CONTENT

Abstract

Surface mining is the major part of mineral production . There has been rapid growth in this sector by deploying high capacity equipment (HEMM). There machineries involve high capital cost and thus it necessary to prepare a proper plan to achieve best performance these machineries . Performance and efficiency of these large equipment depend on the blast result .fragments size distribution and muck profile . Thus blast design is an important factor which affect the entire mining activities carrying out. In this presentation we have reviewed various approaches (techniques) to blast design to properly understand the present stage of knowledge in this field . Blast designer may use available aided model for prediction of fragmentation ,muck pile and vibration . However the empirical method is the most common way to calculate the blast design parameter. In this presentation the empirical method and fragmentation which have significant effects on surface blast design has been identified .

Introduction

Overview

Mining is process of excavating minerals of economic value from the earths crust . Basically mining operation is divided into two section underground and open cast mining . Underground mines are excavated using a variety of methods like room and pillar or board and pillar mining In which excavation is done by large open rooms supported by pillars, where as long wall mining is the form of underground mining widely used in the coal industry for more production. open cast/surface mining may be less expensive and safer then underground mining but it accounts a higher production . To meet the high requirements of minerals . Large surface mines with million tone production target are establish . The basic aim in mining operation is to achieve maximum extraction of minerals with profit ,environmental protection and safety . For improvement in production large machineries , continuous mining machineries are implemented , improve explosives and accessories . In spite of introduction of rock cutting equipment, drilling and blasting continue to dominate the production due to applicability ,less cost and care of use .

Objectives

The basic objective of this project is to find adequate blasting parameters .The following parameters are calculated successfully.

1.Drill diameter
2.Bench height
3.Burden and spacing
4.Stemming
5.charge distribution
6.Sub drilling
7. Drill pattern
8.powder factor

Method and Materials

The following are the some of the important parameter which generally govern for blast design:

1. **Physico-mechanical properties of rock***:* Here type of the rock, dynamic tensile strength, tensile strength, compressive strength, young’s modulus, Poisson’s ratio, density and hardness of the rock mass, presence of discontinuities, bedding plane and joints, etc. are very important.
2. ***Geology***
3. **Pit geometry***:* Under this heading thickness of coal seam or ore body and bench height, over burden bench height, bench slope angle, strip width, height to width ratio, and length to width ratio are generally considered.
4. **Explosive characteristics***:* Factors generally considered under this heading are type of explosive, type of booster, bulk strength, energy release per unit mass of explosive, detonation pressure, explosion pressure, ratio of decoupling, strength of explosive used, time taken for explosive wave to travel to the free face and back, volume of gaseous product per unit mass of the explosive, velocity of detonation, velocity of explosion propagation, explosion wave length, weight strength, number of spalls that an explosive wave may produce, length, diameter and weight of the cartridge, loading density, bottom charge and column charge density, etc. are very important. Characteristics of blasting accessories - type, thermal properties are also important.

5. **Burden distance**
6. **Spacing of the holes**
7. **Ratio of spacing to burden**
8. **Depth of hole**
9. **Diameter of blast holes**
10. **Consideration of toe and depth of sub-grade drilling**
11. **Blasting technique**: Here objective of blasting, drilling pattern, number of availability of free faces, manner of charging, charge per hole and per delay, sequencing of initiation i.e. delay between
two holes in a row and delay between two rows, decking, length of explosive column, height of the bottom charge, volume of the explosive in the blast hole, etc., are to be considered
12. **Powder factor:** The size of the fragmented rock should match the bucket size of the excavator and also the grizzly size of the primary crusher.
13. **Length of stemming column, the size and quality of stemming**
14. **Angle drilling**
15. **Amount and direction of throw requirement and problems of fly rock.**
16. **Requirement of muck profile**
17. **Vibration level**
18. **Presence of water**

Some of the important parameters apart from above discussed are mentioned here.

Bench Geometry

a. Bench Height- The bench height is the vertical distance between each horizontal level of the pit. Unless geologic conditions dictate otherwise, all benches should have the same height.

