OVERVIEW OF BLASTING PARAMETERS OPTIMIZATION IN OPENCAST MINES

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Abstract - Drilling and blasting are the major unit operations in opencast mining. Inspite of the best efforts to introduce mechanization in the opencast mines, blasting continue to dominate the production. Therefore to cut down the cost of production optimal fragmentation from properly designed blasting pattern has to be achieved. Proper adoption of drilling and blasting can contribute significantly towards profitability and therefore optimization of these parameters is essential.

.***Key Words: Optimization, Drilling, Blasting, Opencast mine, Blast model, Explosives, Machinery.***

1. INTRODUCTION

Rock breaking by drilling and blasting is the first phase of the production cycle in most of the mining operations. Optimization of this operation is very important as the fragmentation obtained thereby affects the cost of the entire gamut of interrelated mining activities, such as drilling, blasting, loading, hauling, crushing and to some extent grinding. Optimization of rock breaking by drilling and blasting is sometimes understood to mean minimum cost in the implementation of these two individual operations. However, a minimum cost for breaking rock may not be in the best interest of the overall mining system. A little more money spent in the rock-breaking operation can be recovered later from the system and the aim of the coordinator of the mining work should be to achieve a minimum combined cost of drilling, blasting, loading, hauling, crushing and grinding. Only a "balance sheet" of total cost of the full gamut of mining operations vis-à-vis production achieved can establish whether the very first phase- rock breaking- was "optimum" financially; leaving aside factors of human safety.

Pre commencement of topic to introduce MINING INDUSTRY, the mining industry plays a prominent role of economy of that county. In mining the fundamental point is to accomplish greatest extraction of minerals keeping in see the ecological, monetary and rent limitations. With the increase of human progress, the essential of various minerals has expanded complex to fulfill this need.

In mining industry the mineral resource extracted by both opencast and underground mining. In both cases the extraction is done by loosening the mineral through mainly perform the operations of DRILLING and BLASTING. In India many of the mines are working on with opencast mining and most of the mining operations are performingwith drilling and blasting. The opencast working plays a crucial role in mining because of the improvedproductivity.

The topic is OPTIMIZATION OF BLASTING OPERATION. This topic mainly works on the study and evaluation of optimum blast and blasting parameters. In mining industry OPENCAST mining, the DRILLING AND BLASTING is the major unit operation. The BLASTING is an important process which influences directly on loading, hauling and crushing and milling phase.

Now-a-days, there are many achievements conducted in research of blasting theory and blasting parameters in mining industry, especially of blasting parameters for improving rock fragmentation and reducing blasting cost. The better result of rock fragmentation is obtained by the process of OPTIMUM BLAST. The blasting efficiency is improved through the reducing of wastage of explosive energy in blasting, less throw of blasted material and reducing of blast vibration resulting in greater degrees of safety and stability to the nearby structures.

Optimization means action of making the best i.e. to achieve maximum or minimum charge of the operating parameters. Optimization of blast is depends on a host of complex factors related to the rock, explosive, initiation, drill-hole parameters and their layout. The present operation is a step in the direction of developing a suitable blast model, with simple methodologies which can be adapted by the mining industry to achieve better blasting results.

1.1 Objectives

The goal of the investigation is to develop a result of optimum blast design through some parameters, as type of explosive, explosive quantity, blast pattern and fragmentation.

The main objective addresses towards:

1. To study the drilling methods and their machineries for effective drilling.
2. To understand the blasting parameters to their suitable working conditions.
3. To study the optimization techniques.
4. Design of optimum blast model to our recommendations.

1.2 Need for study

Most of the economic mineral deposits occur in association with massive hard rock. These rock masses should be fragmented to obtain the valuables and separate the materials for further processing. This process can be achieved by conducting of DRILLING and BLASTING.

But, sometimes these operations cannot give better results because some parameters effects the blasting results i.e., improper design of blast pattern, poor implementation of blast design in field work and poor use of explosives. So, these operations are eliminated with making of better blast design from old ones means optimize the blast designs for better results and improve productivity.

2. DRILLING AND BLASTING

2.1 Drilling

In the field of operation, the rock drilling is the first operation accomplished and its purpose is to drill holes or opening of holes, with the accurate dimension and distribution within the rock masses, where the explosive material are kept along with their initiating devices. This operation comes into two forms, rock penetration and rock fragmentation. This operation termed as drilling, cutting, boring, etc.

