Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

6th International Conference
on
Chemical & Environmental
Engineering
29 -31 May, 2012.

ENMB-2

THE CENTRAL BLASTING A NEW PRESPECTIVE IN ROCK PRODUCTION

Eng. Ibrahim A. Ibrahim* and Dr. Eng. Mohammed H. M. Abuuznein**

Abstract

In addition to the performance and safety factors in the rock production field, researchers look for open extend vision to the small contractors to solve their main problems, which are represented by the machines and explosive expense and availability [1]. In this work central blasting method was applied in various rock structures and geology in Sudan to know the opportunity of other alternative solutions of these sites problems. The mentioned rocks include black granite in White Nile, the white granite in Alseleet (Near Khartoum), and the marble in Atbara. Results show that this method solves the problem of preparations, drilling, primary blasting tasks efficiently according to the explosive amount and machines expenses. This method shows more cost in the stage of secondary blasting, comparing with the bench blasting methods, but this can be considered as a minor effect compared to the major advances of using this method. On other hand it was found that there were unacceptable sites to deal with the traditional bench blasting theory of Livingston, in these cases the central blasting theory becomes a unique absolutely solution.

Keywords: Civil explosives, Central blasting, Bench blasting, Fragmentation, Fly rocks, Livingston theory, Crater Theory.

* Department of Chemical Engineering Karary University – Sudan

** Associate Professor, Head of Department of Chemical Engineering, Karary University - Sudan

NOMENCLATURE

AN	Ammonium nitrate	
ANFO	Ammonium nitrate/ fuel oil	
B	Burden	m
C	Wave velocity	m/sec
E	concentration of explosive energy	J/m^3
H	Height of bench blasting	m
h_b	Height of charge	m
NG	Nitro glycerin	
PF	Powder factor	
R	distance between observation points	m
S	Practical spacing	m
TNT	Trinitrotoluene	
TS	Tensile strength	
VOD	Velocity of detonation	

1. Introduction

The using of explosive in the quarries added a big economic value in the task of rock production. This fabrications needs a big facilities to cover the mean of mass production at quarries which available to the equipped contractors. This is called bench blasting (Livingston theory) and it depends on heavy machines for excavation and drilling task, and about 0.4 kg explosive per rock cubic meter. This research deals with the central blasting method which depends on small air compressor and about 0.15 kg explosive per rock cubic meter. [2, 3]

2. Centeral Blasting Theory And Calculations

2.1 Definition Of Quarry Solution

In open pit operations, the bench height varies within relatively narrow limits. The intention is to mass produce blasted rock in a standardized manner in order to achieve lowest possible cost. The bench height is normally between 15 and 18 m but may occasionally go up to 40 m. Reasons for limiting the bench height are safety, risk of falling rock, and problems with precision in drilling. The hole deviation is more difficult to be controlled in higher benches. So, we define Bench as the most common kind of blasting work, it can be defined as blasting of vertical or close to vertical blast-holes in one or several rows towards a free surface [4]. Rock formation is rarely homogeneous, the rock formation in the blast area consist of different type of rock. Furthermore fault and dirt may change the effect of the explosive in blast. By the bench blasting method of Livingston it is clear that there are some problems regarding the using of the machines and explosives in high benches. So the concept of central blasting is derived from the theory of rock blasting and theory of detonation. The central blasting can be defined as a method which depends on cheap light machine and small quantity of explosive. Explosive is put inside two rooms made in the mountain through tunnel ended by these rooms. This tunnel behaves as stemming so the blast in full confine. The explosive make damage in the boundary of crushing zone and the upper remaining rock fall back and crushed by the gravity out of the explosive effects.

To approach the principle of central blasting theory the following assumptions were taken:

1- Vertical drilling operations

2- The behavior of the blasting charge is spherical.
3- It's like any blast hole but in a big scale.
4- There is an additional stress in the un-blasted falling rock area in the mountain.

2.2 The Procedures Of Central Blasting

The procedure of central blasting was divided into four stages. This give a chance to analyze every stage alone to discover the points of strength and weakness of this method compared to Livingston theory which also can be divided to the same stages.

Four stages were as follows:

Preperations:

In the bench blasting theory we need to prepare access road to take the machine over the bench and mountains but in the central blasting we didn't need so [5].

Drilling:

In bench blasting theory the drilling perfume from the upper surface of mountain along the bench height by pneumatic or hydraulic drilling machine, but in the central blasting the drilling is performed horizontally by small air compressor and one handheld

MAIN BLASTING:

The explosive in the bench blasting is distributed in more than ten holes but in the case of central blasting all explosive is charged at one hole and tunnel builds up to achieve full confinement.

Secondary blasting:

The secondary blasting performed by the same equipment for both cases (central and bench blasting).