The height will depend on the physical characteristics of the deposit; the degree of selectivity required in separating the ore and waste with the loading equipment; the rate of production; size and type of equipment to meet the production requirements; and the climatic conditions. The elements of a bench are illustrated in the above figure.

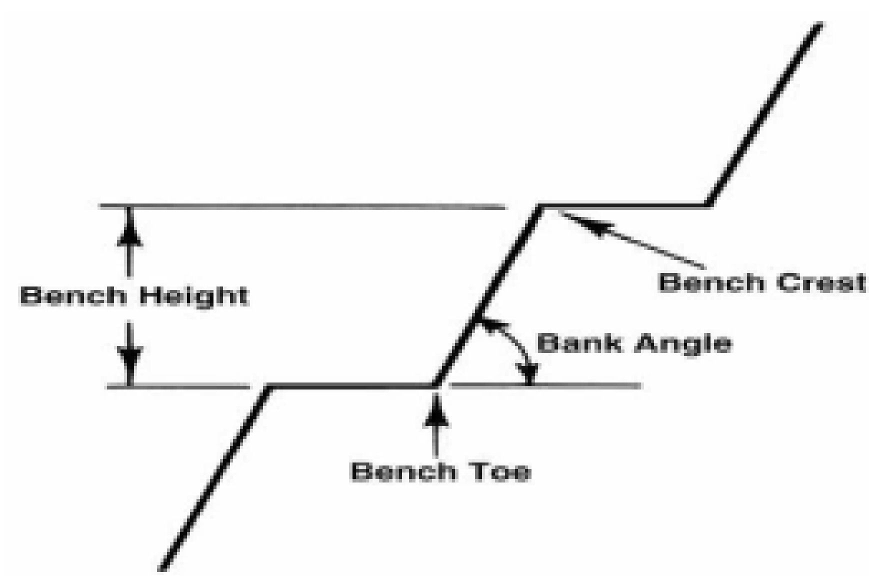


Fig. 1-Bench cross section

b. Bench Width: There is a minimum bench width, measured horizontally in a direction perpendicular to the pit wall. For each bench height and set of pit operation conations whose
value is established by the working requirements of the loading and hauling equipments. The width also must be such so that to ensure stability of excavation both before and after blasting. The drilling and blasting will become economical with increase in diameter. When the blast hole diameter is increased & the powder factor remains constant the large blast hole pattern gives coarser fragmentation. By keeping burden unchanged & elongating spacing alone the problem can be overcome. Hole diameter varies from 35 in small benches up to 440 mm in large benches. In India 100-150 mm blast hole diameter are used in limestone mines,150-270 mm in coal mines & 160 mm or above blast hole are used in iron ore mines is used. Langefors and Kihlstrom suggested that the diameter be kept between 0.5 to 1.25 percent of the bench height.

***c. Sub Drilling (J)*:** To avoid formation of toe in bench blasting the blast hole are drilled below the floor or grade level (figure 2). This is termed as sub grade drilling or sub drilling. If the toe formation will not avoid it may increase the operating costs for loading, hauling equipment. The optimum effective sub drilling depends on

1. The structural formation
2. Density of the rock
3. Type of explosive
4. Blast hole diameter & inclination
5. Effective burden
6. Location of initiators in the charge

In generally sub drilling should be 0.3 times the burden. Under different toe conditions sub drilling may be up to 50 percent of the burden

