Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.3, No.13, 2013

Investigating the Effect of Initiation Device on Environmental Effect of Blasting: A Case Study of Beautiful Rock Lokoja, Nigeria (A subsidiary of resurrection Power Inv. Ltd)

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Abstract
The research investigates the effect of initiation device on environmental effect of blasting. The objectives of the research were achieved through field measurement and data collection. Vibration and noise generated during blasting operations were estimated using mathematical models. Various blasting agents and accessories used for blasting operations were also collected. The results revealed that the noise and vibration generated during blasting with NONEL is minimal as compared to the safety fuse and the electrical methods. It also has high blasting efficiency of 99.1%.
Keywords: Initiation device, vibration, noise, blasting agents, blasting accessories, NONEL, safety fuse method, electrical method.

1. Introduction

Rock blasting is an essential component of surface mining and one of the most applied method applied in rock excavation both applicable in surface and underground mines (Edward, 1990). The effects of blasting arising from the excavations is one of the fundamental problems in the mining industry, rock fragmentation also plays a pivotal role in large scale mining because of its direct effect on cost of drilling, blasting, secondary blasting and crushing.

Thus, it is essential to consider rock fragmentation in blast design, the optimum blasting pattern to excavate a quarry efficiently and economically can be determined based on the maximum production cost which is generally estimated based on the rock fragmentation.

Blasting operations need cogent measures due to its remarkable influence on the stability of rock slopes especially in situations where blasting operation is not being carried out with utmost or designed accuracy. Various ways in which blasting operations affects its environment needed to be accountable for but the most relevant is the structural damage due to vibration inductions, noise, fly off materials, air blast and shock waves resulting in the rock slope failure by creating a new joints or extension of the existing ones.

A good fragmentation is described as that which produces rock fragment that are easy to dig and which will not require secondary blasting before they are loaded in haulage trucks and transported to crushing unit in preparation for crushing operation (Djordjevic, 2010). Proper fragmentation hereby eliminates the need for a secondary blasting thereby reducing the cost involved in operations.

However, it has been proven that fragment size distributions depend on the extent of fracture propagation, coalescence and interaction of the propagation stress wave with any free surface, it is therefore necessary to carefully apply effective blasting techniques (blasting methods) to achieve the desired result within the minimum possible cost as well to minimize environmental fall outs such as ground vibration, air blast and fume production (Jimeno *et al*., 1995).

1.2 *Description of the Study Area*

Beautiful Rock company is a subsidiary of Resurrection Power Inv. Ltd., located at Jimgbe along Ajaokuta road with coordinates of N 07° 42' and E 06° 44' which lies along the River Niger bank of Kogi state Nigeria. Figure 1 shows the map of Kogi State indicating the study area.

Beautiful Rock Company is a private owned mining company which ventures in quarry operation which started operation fully in 2009 with an employment size of 48 workers, comprising of 40 professionals and 8 non-professional workers with a capital investment of 500million update.

2. Method

2.1 Determination of Ground Vibration and Noise Generated during Blasting

The ground vibration generated from various operations was estimated using Equation 1.

$$V = k\left(\frac{R}{Q^{1/2}}\right)^{b} \quad (1)$$

Where, R is the distance in meters, Q is the maximum instantaneous charge per delay in kg, k is the site factor constant and b = site exponent constant which is usually taken as -1.6 and

The expected noise from the operations was measured using Equation 2.

$$P = k\left(\frac{R}{Q^{1/3}}\right)^{b} \quad (2)$$

Where, P is the Pressure (kPa),Q is the maximum instantaneous charge per delay (kg), R is the distance from charge (m), k is the state of confinement which is 185 for unconfined condition and 3.3 for confined condition, and b = Site exponent constant which is usually taken as -1.2.

2.2 Methods of Blasting

2.2.1 *Electrical Method*

Two kinds of method are generally adopted in electrical blasting method;

1. V- firing pattern and;
2. U- firing pattern

V- Pattern: It is the most applicable, the forward movement is controlled within reasonable limits and the broken muck is deposited at an angle 90° to the open face and it is the most efficient firing pattern because minimal noise and vibration are generated. The Table 1 shows the distribution of detonators used in carrying out blasting operation for 50 holes of bench height 9m while using v-firing pattern. Figure 2 shows a V-firing pattern for electric blasting operation.

Materials used for Blasting

1. Exploder
2. Connecting wire
3. Bus wire
4. Permanent blasting wire
5. High explosive (ammonium gel)
6. Low explosives (Ammonium Nitrate with fuel oil)
7. Stemming :earth material
8. Detonators: 50 electric detonators
9. Stemming rod
10. Burden and spacing: 1m and 1.5m resp.
11. Firing pattern : point 6 and 9
12. Hole diameter:68mm
13. holes: 50 holes

U- pattern: opening the blast with two middle holes which will result in slightly more forward movement of the rock or muck pile.

