive (ANFO =100) and A is a constant based on rock factor (that depends on rock density, rock strength and jointing)

2.3 Determination of Extra Costs

Extra cost for drilling was determined using Equations 3-5.

$$\text{Hole per } 100\ 000\ \text{bcm} = \frac{100\ 000\ \text{bcm}}{\text{Burden} \times \text{Spacing} \times \text{Hole length (m)}} \tag{3}$$

$$\text{Drilling Shifts per } 100000\ \text{bcm} = \frac{\text{Holes per } 100000\ \text{bcm}}{\text{Drilling metre per shift}} \tag{4}$$

$$\text{Extra cost} = \text{Extra Shift} \times \frac{\text{Labour}}{\text{shift}} + \text{Extraholes} \times \text{D\&B cost per hole} \tag{5}$$

3. RESULTS AND DISCUSSION

Tables 2-3 present scenario A and B coupled with design pattern, bit size and the explosive used. For scenario (A) the design is 5.6 m burden, 6.5 m spacing, 191 mm bit diameter and the explosive used is ANFO respectively. The blast-hole deviation varied from 0.1 – 0.5 m hence effecting change spacing and burden. The fragment size varied from 332 mm for 0.1 m blast-hole deviation to 289 mm for blast-hole deviation of 0.5 m. It could be deduced that as the blast-hole deviation increases the fragment reduces in size; there may be possibility of fly rocks as blast-hole deviation increases. Furthermore, as the blast-hole deviation increases there is corresponding increase in cost of drilling and blasting.

Table - 2: Scenario A with Design Pattern (5.6x6.5), 191mm Bit and ANFO

Devia (m)	Burden (m)	Spacing (m)	Frag. Size X50 (mm)	Dril. & Blasting Cost (\$/bcm)	Block Area (m ³)
0	5.6	6.5	332	0.51	36.40
-0.1	5.5	6.4	323	0.53	35.20
-0.2	5.4	6.3	314	0.55	34.02
-0.3	5.3	6.2	305	0.57	32.86
-0.4	5.2	6.1	297	0.59	31.72
-0.5	5.1	6.0	289	0.61	30.60

Table -3: Scenario B with Design pattern (5.6 x 6.5), 311mm bit and ANFO

Devia. (m)	Burden (m)	Spacing (m)	Frag. Size X50 (mm)	Dril. & Blasting Cost (\$/bcm)	Block Area (m ³)
0	5.6	6.5	216	1.07	36.40
-0.1	5.5	6.4	211	1.11	35.20
-0.2	5.4	6.3	205	1.15	34.02
-0.3	5.3	6.2	199	1.19	32.86
-0.4	5.2	6.1	194	1.23	31.72
-0.5	5.1	6.0	188	1.27	30.60

Tables 4 and 5 present scenario C-and D coupled with design pattern, bit size and the explosive used. For scenario (C and D) the design is 5.6 m burden, 6.5 m spacing, (191 mm and 311 mm) bit diameter and the explosive used is heavy ANFO respectively. The blast-hole deviation varied from 0.1 – 0.5 m hence effecting change in the spacing and burden dimension. The fragment size

varied from 230 mm for 0.1 m blast-hole deviation to 206 mm for blast-hole deviation of 0.5 m. It could be deduced that as the blast-hole deviation increases the fragment reduces in size there may be possibility of fly rocks as blast-hole deviation increases. Furthermore, as the blast-hole deviation increases there is corresponding increase in the cost of drilling and blasting. Larger fragment sizes were achieved with use of ANFO than size distribution achieved when heavy ANFO was applied; this means that the performance of heavy ANFO is better.

Table - 4: Scenario C with Design pattern (5.6x6.5), 191mm bit and Heavy ANFO

Devia. (m)	Burden (m)	Spacing (m)	Frag. Size X50 (mm)	Dril. & Blasting Cost (\$/bcm)	Block Area (m ³)
0	5.6	6.5	237	0.77	36.40
-0.1	5.5	6.4	230	0.8	35.20
-0.2	5.4	6.3	223	0.83	34.02
-0.3	5.3	6.2	218	0.85	32.86
-0.4	5.2	6.1	212	0.89	31.72
-0.5	5.1	6.0	206	0.92	30.60

Table 5 presents scenario D where the blast-hole diameter is 311 mm, it could be deduced that with larger diameter there is reduction size of fragments compared scenario utilizing blast-hole diameter of 191 mm.

Table - 5: Scenario D with Design pattern (5.6x6.5), 311mm bit and Heavy ANFO

Devia. (m)	Burden (m)	Spacing (m)	Frag. Size X50 (mm)	Dril. & Blasting Cost (\$/bcm)	Block Area (m ³)
0	5.6	6.5	154	1.76	36.40
-0.1	5.5	6.4	150	1.82	35.20
-0.2	5.4	6.3	146	1.89	34.02
-0.3	5.3	6.2	142	1.95	32.86
-0.4	5.2	6.1	138	2.02	31.72
-0.5	5.1	6.0	134	2.09	30.60

Tables 6 and 7 present scenario E-and F coupled with design pattern, bit size and the explosive used. For scenario (E and F) the design is 5.6 m burden, 6.5 m spacing, (191 mm and 311 mm) bit diameter and the explosive used is emulsion respectively. The blast-hole deviation varied from 0.1 – 0.5 m hence effecting change in the spacing and burden dimension. For blast-hole

diameter of 119 mm, the fragment size varied from 257 mm for 0.1 m blast-hole deviation to 230 mm for blast-hole deviation of 0.5 m. It could be deduced that as the blast-hole deviation increases the fragment reduces in size there may be possibility of fly rocks as blast-hole deviation increases. Furthermore, as the blast-hole deviation increases there is corresponding increase in the cost of drilling and blasting.