Graph Showing relation of Sub grade drilling and Inclination of Blast hole

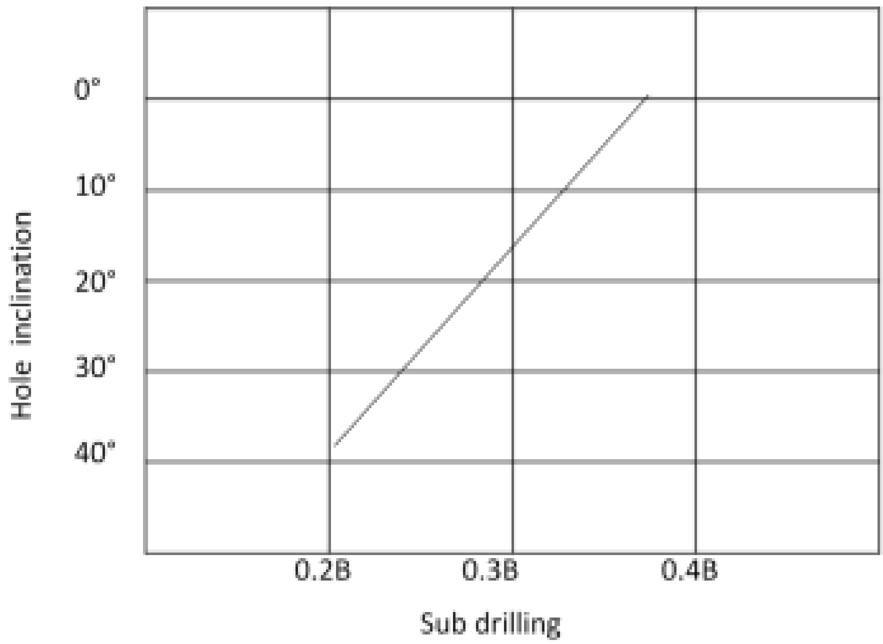


Fig.3-Sub drilling with inclination of blast hole

Disadvantages of Subgrade drilling- Excessive sub grade drilling causes more vibrations, under fracturing at the bottom and depressed floor conditions. I should be avoided for below reasons

1. waists drilling and explosives expenditure
2. increased ground vibration level
3. may cause undesirable shattering of the pit floor
4. Increase the vertical movement of the blast.

d. Stemming (T): Stemming is the process of filling up the blast hole after the explosive cartridges are inserted. It is done to prevent the gas produced during the blasting to come out before fracturing the ground. A suitable stemming column of suitable length and consistency enhances fracture & displacement by gas energy. The amount of unloaded collar required for stemming is generally from one half to two third of the burden, this length of stemming usually maintains sufficient control over the generation of the objectionable air blast, fly rock from the collar zone.

For blast hole diameter in the 230-380 mm range, angular crushed rock in the approximate size of 23 to 30 makes a very effective stemming column larger fragments tends to damage the detonating curd and the detonator lead wire dry granular staining is much more efficient then material behave like plastically or tend to flow. In coal blast inert stemming material should be used rather than coal cutting. In multi row blast when the mean direction of rock movement tends to more and more towards the vertical with successive rows a longer stemming column is often used in the last row to avoid over break. When large stemming is kept in rocks with discontinuities large boulders may result. From the field experience, it is realized that stemming length of 70 percent of the burden dimension a good approximation. This length has a sufficient control over production of objectionable air blast and fly rock from the Collar zone. It is recommended that the crushed and sized angular rock fragments works best as stemming. But it is common practice to use drill cuttings as a stemming material .

e. Burden (B): This is one of the most critical parameter in designing of blast. It is the distance from a charge axis to the nearest free face at the time of detonation .As the boreholes with lower delay periods detonates, they create new free faces. As a result the effective burden will depend upon the selection of the delay pattern. When the distance between discontinuities is larger, smaller burden is required. A relationship between burden with blast hole diameter has been shown in the figure 4 below.