The Table 2 shows the distribution of detonators used in carrying out blasting operation for 72 holes of bench height 9m while using v- firing pattern. Figure 3 shows a U-Firing Pattern for Electric Blasting Operation

Materials

1. Exploder
2. Connecting wire bridge point
3. Bus wire
4. Permanent blasting wire
5. High explosive (ammonium gel)
6. Low explosives (Ammonium Nitrate with fuel oil)
7. Stemming :earth material
8. Detonators: 72 electric detonators
9. Stemming rod
10. Burden and spacing: 1m and 1.5m resp.
11. Firing pattern : point 6 and 9
12. Hole diameter:68mm
13. holes: 50 holes

2.2.2 Safety Fuse or Plain Cap Method

To aid proper detonation a knot-type connection is made which are arranged in various patterns.

1. V-connection pattern
2. L-connection pattern
3. Rectangular pattern.

V-connection Pattern: a centre is been picked and the detonating cord are been attached to the centre in a diagonal pattern, in which the connections form a v-shaped heaping pattern. Figure 4 is a typical diagram showing V connection pattern.

Materials → ← *bridge point*

1. Exploder
2. High explosive (silica gel)
3. Low explosives (Ammonium Nitrate with fuel oil)
4. Stemming :earth material
5. Stemming rod
6. Burden and spacing: 1m and 1.5m resp.
7. Hole diameter:68mm
8. holes: 50 holes
9. bench height: 9m
10. Detonating cord: 900m
11. Safety fuse:1m
12. Plain cap:1pc
13. Delay relay:53pcs
14. Igniter: cigarette and lighter

L-connection Pattern: the drill-holes are been connected in the form of L-shape, the front, back or sides are not been delayed but the non electric blasting caps are been connected in such a way that they fall within the diagonal of the drilled holes while others are attached across and along the burdens and spacing. Figure 5 is a typical diagram showing L-connection pattern.

Materials

1. Exploder
2. High explosive (silica gel)
3. Low explosives (Ammonium Nitrate with fuel oil)
4. Stemming :earth material
5. Stemming rod
6. Burden and spacing: 1m and 1.5m resp.
7. Hole diameter:68mm
8. holes: 60 holes
9. bench height: 9m
10. Detonating cord: 800m
11. Safety fuse:1m
12. Plain cap:1pc
13. Delay relay:19pcs
14. Igniter: cigarette and lighter.

Rectangular Connection Pattern: the Non electric caps are been attached to the side and centre burden while also attached to the frontline and the backline not connected. Figure 6 is a typical diagram showing a rectangular connection pattern.

Materials

1. Exploder
2. High explosive (silica gel)
3. Low explosives (Ammonium Nitrate with fuel oil)
4. Stemming :earth material
5. Stemming rod
6. Burden and spacing: 1m and 1.5m resp.
7. Hole diameter:68mm
8. holes: 50 holes
9. bench height: 10m

10. Detonating cord: 1000m
11. Safety fuse:1m
12. Plain cap:1pc
13. Delay relay:25pcs
14. Igniter: cigarette and lighter

2.2.*3* ***Non Electric Blasting Method***

They are been connected in such a way that the relay time increases along the column, the 1st row having lesser delay time. Figure 7 shows the NONEL method of connection.

Materials
Exploder
High explosive (silica gel)
Low explosives (Ammonium Nitrate with fuel oil)
Stemming: earth material (20mm granite size)
Stemming rod
Burden and spacing: 1m and 1.5m resp.
Hole diameter: 68mm No of holes=44
Average Depth: 15m
Detonating cord: 900m
Safety fuse: 1m
Electric detontor: 1pc
NONEL detonator: 88pcs
Multimeter and cello tape
Connecting wire
Permanent blasting wire

NONEL DETONATORS	NONEL CONNECTOR (3m)
500ms-18m/44 pcs	97ms-2pcs
500ms-6m/44pcs	67ms-11pcs
42ms-11pcs	
25ms-11pcs	
1. 17ms-9pcs	

2.3 Efficiency of Initiation Methods

Efficiency of each initiation methods was calculated using Equation 3.

$$Efficiency = \frac{Vol.hauled}{Vol.blasted} \times 100\% \tag{3}$$

3. RESULT

3.1 Electrical Initiation Method

For U- firing pattern

The result generated for the environmental effect i.e. in term of noise and vibration produced by initiation method using U– firing pattern is presented in Table 3;

For V- firing pattern

The result generated for the environmental effect i.e. in term of noise and vibration produced by initiation method using V – firing pattern is presented in Table 4;

3.2 Safety Fuse Initiation Method

For V-firing pattern

The result generated for the environmental effect i.e. in term of noise and vibration produced by initiation method using V – firing pattern is presented in Table 5;

For L-firing pattern
The result generated for the environmental effect that is in term of noise and vibration produced by initiation method using L– firing pattern is as presented in Table 6;

For U – firing pattern
The result generated for the environmental effect i.e. in term of noise and vibration produced by initiation method using U– firing pattern is as presented in Table 7;

3.3 For NONEL Method
The result generated for the environmental effect i.e. in term of noise and vibration produced by initiation method using 15m hole depth is shown in Table 8.

Recall that safety fuse, electrical method both used for hole depth of 10m while NONEL hole depth of 15m.

3.4 *Efficiency*
Table 9 shows the volume blasted, volume hauled, secondary blasting and efficiency of each blasting methods.