2.3 Theories For Derivation Of Central Blasting

Detonation Theory of Explosives:

The simplest theory to predict the behavior of detonations in gases is known as Chapman-Jouguet (CJ) theory, developed around the turn of the 20th century. This theory is described by a relatively simple set of algebraic equations. It models the detonation as a propagating shock wave accompanied by exothermic heat release. Such a theory confines the chemistry and diffusive transport processes to an infinitely thin zone [6].

Rock Breakage Theory:

Rock breakage by explosives can be explained in three principal stages. In the first stage the detonating explosive crushes the rock in the proximity of the hole-wall due to high detonation pressure. In the second stage, compressive stress waves created by the blasting propagate in all directions with a velocity equal to the sonic wave velocity through the-rock-material. When the compressive stress waves are reflected by a free rock face, they return as tensile stress waves. This causes rock failure if the energy in the shock wave is large enough [7]. The energy that is released from the detonating charge along the distance between the hole/row and the free face satisfy a relation that generates the failure of the rock. The tensile strength of the rock is approximately 1/10 of its compressive strength [8, 9].

2.4 Centeral Blasting Theory

Depending on the detonation and rock breakage [10,11] the concept of the central blasting theory was built up. After any blasting there are angles created, the important of these angles represents the design of the optimum burden (the length of tunnel). This considers the main control of material ejection. The reflected theory was chosen in this term for its simplicity and ease of application. Rock fracture resulting from explosion process depends on the orientation of the free faces, the burden, the rock geometry, the physical properties and loading density of the explosive, the type of materials which is built to confine the tunnel, the rock structure and mechanical strength.

2.5 Parameters Of The Central Blasting Module

From figure (1)

$$\frac{2B\text{-}X}{C}=\frac{X}{0.38C} \qquad 1$$

Where:

X = 0.55 B
B is the burden, m.
C is the crack velocity, m/ sec.

From figure (2)

$$t_{track} = \frac{e}{V_{track}} = \frac{g+h}{c} = t_{wave} \qquad 2$$

$$g+h=\frac{B}{\cos \square}[1+\cos 2\square] \qquad 3$$

Modeling of spherical charges: The tangential strain ε at any distance R from a spherical explosive charge of radius b is [12]

$$\varepsilon=\frac{K^{-\square R/b}}{\frac{R^{e}}{b}} \qquad 4$$

Where

ε is the strain absorption coefficient and
K is the strain at the blast hole wall.
This is given by

$$K = \frac{(1\text{-}\sigma)\,P_e}{2\,(1\text{-}2\sigma)\,pV^2 + 3\,(1\text{-}\sigma)\,\gamma P_e} \qquad 5$$

Where

ρ_e is the explosion pressure,
γ is the adiabatic exponent of the detonation products,
p is the density of the rock,
V is the longitudinal sound speed of the rock and
is the Poison ratio of the rock.

3. Expremental Work And Results:

In general the experimental work intends to study the following points:

1. The mechanism of central blasting
2. To calculate angle of cratering practically to study the practical reaction between the quantity of explosive and the mass of specific rock
3. To evaluate the fragmentation from the field method
4. To estimate the fly rock distances and height.

Experimental works were achieved in three areas in the Sudan. Test No. 1 and 2 were done in the White Nile, Test No. 3 was done in Alseleet (near Khartoum) and Tests 4 to 6 were don in Atbara. Same procedure was applied for different tests. The input data for different cases include type of rock, type of explosive and its quantity, bench height, tunnel length (burden), tunnel branches. The results include fly rock distances and quantity; fly rock height, fragmentation distribution ranges, cratering angle and secondary blasting solutions.
Experimental input data and output results are shown in table (1)

4. Discussion

Test 1: in this situation fly rock moves more than 200 m in heavy bolders which is consider very risky, the fragmentation size is very huge and inapplicable to solve, this was the first experiment. The result of this test is a total failure.
Test 2: in this experiment the tunnel length was increased from 8m to 9m using the same quantity of explosive. It is remarkable the high control in fly rock distance in the range of 20m with very light fly rocks. There is an acceptable range of fragmentation size and can resolved by the secondary work. It observed that the height of the bench in this experiment play a role to control the rock acceleration by the gases expanding. This agreed by the calculation parameters for spherical charge explosion.
Test 3: all the entity and variables of test No. 2 were applied because of similarity of the conditions in both cases, controlled fly rock and acceptable fragmentation size distribution are achieved in this test.
Test 4,5: after the hazard of test.1 in granite, these tests (in marble sites) were achieved carefully because marble has less strength than granite. In beginning 6 m tunnel length and about 400 – 500 kg explosives were used. The result is the same in both cases but it is observed that the fly rock travel more the 200 m. This is not risky like test No.1 because it’s oriented and in very light weigh the fragmentation. This may be explained by gases escaping during blasting.
Test 6: applied the same conditions of test 4,5 with less explosive quantity. Fly rock is still take the same behavior of test 4 and 5, although the changing of the entity. There were fly rocks in the range of distance 200 but with less weigh. Here the fly rock was not accelerating by gases expanding but by the spalling phenomena. This is explained by the light weight of the fly rock.
Generally:
A practical reliable table data was builds up. This table can be used to achieve works in rock production areas in White Nile, Alseleet, and Atbara considering the following points:

1- Cratering theory is more applicable in the case of central blasting as theory and calculation bases.
2- There are differences in the behavior of explosive and its effect if we change the media from granite to marble.