During the process of drilling the rock mass through the drill tool, the first action is percussion; the drill tool penetrates and breaks the rock surface. After the drill tool expands the breakage continual penetration together with the rotation of the drill bit or continual cut by push or percussion force. The drill bit or drill tool penetrates and breaks the rock surface by a thrust force or impact force; this is the basic mechanism of rock breakage by mechanical method.

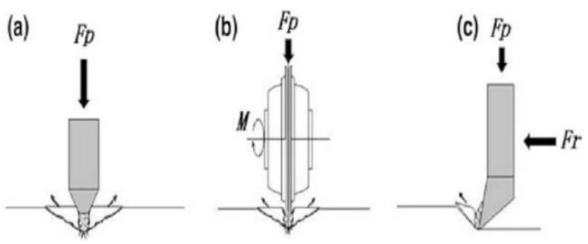


Fig-1 Types of rock breakage during drilling: (a) percussive, (b) rotation, (c) cut.

The drilling machines used in opencast mining can be classified in the following ways:

1) Depending upon the principle of working:
    a) Percussive drilling
    b) Rotary drilling
    c) Rotary-Percussive drilling

2) Depending upon the type of Prime mover:
    a) Used Fuel driven drilling machines
    b) Electrically driven drilling machines

3) Depending upon the means of power transmission:
    a) Pneumatically operated machine
    b) Hydraulically operated machine
    c) Electrically operated machine
        i. Hydraulic system
        ii. Pneumatic system

2.2 Blasting

Blasting is the process of breaking of hard rock mass into loose fragments by using explosive compounds. The explosive compounds are placed in the hard rock through drill hole. Sometimes, blasting is also accomplished for removing the overburden from the surface of the earth for excavating a mineral resource through creates an opencast mine.

An explosive is a solid or liquid substance or a mixture of substances which, in a short period of time after applying a flame, heat or shock (explosion), the mixture coverts to large volume of gases at high temperature and pressure. The explosive substance may be the mixture of various elements none of which is explosive by itself or a chemical compound.

An explosive contains, apart from the explosive substance. The following materials:

1. Combustible material (wood, fibre, charcoal etc.).
2. Oxidation agents (Ammonium nitrate, Sodium nitrate, etc.).
3. Stabilizers (Magnesium and Calcium Carbonates).
4. Antisetting agents (Preventing the caking of salts).
5. Sensitizers (Metallic powders)

According to explosives the explosives can be classified into two categories:

i. Low Explosives
ii. High Explosives

Low explosives:

Low explosive means a mechanical mixture of two or more substances. It includes a supplier of fuel and oxygen. When burned, it burns but when confined, it explodes. It burns comparatively slowly and explodes by direct ignition. This gives the shattering effect when the explosion explodes.

Low explosive: Gun powder (It is a common and earliest known explosive of low explosives). The constituents of Gun powder are Charcoal 15%, Sulphur 10% and Potassium nitrate 75%.

High explosives:

A high explosive is a chemical compound and combines directly with the fuel and oxygen atoms. These explosives are exploding at velocities of 1500 to 8000 m/s and produce large volume of gases at considerable heat and high pressures.

These are classified into two categories, depending upon their composition and explode rate:

1) Primary Explosives and
2) Secondary Explosives

Primary explosives:

Primary explosives are characterized by their sensitivity to impulses such as weak mechanical shock, spark or flame, the use of which allows the explosive compounds to be easily detonated from the deflection state. These explosives are used in starting devices such as detonators to initiate charges. Examples of these explosives include mercury fulminate, lead azide, lead stifnate, tetra zine and other alloys.

Secondary explosives:

Secondary explosives of this type are military explosives such as TNT, RDX, PETN, and Tetrile, and industrial explosives such as nitro-glycerine, emulsion, slurries, water gels, ANFO and other powder explosives.

In opencast mining both vertical and inclined holes practiced with the bench face. The holes drilled in a row may be single or multiple. So those two patterns are used, mainly in the opencast mines. They are:

a) Single row blasting pattern
b) Multi row blasting pattern

Single row blasting pattern:

In single row blasting pattern only one row of holes are drilled and charged in a bench face. In this method the hole diameter is more than multi row blasting pattern and consumption of explosive is also more but getting the fragmentation is minimal.