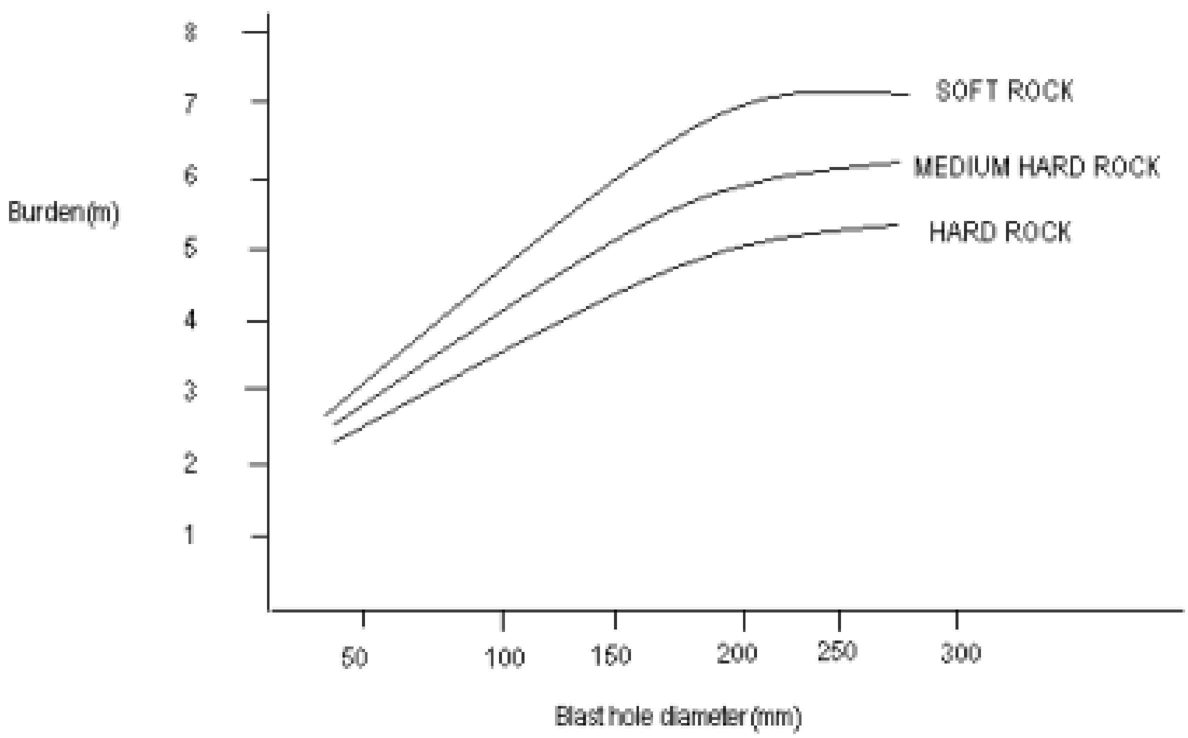


Fig. 4-Size of burden in function with drilling diameter

f. Spacing (S): Spacing is an important parameter in blast design. It is defined as the distance between any two adjacent charges in the same row and it controls mutual stress effect between charges. Spacing is calculated as a function of burden, hole depth, relative primer location between adjacent charges and depends upon initiation time interval. Over past several decades in most mining operations the spacing distances have been decided in relation to burden. The value of the spacing to burden ratio (S: B) which has been commonly used in different formulas lies between 1 and 2. From the production scale test with the spherical charges breaking to crater geometry, many workers suggested that the spacing be kept about 1.3 times the burden. When this ratio increases more than 2, unexpected results were found.

g. Powder factor : The powder factor is defined as the explosive necessary to fragment 1m^3 of rock. This equation can also be defined as the amount of explosives over the cubic yards of material desired to be blasted.

Kg of explosive used/volume of material blasted. =kg/ m^3

It is the opinion of many specialists this is not the best tool for designing a blast, unless it is referring to pattern explosives or expressed as energetic consumption. The size of the fragmented rock should match the bucket size of the excavator and also the grizzly size of the primary crusher. it can be also expressed in ton/kg. The following figure 5 shows, how the total operating cost varies with the powder factor.