Table - 6: Scenario E with Design pattern (5.6x6.5), 191mm bit and Emulsion

Devia. (m)	Burden (m)	Spacing (m)	Fragment Size X50 (mm)	Dril. & Blasting Cost (\$/bcm)	Block Area (m ³)
0	5.6	6.5	264	0.78	36.40
-0.1	5.5	6.4	257	0.81	35.20
-0.2	5.4	6.3	250	0.84	34.02
-0.3	5.3	6.2	244	0.87	32.86
-0.4	5.2	6.1	237	0.9	31.72
-0.5	5.1	6.0	230	0.93	30.60

Table 7 presents scenario F using blast-hole diameter of 311 mm, the fragment size varied from 172 mm for 0.1 m blast-hole deviation to 150 mm for blast-hole deviation of 0.5 m.

Table - 7: Scenario F with Design pattern (5.6x6.5), 311mm bit and Emulsion

Devia. (m)	Burden (m)	Spacing (m)	Fragment Size X50 (mm)	Dril. & Blasting Cost (\$/bcm)	Block Area (m ³)
0	5.6	6.5	172	1.79	36.40
-0.1	5.5	6.4	168	1.85	35.20
-0.2	5.4	6.3	163	1.91	34.02
-0.3	5.3	6.2	159	1.98	32.86
-0.4	5.2	6.1	154	2.05	31.72
-0.5	5.1	6.0	150	2.13	30.60

Figure 1 presents plot of extra cost against percentage pattern of blast-hole deviation for Scenario A where the blast-hole diameter used is 119 mm. The extra cost incurred for drilling and blasting increases as the blast-hole deviation increases. Also, in Figures 2-6 the trend that as deviation increases extra cost of drilling and blasting increases as well were experienced for scenarios B to F. There appears to strong correlation between blast-hole

deviation and extra drilling and blasting cost. The highest cost incurred in scenarios A and B are \$10, 631.39 and \$23,769.34 respectively.

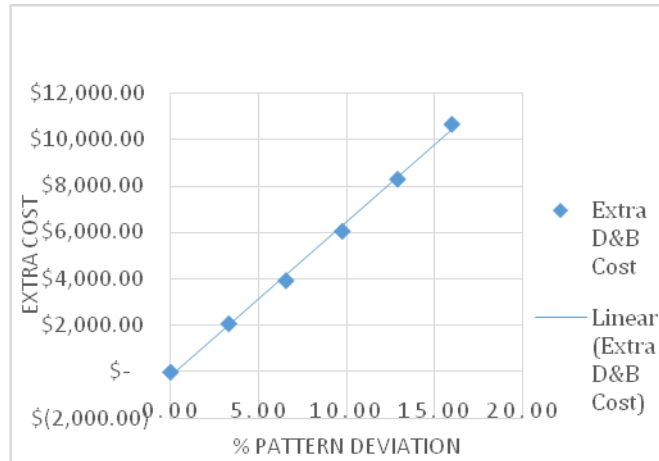


Chart - 1: Extra D&B cost against % pattern deviation for scenario A

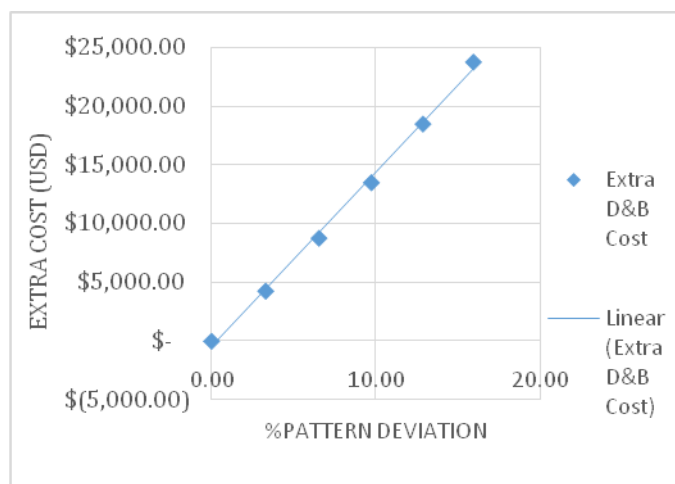


Chart -2: Extra D&B cost against % Pattern Deviation for Scenario B

In Figures 3 and 4 the highest extra cost of drilling and blasting incurred are \$15,274.47 and \$ 36,093.07 respectively. It was observed that blast-hole diameter has effect on extra cost incurred with increasing blast-hole diameter there is also corresponding increase in the cost of drilling and blasting cost incurred.