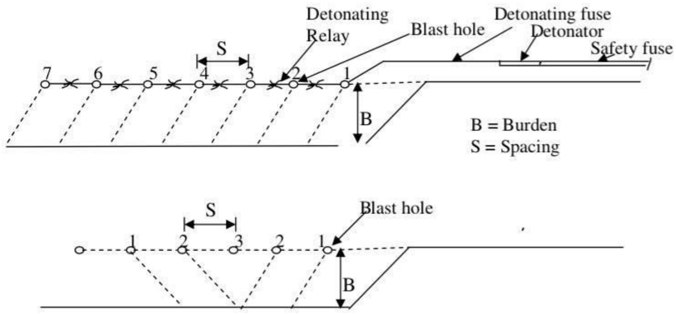


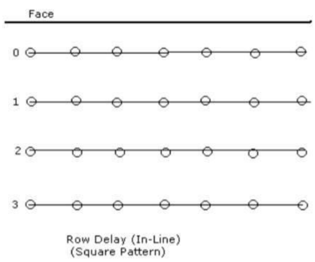
Fig-2 Sequence of initiation in single row blasting

Multi row blasting pattern:

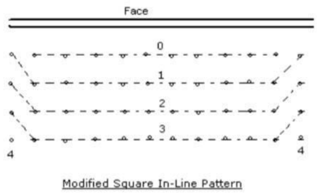
In multi-row blasting pattern number of rows of holes are drilled and charged in a bench face. In this the hole diameter is small compared to single row blasting and consumption of explosive is low in a single hole but overall total holes consists more explosive compared to single row blasting. This method gives better fragmentation of rock.

The following blasting patterns used in multi-row blasting pattern:

a) Square grid in-line initiation (spacing(S) = effective burden (B)).
b) Modified square in line pattern (spacing(S) = effective burden (B)).
c) Square grid 'V' pattern (S = B; SE =2.BE).
d) Square grid 'V1' pattern (S = B; SE = 5.BE).
e) Staggered grid 'V' pattern (S = B; SE = 1.25BE).
f) Staggered grid 'V1' pattern (S = B; SE = 3.25BE).



(a)



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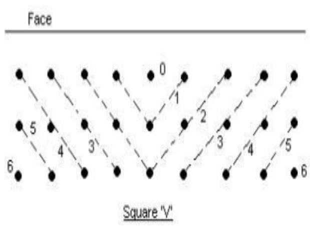

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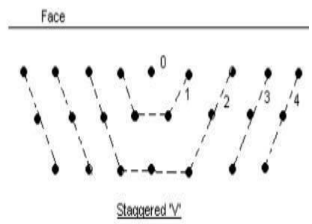

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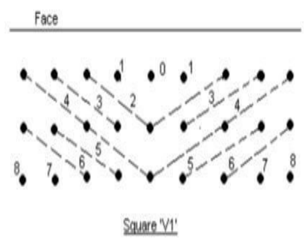

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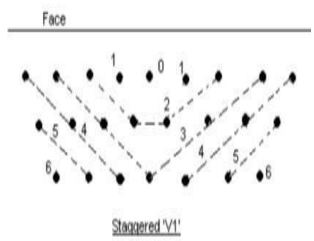

(f)

Fig-3 Sequence of initiation in multi-row blasting

2.3 Recent advancements in drilling and blasting

Digital drilling:

The two new technologies have recently been implemented in drilling, that are computerized drilling and (MWD) measuring while drilling systems. These systems can provide response on the main functions of the drilling.

They are:

- Correct location and depth of blast holes
- Accurate recording of drilling conditions

Computer aided blast design:

In the recent past, computer simulation of blasting has made tremendous improvements in explosive efficiency and consistently replaces the trial and error approach to fragmentation. Computer aided programs allow mine operators to examine combinations of explosives and explosive parameters in a very short time. This allows for faster optimization of drilling and blasting patterns and costs, and affects operational procedures, such as minimizing mucking costs by fine breakage, or examining the effect of different explosive parameters on explosive shapes.

The Computer Aided Blast Design Program treats all aspects of the blasting process as input:

a) Rock properties;
b) Blast parameters;
c) Explosive parameters;
d) Fragmentation parameters.