3- There are two kinds of fly rock. Fly rock by gas acceleration like what happened in test No.1, which is too risky, the other produced by the spalling phenomena and gives light and oriented fly rocks.
4- In some site locations no ways for bench blasting theory.
5- Tests No.2,4.6 achieved the requirement of rock blasting safety, performance and the mass production without need of heavy drilling machine, but only small air compressor. This accompany with bigger fragmentation size.

5. Economical Analysis:

The main target of this research is to find alternative to the high costly heavy equipment in the task of preparation, drilling, and primary blasting. In these tasks the central blasting is unique, but in the task of secondary blasting the cost of the central blasting is more than bench blasting method.
The economic comparison was done in two bases; the quantity of machines and explosive. Table (2) shows these comparisons

6. Conclusion

In the course of this study the following points can be concluded:

1- The central blasting can be used as a solution for sites where bench blasting method is inapplicable.

2- The central blasting is an alternative to achieve a mass production in the absence of crawler drilling machines when small size is needed.

3- The importance of this method increases in the case of producing rocks with size of one cubic meter or more to avoid the cost of secondary blasting.

4- By this study a reliable central blasting data in White Nile, Alseleet and Atbara were achieved on the base of safety (fly rock), and performance (in limited range of size fragments).

References

[1] Urbanski T., chemistry and technology of explosives, press Oxford, USA, 1984.

[2] http://www.explosives.org/HistoryofExplosives.htm. Society of explosives engineers, History of explosives and blasting, 2006,

[3] Mary B., The history of explosives, 1997, http://inventors. about.com /explosives.htm.

[4] Marcia L., Michael J., Toxic Fume Comparison of a Few Explosives Used in Trench Blasting, National Institute for Occupational Safety and Health Pittsburgh Research Laboratory.

[5] Aydin B., and Sedat E., Assessment of Ideality of some Commercial Explosive, 1999G Volume1, International Society of Explosives Engineers, 2000.

[6] Takis K., Explosives technology, Queen university, 2000.

[7] Cam T., Commercial Explosive Specifications), Queen university, 2000.

[8] Sergey Victorovych Zagreba, Fragm: A Blasting Fragmentation Model of Rock. A Thesis submitted to the College of Engineering and Mineral Resources at West Virginia University, 2007.

[9] Stig O., Applied Explosive Technology for Construction and Mining, Printed by Ljungforetagen, October, 1997.

[10] Lyall W. and Workman, (Blast Design), Department of Mining Engineering Queen's, University Kingston, 2000.

[11] Kaushik D. and Phalguni S., Concept of blastibility, Indian Mining and Engineering Journal, 2003.

[12] Hoekand E., Practical estimates of rock mass strength, International Journal of Rock Mechanics and Mining Sciences, 1997.

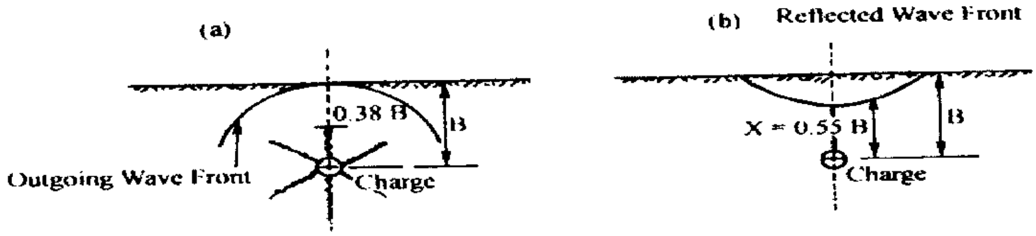

Figure (1): Diagrammatic representation of the interaction of spherical wave with the redial cracks system.