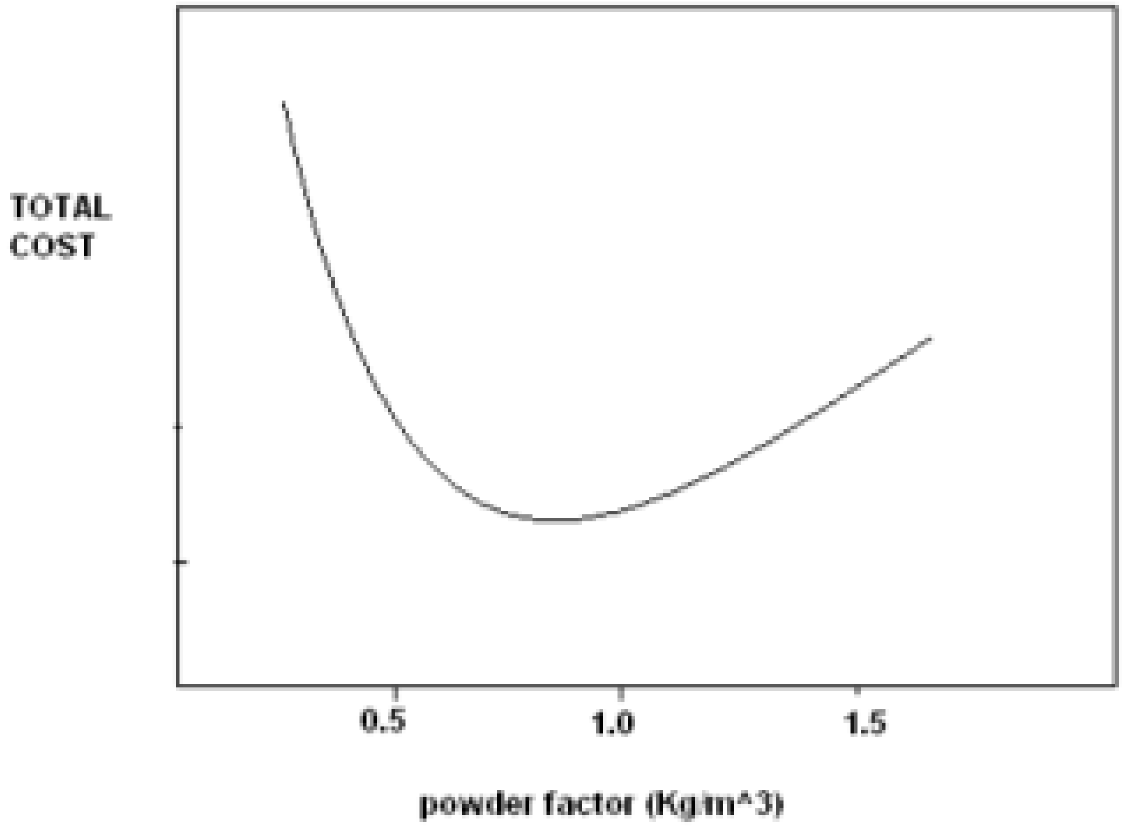


Fig. 5-Reduction of total cost with powder factor

h. Explosive Selection Criteria

This selection plays a major role in the blast design and the blast results that will occur. An explosive has many characteristics that need to be analyzed in making this decision. These include: minimum diameter in which detonation will occur, the ability to resist water and water pressure, generation of toxic fumes, ability to function under different temperature conditions, input energy needed to start reaction, reaction velocity, detonation pressure, bulk density, and strength. Other things the technician must consider are: explosive cost, charge diameter, characteristics of the rock to be blasted, volume of the rock to be blasted, presence of water, safety conditions, and supply problems.

Empirical Equation For Blast Parameters:

1. Equation suggested by Langefors And Khilstrom (1968)

$$B_{max} = \frac{D}{33}\sqrt{\frac{pexPRP}{Coxfx\frac{s}{b}}}$$

B_{max}= Maximum burden
D= Diameter of hole
Pe= Density of the explosive in the bore hole
PRP=relative weight and strength of the explosive
F= degree of confinement of the blast hole
$\frac{s}{b}$ = spacing to burden ratio
Co= corrected blastability factor (kg/ m^3)

= c +0.75 for B_{max} = 1.4-1.5 m
= c+0.07/B for B_{max} = < 1.4 m

When c= rock constant

2. Equation Suggested by Konya and Walters (1990)

Konya and Walters recommended that the crushed and sized angular rock fragments works best as stemming material.