4. Discussion
Tables 3 and 4 show noise and vibration produced at various distance from the point of detonation for U and V firing pattern using electrical initiation method. The values of noise for U firing pattern vary from 6.7 to 0.47 kPa and that of V firing pattern vary from 6.5 to 0.46 kPa. The vibration produced for U firing pattern varies from 60.1 to 1.79 kPa and that of V firing pattern varies from 55.95 to 1.66 kPa. Tables 5, 6 and 7 show noise and vibration produced at various distance from the point of detonation for V, L, and U firing patterns. The values of noise for V firing pattern vary from 6.5 to 1.06 kPa, for L firing pattern the values vary from 8.52 to 1.66 kPa and for U firing pattern it varies from 7.12 kPa to 1.07 kPa. Table 8 shows noise and vibration produced at various distance from the point of detonation for NONEL initiation method. The values of noise vary from 6.97 to 0.5 kPa while that of vibration vary from 64.4 to 1.9 kPa. Out of the initiation methods used only NONEL gives the highest efficiency and lowest number of boulders.
For Electrical method, it was discovered that the best connection when carrying out initiation is the V-connection pattern, when twenty thousand, two hundred and sixty three tons (20,263) was blasted, the amount hauled was eighteen thousand and seventy nine (18,079) tons and the efficiency of 89% was obtained compared to U-connection pattern where the same quantity of rock was blasted and seventeen thousand, five hundred and eighty nine (17,589) tons was hauled and the efficiency of 86% was obtained which lower that of V connection pattern.

For Safety Fuse initiation Method the best connection to be adopted is V- connection Pattern that produced seventeen thousand and seventy eight (17,078) tons when twenty thousand two hundred and sixty three tons of granite rock was blasted and efficiency of 84%, compare to L and U- connection method producing lower efficiency of 74% and 79% respectively.

The Table 9 shows the volume of material blasted and the volume hauled, efficiency and fly off material, thus, it was determined that when twenty five thousand three hundred and 28 tons was blasted (25,328), twenty five thousand three hundred and eight tons (25,308) was hauled and the corresponding efficiency is 99.1 % for NONEL initiation method.
Figure 7 depicts the plot of noise and vibration produced against the distance for electric blasting method with U blasting pattern. From the graph noise and vibration produced varies inversely with the distance from the source. The equations of the graph are as written in Equations 5 and 6, the R^2 values are 0.8799 and 0.9083 indicating very strong correlations between them.

$$y = 6.0155e^{-0.003x} \tag{5}$$

$$y = 54.566e^{-0.004x} \tag{6}$$

Figure 8 shows the plot of noise and vibration produced against the distance using electric blasting method with V- firing pattern. From the graph noise and vibration produced varies inversely with the distance from the source. The equations of the graph are as written in Equations 7 and 8, the R^2 values are 0.9014 and 0.905 indicating very strong correlations between them.

$$y = 5.9586e^{-0.003x} \tag{7}$$

$$y = 50.616e^{-0.004x} \tag{8}$$

Figure 9 shows the plot of noise and vibration produced against the distance using safety fuse method with V-firing pattern. From the graph noise and vibration produced varies inversely with the distance from the source. The equations of the graph are as written in Equations 9 and 10, the R^2 values are 0.8551 and 0.9248 indicating very strong correlations between them.

$$y = 7202e^{-0.002x} \tag{9}$$

$$y = 85.301e^{-0.002x} \tag{10}$$

Figure 10 indicates the plot of noise and vibration produced against the distance using electric blasting method with L- firing pattern. From the graph noise and vibration produced varies inversely with the distance from the source. The equations of the graph are as written in Equations 11 and 12, the R^2 values are 0.7892 and 0.9163 indicating very strong correlation between them.

$$y = 7.0216e^{0.002x} \tag{11}$$

$$y = 78.149e^{-0.004x} \tag{12}$$

Figure 11 depicts the plot of noise and vibration produced against the distance using electric blasting method with U- firing pattern. From the graph noise and vibration produced varies inversely with the distance from the source. The equations of the graph are as written in Equations 13 and 14, the R^2 values are 0.8544 and 0.8934 indicating very strong correlation between them.

$$y = 6.2216e^{-0.002x} \tag{13}$$

$$y = 55.003e^{-0.004x} \tag{14}$$

Figure 12 shows the plot of noise and vibration produced against the distance using NONEL blasting method. From the graph noise and vibration produced varies inversely with the distance from the source where the noise and vibration were generated. The equations of the graph are as written in Equations 15 and 16, their respective R^2 values are 0.9084 and 0.9095 indicating very strong correlation between them.

$$y = 6.4822e^{-0.003x} \tag{15}$$

$$y = 58.632e^{-0.004x} \tag{16}$$

5. Conclusion

It has been revealed that the best initiation or blasting method to apply is the non-electrical blasting method (NONEL), because of the following reasons:

1. It has safe environmental effect and ;
2. High productivity rate.

Safe environmental effect involves bearable or minimal noise, vibration and amount of fly off rocks to the environments; different methods have been critically analysed, which are safety fuse method, electrical method and NONEL method that show various degree of fragmentations, noise produced and vibration generated, which shows that NONEL method is the safest way of carrying out blasting operation because it consists of varied large delay-relay time that enables the release energy in successive row to be exhausted before subjecting the next row to detonation and NONEL uses a hollow plastic tube to deliver the firing impulse to the detonators also making it immune to most of the hazardous effects associated with stray electrical current. The equations generated which are Equations 5 to 15 could be used to determine noise and vibrations generated after blasting.