a) Outgoing wave front b) Reflected wave front

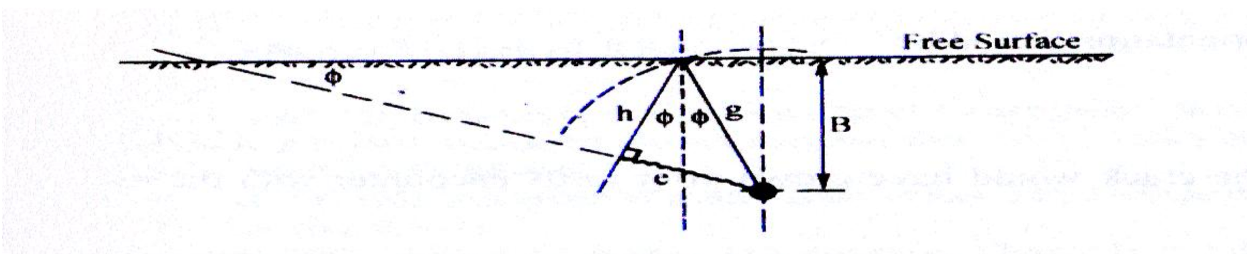

Figure (2): Favorable reflection geometry for extending cracks toward the free surface

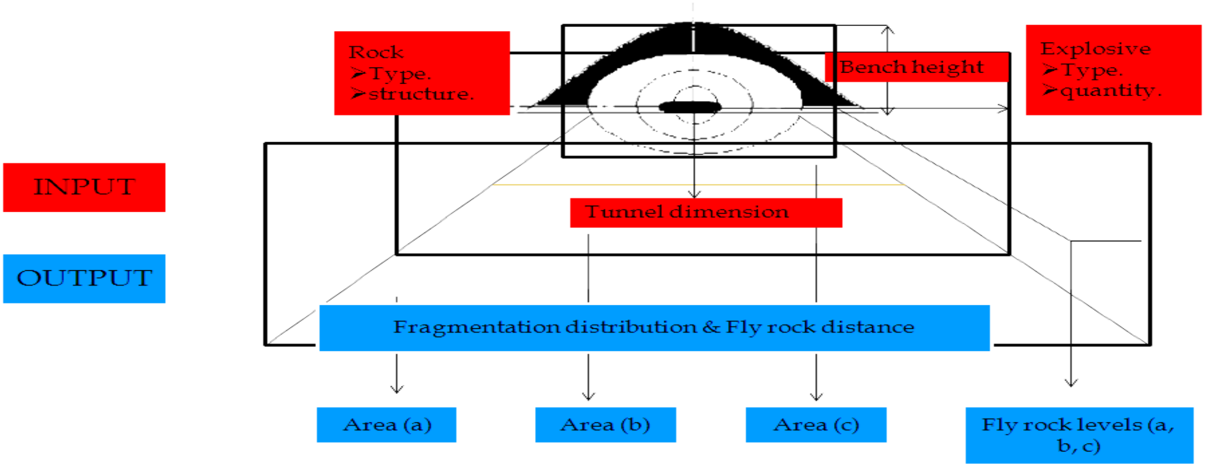

Fig. (3) Input and Output Data for Central Blasting

Input: Rock type and structures, Explosive type and quantity, Bench height and Tunnel dimensions
Output: Fragmentation distribution and Fly rocks

Table (1) Experimental Input Data and Output Results

	Test no.1	Test no.2	Test no.3	Test no.4	Test no.5	Test no.6
Rock type	Black granite	black granite	Grey granite	marble	marble	marble
Explosive type	AN	AN	AN	AN	AN	AN
Tunnel length	8 m	9 m	9 m	5 m	6 m	9 m
Tunnel branch	3	3	3	3	3	3
Quantity of explosive	900 kg	900 kg	900 kg	400 kg	500 kg	800 kg
Bench height	12 m	12 m	30 m	18 m	30 m	30 m
Fly rock distances	75 ton – 200 m	20m- less than 0.5cubic meter boulder (about .02tonees)	20m- less than 0.5cubic meter boulder (about .02tonees)	75m- less than 0.5cubic meter boulder (about .02tonees)	150m- less than 0.5cubic meter boulder (about .02tonees)	75m- less than 0.5cubic meter boulder (about .02tonees)
Fly rock height	15 m	3 m	3 m	15 m	15 m	20 m
Fragmentation distribution	(0.5–5 cubic meters)	(0.5 – 3 cubic meters)	(0.5 – 5 cubic meters)	(0.5 – 2 cubic meters)	(0.5 – 2 cubic meters)	(0.5 – 2 cubic meters)
Cratering angle	2tan(8/18)	2tan(25/9)	2tan(20/9)	2tan(20/9)	2tan(20/6)	2tan(35/9)
Secondary blasting solutions	300 blasting holes	500 blasting holes	500 blasting holes	500 blasting holes	500 blasting holes	500 blasting holes

Table (2) Economical Comparisons between Bench and Central Blasting

	Central blasting	Bench blasting
Preparation	No needs	Dozer (may need)
Drilling	Small air compressor	Crawler drilling machines (obliged)
Secondary blasting	Blasting & hydraulic breaker (obliged)	Blasting & hydraulic breaker (may needs)