The computer model requires maximum data input to provide the design for specific operation. This data is separated into three categories with some typical examples as follows:

1) Rock mass parameters
   a) Rock density
   b) Tensile and compressive strength of rock
   c) Young's modulus of rocks
   d) Longitudinal wave velocity
   e) Poisson's ratio
2) Explosives
   a) Type of explosives
   b) Strength properties
   c) Velocity of detonation
   d) Hole density
   e) Initiating and delay system
   f) Explosive cost
3) Site factors
   a) Face height
   b) Bench width/ length
   c) Drill hole diameter
   d) Fly rock range
   e) Loading and hauling equipment information
   f) Fly rock range
   g) Ground vibrations
   h) Drilling cost per meter

The input information is provided to blast design to achieve the objectives. Mini computers, micro computers or programmable hand calculators are used for designing blasts and there are many programs are available and used.

3. ANALYSIS OF OPTIMIZATION TECHNIQUES

General:

The optimization of mining process can be accomplished in a variety of methods. They are:

i. Optimization of drilling efficiency
ii. Optimization of explosive and blast
iii. Optimization of mine production system

Optimization of drilling capacity:

An improvement in drilling efficiency was achieved by gradually expanding the drilling parameters from the existing parameter for different benches of the mines. The optimum drilling parameters are achieved by studying the rock properties scientifically and analyze the type of explosives for various benches. So with the help of a computer-assisted method or module, 'SABREX' was helpful.

Computer programs for optimum drilling operation:

The following are the computer programs for performing of optimum drilling operation:

- Dialog's program.
- Explosives loading design program.
- Care program
- Program for jumbo drill machine.

So, it is concluded that the computer-aided drilling is very useful in achieving high-production goals by increasing drilling efficiency, saving on drilling rate; saving time of drilling cycle and reducing the cost of drilling and the ability to m1ute back in the offensive face.

Optimization of explosive and blast:

We know that the cost of drilling and blasting is a very prominent part of the total operating cost, i.e. the blasting explosive cost may vary from 4 to 12 % of total operating cost. So this cost can be controlled by the following factors. They are;

- Optimum use of detonating fuse.
- Save explosives by using air decks.
- Eliminate the secondary blasting by getting of proper fragmentation of rock.
- Optimum use of booster cartridges and cast boosters.

- Using computer aided blast designs.
- Using computer block models.

Fragmentation optimization can be done by applying engineering systems to the creation of the global model of optimization. Approx. blocks of information given to the model:

- Characteristics of rock mass.
- Properties of explosives
- Technical and economical information on drilling, loading hauling and crushing equipment.

Optimization of mine production system:

The optimization of mine production system is achieved by using of suitable operations research techniques like linear program, waiting line theory, game theory, simulation theory, dynamic programming, network scheduling PERT and CPM.

The following are the various operation research techniques used for the purpose are:

- Queuing model: For optimization of dumper shovel combination.
- Markov model: For production potential assessment
- Reliability model: For evaluate the reliability of the mine production system
- Cargo-loading model: For selection of explosives

4 DEVELOPMENT OF OPTIMIZATION BLAST MODEL

Introduction:

In any mining project, drilling and blasting are the first crucial operations that are part of a comprehensive system and impact the results of the next operations, along with productivity. The main objective of the fragmentation with explosives is to make the operation as low-cost as possible and at the same time comply with the required technical specifications and safety conditions.

Optimization of rock breakage operation is important so that obtained fragmentation affects the cost of the entire spectrum of corresponded mining operations such as drilling, blasting, loading, hauling, crushing and to some enlargement grinding. The goal of optimization of fragmentation is to minimize drilling and blasting costs, deliver better fragmentation results at lower cost, and then use subsequent operations in a better way to reduce that costs.

An optimal blasting is also associated with the most competent use of blast energy in the rock breaking process, reducing the cost of blasting through low utilization of explosive, and minimizing wastage of explosive energy in blasting, less throw of materials and reducing explosive vibrations for safety and stability of nearby structures.

The optimum process is achieved by using of some various important blasting parameters and taking some mathematical formulas. These formulas are related to blasting variables and are taken as input and output characteristics in the design of optimized blast model.