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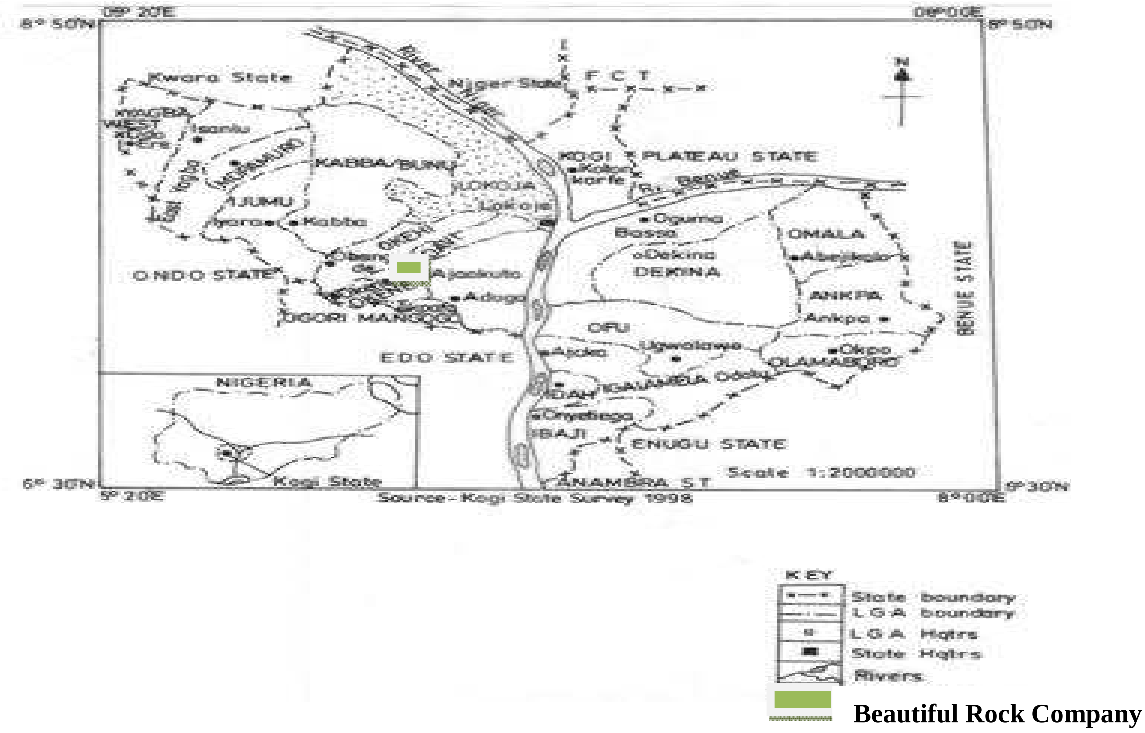

Fig. 1: Map of Kogi State showing the Study Area (Beautiful Rock Company)