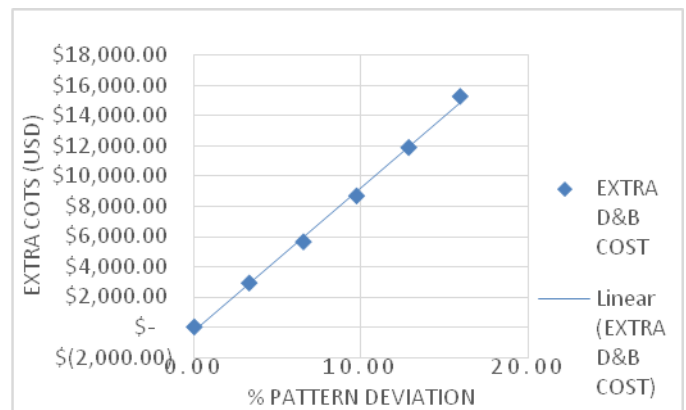


Chart - 3: Extra D&B cost against % Pattern Deviation for Scenario C

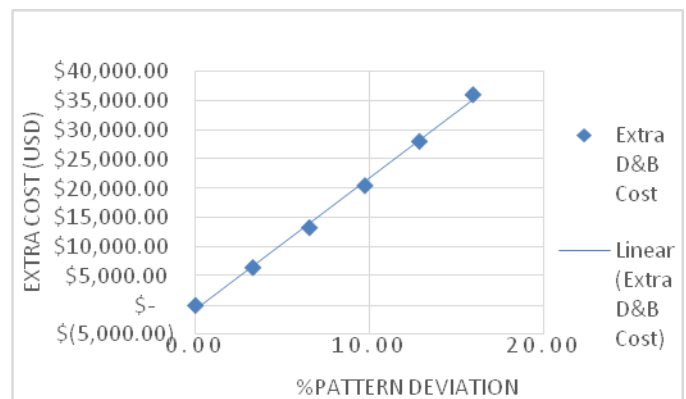


Chart - 4: Extra D&B cost against % Pattern Deviation for Scenario D

In Figures 5 and 6 the highest extra cost of drilling and blasting incurred are \$16,392.46 and \$ 36,093.07 respectively. It was observed that blast-hole diameter has effect on extra cost incurred with increasing blast-hole diameter there is also corresponding increase in the cost of extra drilling and blasting cost. The type of explosive has influence on extra of drilling and blasting; the least cost of \$2, 074.20 was obtained for scenario A, where 119 mm diameter hole and ANFO explosive was used while highest cost of \$36, 093.07 were obtained in scenarios D and F using heavy ANFO and emulsion explosive of same diameter of 311 mm.

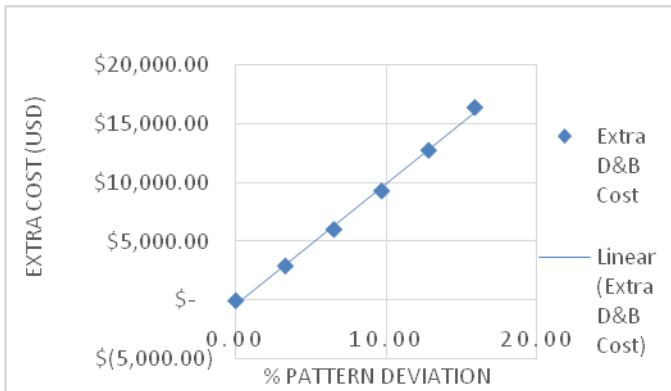


Chart - 5: Extra D&B cost against % Pattern Deviation for Scenario E

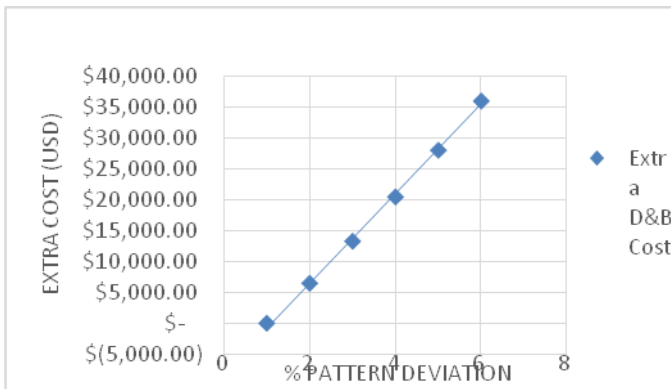


Chart - 6: Extra D&B cost against % Pattern Deviation for Scenario F

4. CONCLUSIONS

The paper had investigated correlation of blast-hole deviation and area of block with fragment size and fragmentation cost (mechanical and chemical). The following are drawn from the work:

1. Increase in blast-hole deviation may lead to reduction in the size of fragments which can produce fly rocks.
2. There is possibility that longer hole will be drilled and charged, hence high extra cost will be incurred.
3. The type of explosive affects fragment size distribution and the largest fragment size of 332 mm was achieved when ANFO was used.

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