Selection of some important parameters for the optimized blast model:

The parameters are:

i. **Powder factor:**
The powder factor is the ratio between the amounts of rock is broken to require the explosive for detonation. It is usually expressed as the Ton per Kilogram or Kilogram per Ton.

ii. **Diameter of hole:**
The optimum blast hole diameter depends upon type of explosive, rock mass properties, degree of fragmentation and bench height. The hole diameter varies with the geographical conditions of the strata.

iii. **Cost of explosive:**
The cost of explosive is apparently a very important selection criterion. It depends upon the type of the explosive and strength of the explosive. Therefore, from an economic standpoint, the best explosive is not always the least expensive, achieving the lowest blast costs.

iv. **Number of holes:**
The required number of holes depends upon the production of blast and required demand. If the demand is high then the holes will also need more.

v. **Bench height:**
Bench geometry is one of the primary factors that control blast design. In general, bench height, H, is relatively stable for most multi-level pits, and its value corresponds to the working details of the loading equipment.

vi. **Burden and spacing:**
This is one of the most critical parameters in the design of blasts. The distance between the crest of the bench and first row of holes is called as burden and the distance between the two holes in the same row called spacing.

vii. **Length of the hole:**
The length of the hole is consists of height of the bench and sub grade drilling. The hole length in relation to the rock burden and bench height.

Hole length = Bench height + sub grade drilling
Hole length = 2.1 to 2.25 * Burden.

viii. **Fragmentation size:**
Fragmentation is the size distribution of the rock that comes after blasting process. The fragmentation size decides the powder factor of the blast.

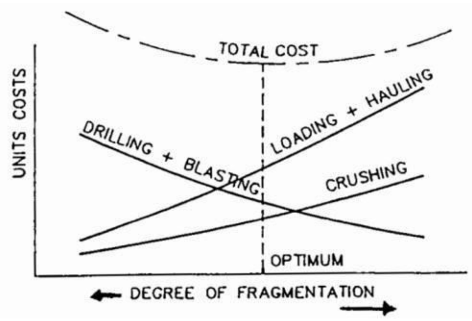

Fig-4 Optimum fragmentation

ix. Cost of blast:

The cost of blast can be obtained by combining of some parameters as number of holes (N), weight of the explosive loaded in each hole (W), cost of explosive (Ce) and cost of drilling and loading of explosive in each hole (Cd). The powder factor can be obtained by using cost of blast.

Cost of blast (Cb) = N + W + Ce + Cd

4.1 Optimization methodology:

The main priority here is to optimize the cost with the desired product. The equations obtained for the optimization process are derived from the basic data from the mines and best combinations and are taken according to the optimization standards (Seti and Dey 2004).

The priority is given to the number of holes and the desired powder factor in the parameters implemented in the method suggested in the present work. Combining these parameters takes into account the energy output of the explosive and the type and density of the explosive.

In the present case, since the drill holes are stable and are not as varied as they are based on the available drill machines, this can be taken as input in the process. The size of the fragmentation must be constant according to the customer's need, which varies by the powder factor, so the powder factor must be constant then it becomes the input data. Explosive pricing, which is the driving data, must also be considered as input.

According to the optimized models practiced so far; the burden, spacing, height of the bench, and length of the hole are easily correlated with the diameter of the drill hole by some derivative, linear equations. The total cost of charge and configuration per hole can be calculated from all previous data. The constants used in the equations are derived from the field data available from some Indian metal mines and some optimization equations already implemented in coal and metal mines. Finally the optimization method executes the parameters and gives the total cost of the blast operation after use.

The following parameters are taken as input and output factors. They are:

Inputs: Powder factor, Number of blasts, Diameter of hole (mm), Cost of explosive (Rs/Kg) and Number of holes.

Outputs: Height of the bench, Burden and spacing, Length of the hole, Fragmentation size, Charge per hole and Total cost.

4.2 Algorithm of the program

The algorithm for implementation of the optimization methodology as given below:

STEP 1: Start

STEP 2: Input the desired powder factor i.e. (z)

STEP 3: Input number of blasts available as (n)

STEP 4: Enter diameter of hole (d), cost of explosive (c) and number of holes required for the required output for case (nh)

STEP 5: Height of bench (h) = d *0.107

Burden (b) =0.4*h

Length of the hole (l) =2.6*b

Spacing (s) =1.4*b

Fragmentation size (x) = 19/ (z^2.5)

Charge per hole (q) = ((2*(b *s *h) ^0.8) / (100*x)) ^1.2

Cost = q *c *nh

Total cost = n*cost

STEP 6: RESULT (Displayed result in the form of the calculated values)

STEP 7: If ((z ||n || d ||c || nh) = NULL)

Go to Step No: 4

STEP 8: Stop.