Table 1 Detonators used in V -electric Blasting Pattern

S/NO	1	2	3	4	5	6	7	8	9	10
Detonators	1	3	5	3	9	9	7	5	3	1

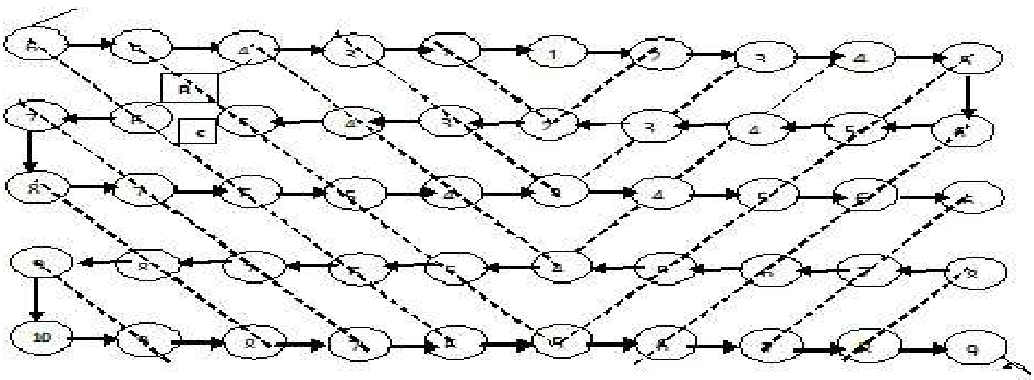

Figure 2 showing a V-firing pattern for electric blasting operation

Table 2 Detonators used in Electric Blasting Method

S/NO	1	2	3	4	5	6	7	8	9	10
Detonators	2	4	6	8	10	12	10	8	6	6

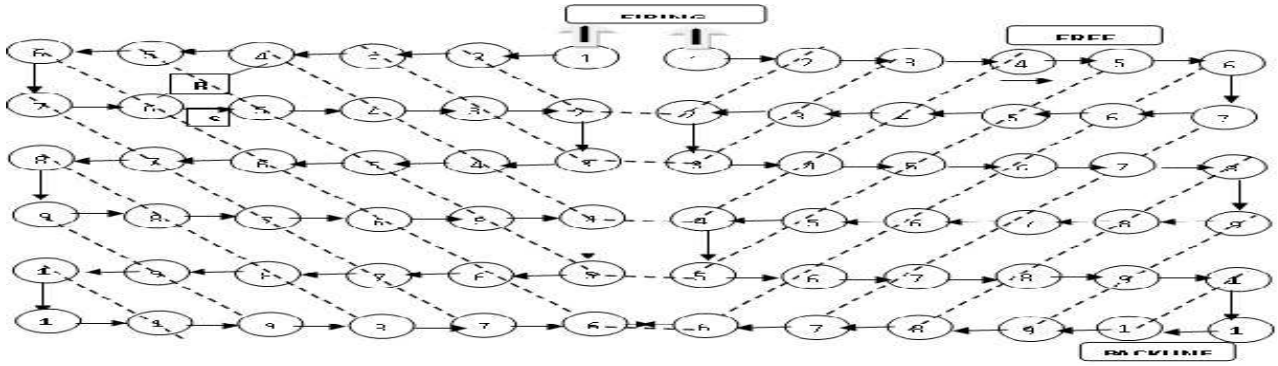

Figure 3 showing a U-Firing Pattern for Electric Blasting Operation

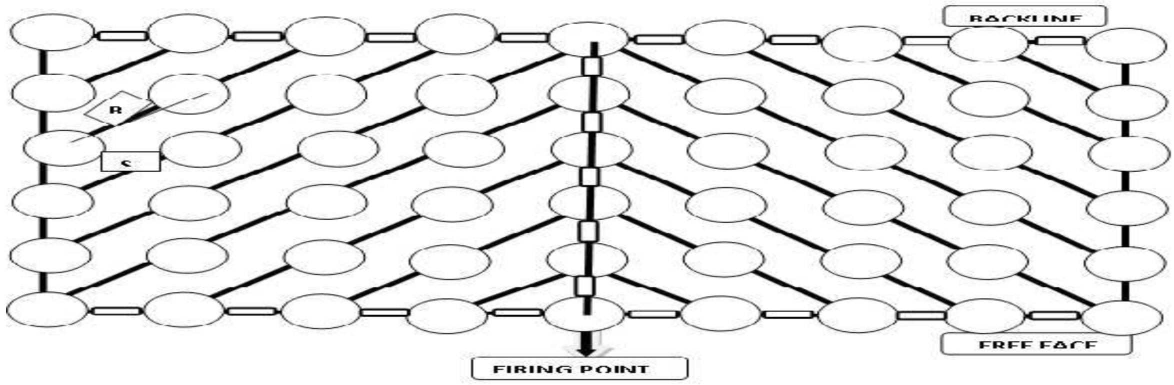

Figure 4 A Typical Diagram Showing V Connection Pattern

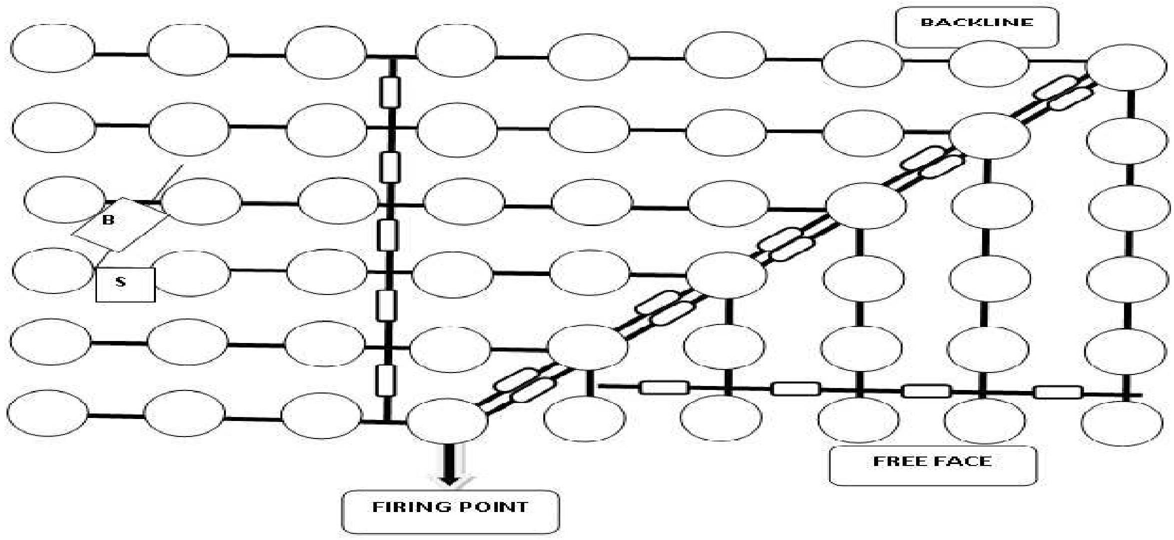

Figure 5 Typical Diagram of L-Connection Pattern

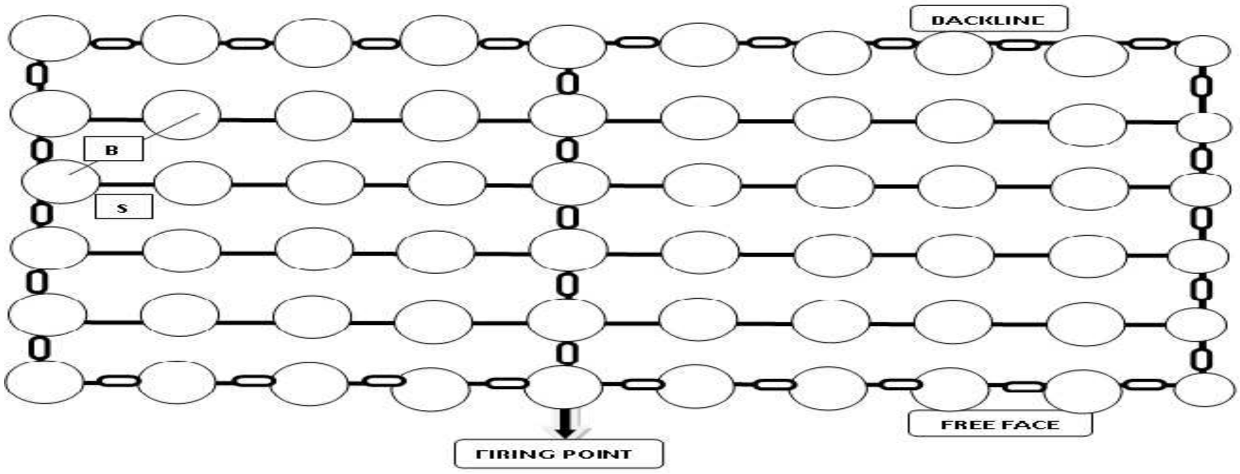

Figure 6 Typical Diagram of Rectangular Connection Pattern

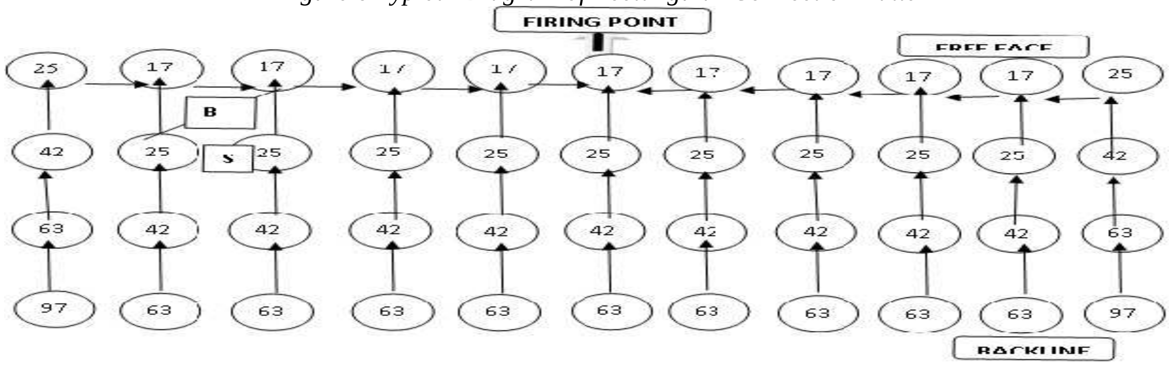

Fig 7 Showing Connection of NONEL Method

Table 3: Noise and Vibration Produced at Various Distance from the Point of Detonation

Dist. (R) m	Noise prod.(kpa)	Vibra. prod kpa
100	6.7	60.1
300	1.8	10.36
500	0.78	4.57
700	0.65	2.67
900	0.47	1.79

Table 4: Noise and Vibration Produced at Various Distance from the Point of Detonation

Distance (R) m	Noise prod.(kpa)	Vib.produced kpa
100	6.5	55.95
300	1.7	9.6
500	0.9	4.2
700	0.62	2.49
900	0.46	1.66