$$B = 3.15 \times D \times \sqrt[2]{\frac{pe}{pr}}$$

Where,
B= Burden
Pe= specific gravity of explosive
Pr= specific gravity of rock
D= Diameter of explosive

Konya and walker also suggested the following empirical relationship-
for instantaneous initiations system,

$$S = \frac{H+2\ x\ b}{3},\ H< 4B$$

$$S = 2\ x\ B\ ,\ H \geq 4B$$

For delay initiation system,

$$S = \frac{H+2\ x\ b}{8}\ ,H < 4B$$

$$S = 1.4 \times B,\ H>=4B$$

where ,

H= depth of blast hole , m

B= burden, m

Konya and walker also suggested the following empirical relationship-

$$B=0.67 \times d \times (s_{anfo}/pr)^{0.33}$$

s_{anfo} = relative strength of explosive

Fragmentation Analysis

Kuz – Ram model (1983)

According to the kuz – Ram model ,the mean fragment size can be calculated by the following equation

$$X = A\,x\left(\frac{V}{Q}\right)x\,(Q)x\,\left(\frac{E}{115}\right)^{-0.633}$$

Where,

X= mean fragment size ,cm

V= volume of blasted rock, m^3

Q= mass of explosive charge per hole , kg

E= relative weight strength of explosive (ANFO = 100)

A= a constant based on rock factor (depends upon rock density , strength and jointing)

Rosin – Rammiler equation

An estimate of the fragment size distribution is given by the Rosin –Rammiler equation which is follows

$$R(x) = 1 - e^{-\frac{x}{xc}\,r}$$

Where ,

R(x)=proportion of the material passing through the screen size X

X= screen size , cm

X_{c}= characteristics size , cm

n= index of uniformity , varies from 0.8 – 2.0

Calculations

The main focus of this Presentation will be on bench blasting (both small and large diameter). Many formulas and methods for calculating geometric parameters such as burden, spacing, and sub drilling have been around. The previously mentioned formulas use one or more of the following parameters: hole diameter, characteristics of explosives, compressive rock strength, and many more. Bench blasting can also be classified by the diameter of the blast hole. These falls into two categories, small diameter blasting (65 mm to 165 mm,) and large diameter bench blasting (180 mm to 450mm).

In small diameter blasting the most common technique developed by **Langefors** and **Kihlstrom** is used; however, it is better to use the crater technique by **Livingston** or the American criteria for the larger diameter blasts. Due to the different nature of rocks the best method is continuous trial and error to arrive at the best conclusion.

A. Small Diameter Bench blast

1. Drill Diameter

Table 4 - Average production with variation of drill hole diameter

	Average production per hour (m3b/h)	
blast hole diameter (mm)	**Medium - soft rock <120 Mpa**	**Hard -very hard rock>120 Mpa**
65	190	60
89	250	110
150	550	270

2. Bench Height

Table 5- Relation between bench height ,blasthole diameter and loading equipmer		
Bench height	**Blast hole diameter D(mm)**	**Recommended loading equipm**
8.0-10	65-90	Front end loader
10.0-15	100-150	Hydraulic or rope shovel

3. Burden And Spacing

Table 6- variation of parameter with UCS of rock & diameter of hole				
	Uniaxial compressive strenght (Mpa)			
Design parameter	**Low <70**	**Medium 70-120**	**High 120-180**	**Very high >180**
Burden - B	39 ×D	37 × D	35 × D	33 × D
Spacing -s	51 × D	47 × D	43 × D	38 × D
Stemming -t	35 × D	34 × D	32 × D	30 × D
Sub drilling - j	10 × D	11× D	12 × D	12 ×D