4.3 Optimization process:

A computer program was written using visual basic on Html platform. A sample presentation of the input and output parameters are as presented below:

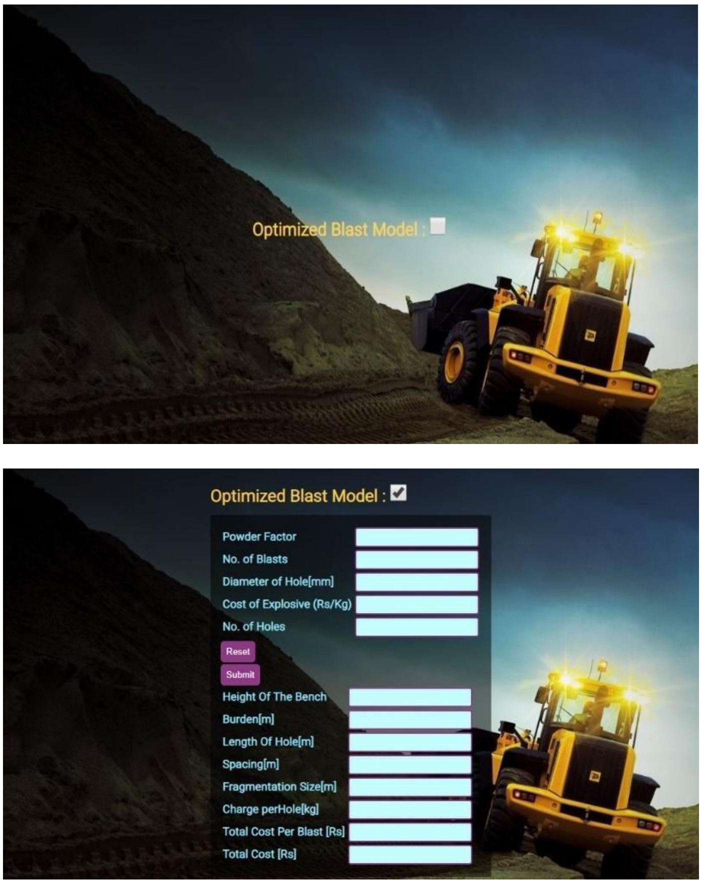

Fig-5 Optimized blast model

5. DISCUSSION

Discussion:

The mining industry is moving towards a technology-based optimization process. Unit operations such as drilling, blasting, excavation, loading, hauling and crushing are identified as correlated variables in the total cost equation. In the current situation, the main objective of the mining industry is to optimize the cost of mining by using the variables in the cost equation. The improvement, progression and use of inventive mechanizations are vital for the mining industry to be cost effective. The last decade has seen a dramatic improvement in the quality of blasting technology and product performance. Checking instruments, estimation of technologies and computing tools now have the capability to provide a bank of useful information about a wide range of applications.

6. CONCLUSION

The productivity of drilling and blasting operations can be determined in various perspectives, but the "bottom line" is that they should contribute to the best possible overall financial results for the entire mining operation. In this manner, decisions on drilling and blasting operations should be considered in the overall context and should not be based on short-term economic factors in general.

In the present work an optimized blast model is created with simple methods that mining industry can follow to compare explosive costs and achieve better explosive results. The model takes into an account the common explosives used by the opencast mine and which is determined by rock properties, density, and other related parameters.

The created model is user-friendly because it can compare explosive performance by keeping the powder factor constant and changing parameters such as drill hole diameter, number of holes and cost of explosives, and consequently make the decision to choose the right type of explosives. It can be noted here that this model was created dependent on contextual investigations of various mines of limestone ore and can be modified with data collection from a large number of mines.

This model will definitely give some alleviation to mine operators and blasting workers to achieve a better product at a lower cost of mining. Because modern mines require large amounts of explosives throughout the mine's life, the cost of blasting operation can be significantly reduced by reducing the cost of explosives.

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