Table 5: Noise and Vibration Produced at Various Distance from the Point of Detonation

Distance (R) m	Noise Produced (kpa)	Vibration Produced (kpa)
100	6.5	63.6
300	2.3	36.7
500	1.54	7.6
700	1.22	5.7
900	1.06	3.8

Table 6: Noise and Vibration Produced at Various Distance from the Point of Detonation

Distance (R) m	Noise produced (kpa)	Vibration produced kpa
100	8.52	82
300	2.9	16.6
500	2.14	6.33
700	1.82	3.82
900	1.66	2.65

Table 7: Noise and Vibration Produced at Various Distance from the Point of Detonation

Distance (R) m	Noise produced (kpa)	Vibration produced kpa
100	7.12	63.10
300	2.4	10.66
500	1.58	4.873
700	1.25	2.97
900	1.07	2.09

Table 8: Noise and Vibration Produced at Various Distance from the Point of Detonation

Distance (R) m	Noise produced (kpa)	Vibration produced kpa
100	6.97	64.4
300	1.866	11.1
500	1.01	4.9
700	0.68	2.87
900	0.5	1.9

Table 9: Sowing Volume Blasted and Efficiency of various Blasting Method

S/No	Methods	Types of firing pattern	Vol. blasted (tons)	Vol. hauled (tons)	Secondary Blasting (tons)	Eff. (%)
1.	Safety fuse	v-shape	20,263	17,078	3185	84
		u-shape	20,263	16,178	4085	79
		L-shape	20,263	15,072	5191	74
2.	Electrical	u- shape	20,263	17,589	2674	86
		v-shape	20,263	18,079	2184	89
3.	NONEL	------	25,328	25,308	20	99.1