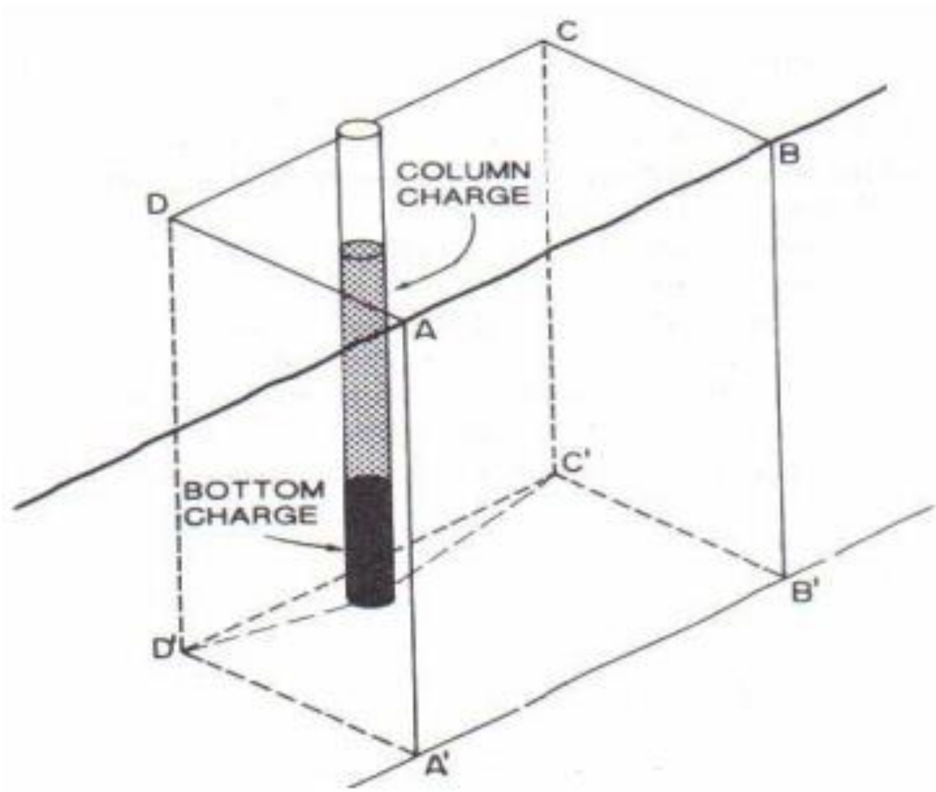
4. Stemming

To properly calculate stemming, the type and size of material used, and the length of the stemming column must be taken into account. Studies have shown that coarse angular material, such as crushed rock, is the most effective stemming product. Crushed rock effectively lowers the stemming length by up to 41%. The optimal stemming length varies between 20 and 60 times the diameter of the blast hole with at least 25 times the diameter maintained to avoid the problems listed above in Table 6.

5. Charge Distribution

The required energy needed to produce rock breakage is not uniform in bench blasting. The energy generated by the explosive must overcome the tensile strength of the rock (section CDD'C') and the shear strength (section A'B'C'D'). To achieve this effect the explosive with the greater density and strength should be placed on the bottom of the blast hole, known as the bottom charge. It should be noted that placing this charge on the bottom of the blast hole increases the diameter of shaped charges by roughly 10%. The explosive with the lighter density should be placed in the column; this is known as the column charge.

Charge distribution Figure and table



(**Fig. 7-**Charge distribution)

Table 7- Variation of bottom charge length with UCS & diameter

Design parameter	**Soft <70**	**Medium 70-120**	**Hard 120-180**	**Very hard >180**
Bottom charge length	30 × D	35 × D	40 × D	46 × D

B. Large Diameter Bench Blast

Diameters from 165 mm to 450 mm are considered to be large diameter bench blasts. Large diameter bench blasts are used mostly in large surface mining operation.