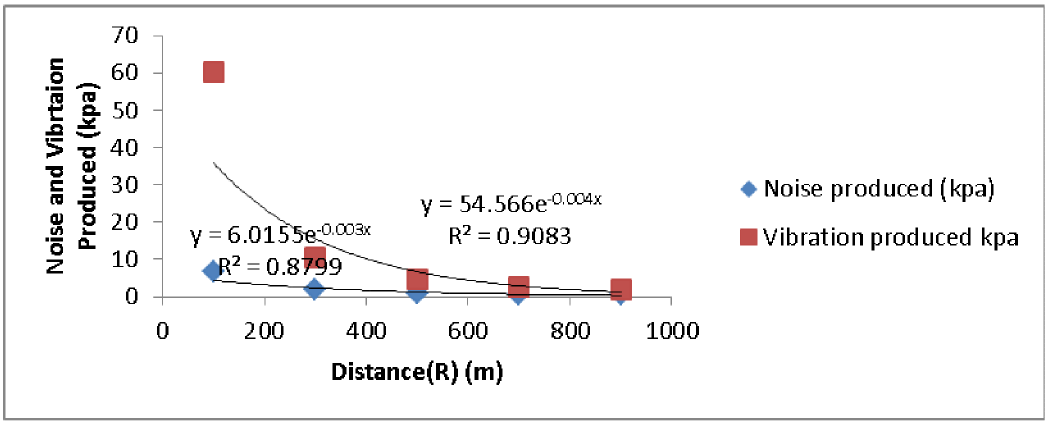

Fig. 7: Noise and Vibration produced using U-shape against Distance (Electric Blasting Method)

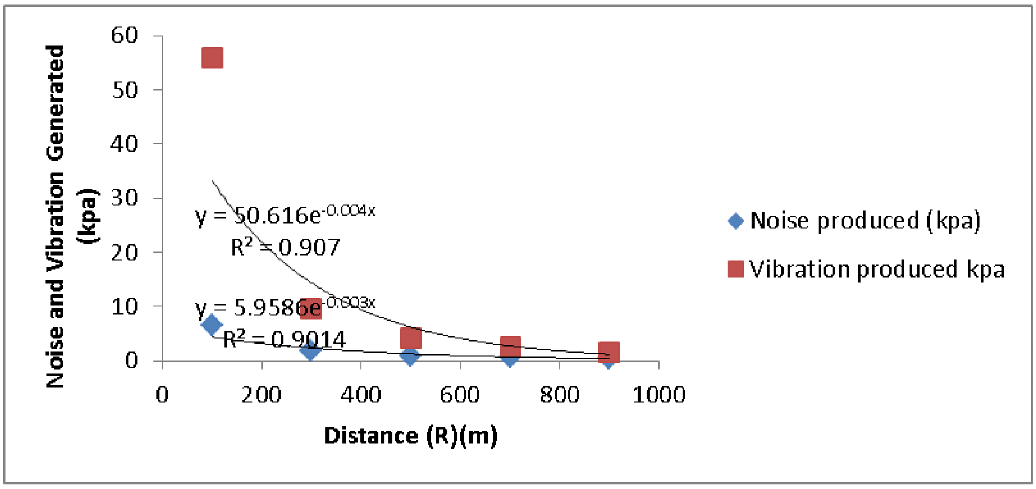

Fig. 8: Noise and Vibration produced using V-shape (Electrical Blasting Method)

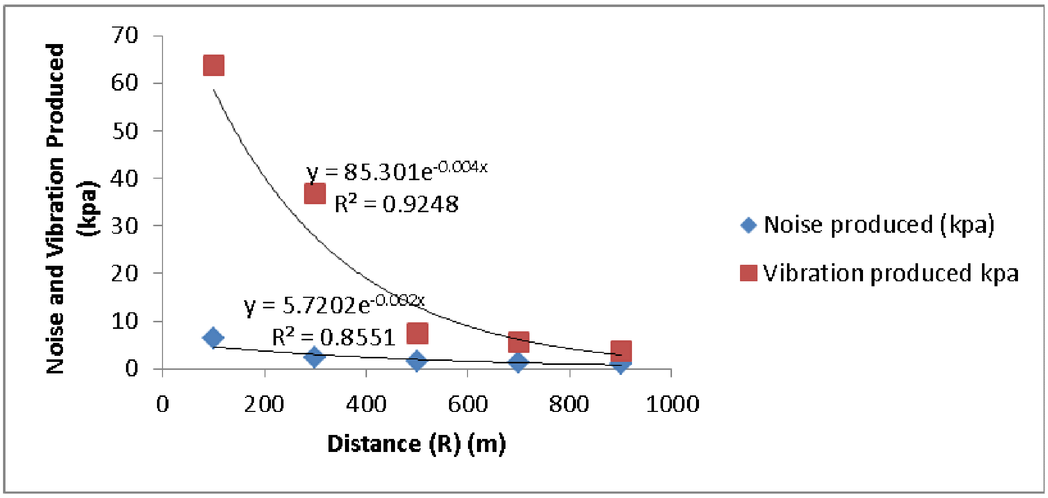

Fig. 9: Noise and Vibration produced using V-shape (Safety Fuse Method)