1. Drilling Diameters:

Table 8- Variation of average production with diameter and rock type

Blast hole diameter D (mm)	Average production per hour (m3 b/h)		
	Soft rock <70 Mpa	Medium hard 70-180 Mpa	Very hard rock >180
200	600	150	50
250	1200	300	125
311	2050	625	270

2. Bench Height :

The height in meters can be estimated by the following equation:

$$H = 10 + 0.57\,(Cc - 6)$$

Where,

Cc = the bucket size of the shovel (m^3),

H= bench height (m)

3. Sub Drilling

Table 10 -	Relationship of sub drilling with blast hole diameter					
Design parameter		**Blast hole diameter (mm)**				
		180-250	250-450			
Sub drilling - j		7-8 × D	5-6 × D			
		j=5+(0-450-D)/0.09467				

4. Drill Pattern

Table 11- Burden and spacing values for various compressive rock strenght and explosive								
Type of explosive		**Design parameter**		**Compressive rock strenght (Mpa)**				
				Soft <70	**Medium hard 70-180**		**very hard >180**	
ANFO		Burden - B		28 × D	23 × D		21 × D	
		Spacing -s		33 × D	27 × D		24 × D	
Water gels		Burden- B		38 × D	32 × D		30 × D	
emulsions		Spacing -s		45 × D	37 × D		34 × D	

5.Powder factor

Powder factor is nothing but the specific charge or we can say it is the m3 of material excavated per kg of explosive used In large diameter blasting the powder factors range from 0.25 to 1.2 kg/m^3

6.Charge distribution

When doing large surface operations ANFO**,** ammonium nitrate fuel oil, is primarily used due to the following advantages.
-Low cost & high Bubble Energy.
-Safety & Easy mechanization.
In the cases where ANFO cannot be used, when the blast hole might be filled with water or when the charges on the bottom have been used as an initiator or primer for the rest of the charge column, water gels have been used as a substitute. Currently the system consists of creating a bottom charge of a high density explosive with a length approximately 8 to 16 times the diameter of the blast hole, in accordance with the rock type, and filling the rest of the blast hole with ANFO. It should be noted that the diameter of the bottom charge does not increase due to compression as there was in small diameter bench blasting. The technique listed above gives the minimum costs in drilling and blasting, while allowing for the optimum results in fragmentation, swelling, floor conditions and geometry of the muck pile.

Discussion

As stated before the dimension of the small diameter bench blast ranges from 65mm to 165mm . The small diameter bench blast are mostly used in small surface mining operation . While selecting the proper blast hole diameter, the average production per hour or excavation must be taken into account . The type of material excavated must also be accounted . An important aspest is the drilling cost . The cost usually goes down as the diameter of the hole increases . The average production per hour and types of rock being fragmented is still the variable needed for consideration in large diameter bench blasting . In small diameter bench blasting while determining the bench height it is important to take into account the drilling diameter and loading equipment used . In large diameter blasting there are couple of ways to calculate the bench height .

1. The first of which relates to the size and reach of the ropes shovel . Height can be calculated by the formula .

$$H = 10 + 0.57 (Cc - 6)$$

Where,

Cc = the bucket size of the shovel (m^3),

H= bench height (m

2. another way to calculate the bench height which take into account the compressive rock strength and relate to the diameter .

the spacing S value is calculated with burden and the delay timing between blast hole . The value for spacing is approximately $1.15 \times B$ for hard rock and $1.30 \times B$ for soft rock.

If the compressive rock strength is low below 70 then stemming is calculated 40 × D . If compressive rock strength is medium to high (70 – 180) then stemming is calculated by 32 × D and if the compressive rock strength is very high more then 180 then Stemming is calculated 25 × D . Subgrade drilling is not used in calculating the volume of rock being blasted . If sub drilling is too small , the rock will not completely shear of resulting in toe formation . The value of sub drilling that produces optimum level of breakage is roughly 0.3 times of burden

Conclusion

Parameters influencing surface blast design have been reviewed extensively . The key parameters having significant influence are identified . Different researches namely **Langefors** and **Kihlstrom** and **Konya** and **Walters** have utilized some of these parameters to arrive at suitable blast design . Among these the most popular one is blast design theory proposed by **Langefors** and **Kihlstrom** (1968). The calculation of this design concept needs longer time duration to arrive at the design solution .

Future work

At present it is a hand calculation which took longer time . In future it may be programed using computer aided equipment to calculate the parameters efficiently and easily.

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