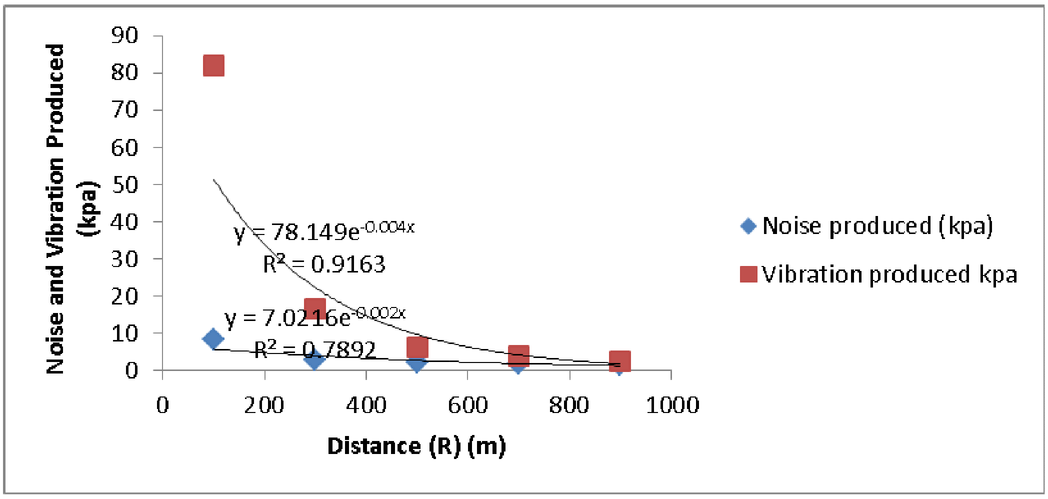

Fig. 10: Noise and Vibration produced against Distance using L-shape (Safety Fuse Method)

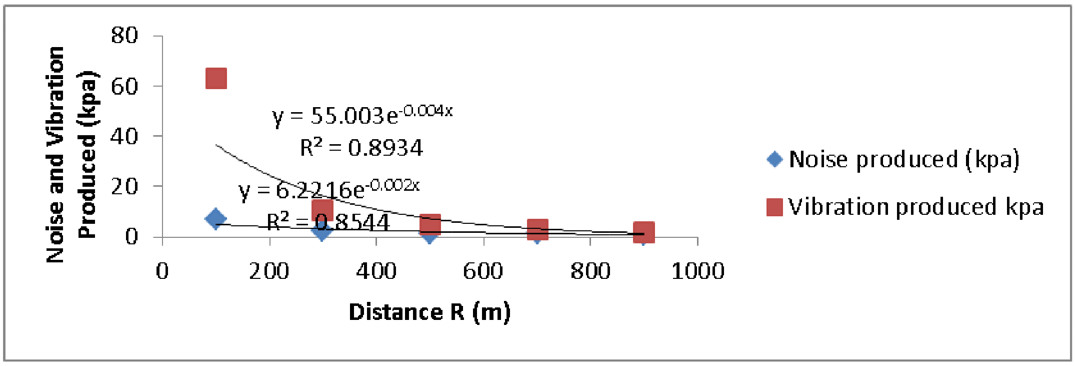

Fig. 11: Noise and Vibration produced against Distance using U-shape (Safety Fuse Method)

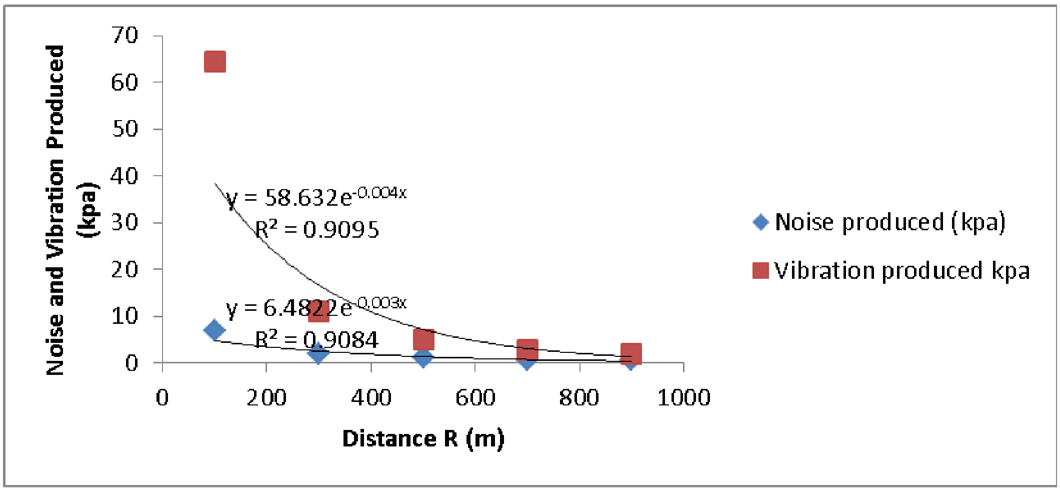

Fig. 12: Noise and Vibration produced against Distance using NONEL