

## **BLASTING IN SURFACE EXCAVATION**

Any blast optimisation programme calls for a clear understanding of the effects of principal blast parameters and their careful application.

The degree of fragmentation of rock depends on:

- a. the rock's characteristics;
- b. the properties and quantities of explosives;
- c. blast geometry;
- d. blast size;
- e. the priming method; and
- f. the initiation sequence

### **Terminology in bench blasting**

*Free face:* This is an exposed rock surface towards which the explosive charge can break out. It resembles a wall.

*Face height (H):* This is the vertical distance in metres between the top and floor of the bench and should be at least twice the burden (2B).

*Blasthole diameter (D)*: Generally, the cost of drilling and blasting decreases as hole diameter increases. The relation between blasthole diameter and face height is approximately:

$$D = 0.001 \text{ to } 0.02 H$$

*Burden (B)* : This is the distance in metres from a blasthole to the nearest free face and has the following approximate relation:

$$B = 25D \text{ to } 40D$$

Or  $B = 25D \text{ to } 30D$  for hard rock

$$B = 30D \text{ to } 35D \text{ for medium rock}$$

$$B = 35D \text{ to } 40D \text{ for soft rock}$$

*Spacing (S)* : This is the distance in metres between adjacent blastholes and is measured perpendicular to the burden. Usually the relation between drilled burden and spacing is:

$$S = 1 \text{ to } 1.8B$$

The above definition is best described by the Figure 1.

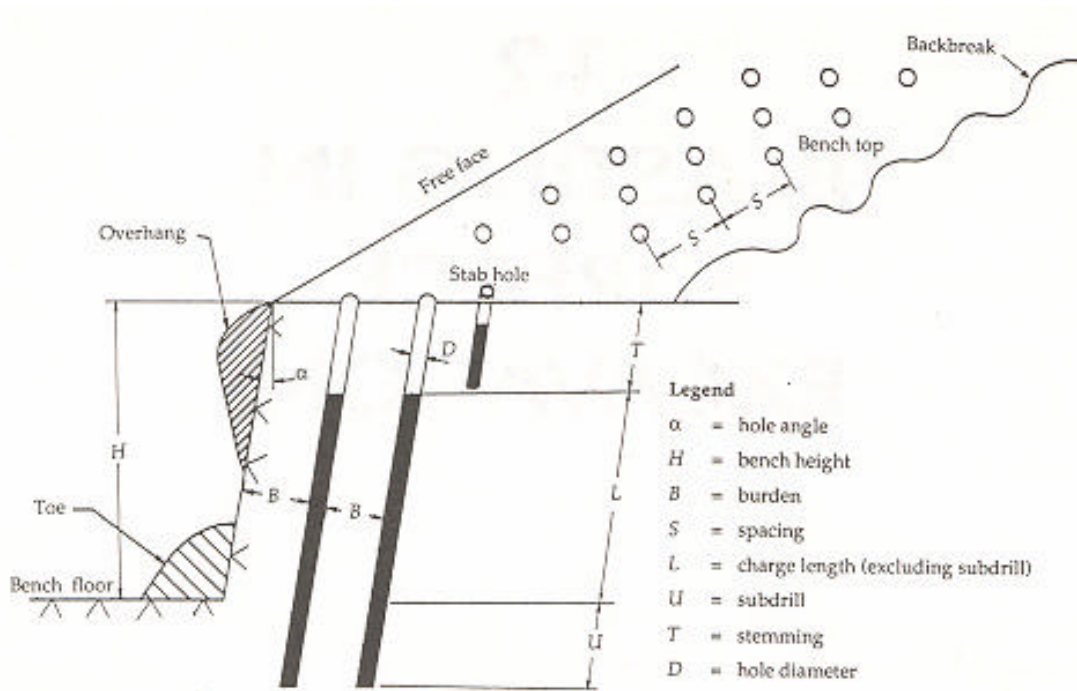


Figure 1: Surface blasting terminology

**Hole angle ( $\alpha$ ):** If the strata conditions permit, inclined blastholes allow better distribution of the explosives (Figure 2).

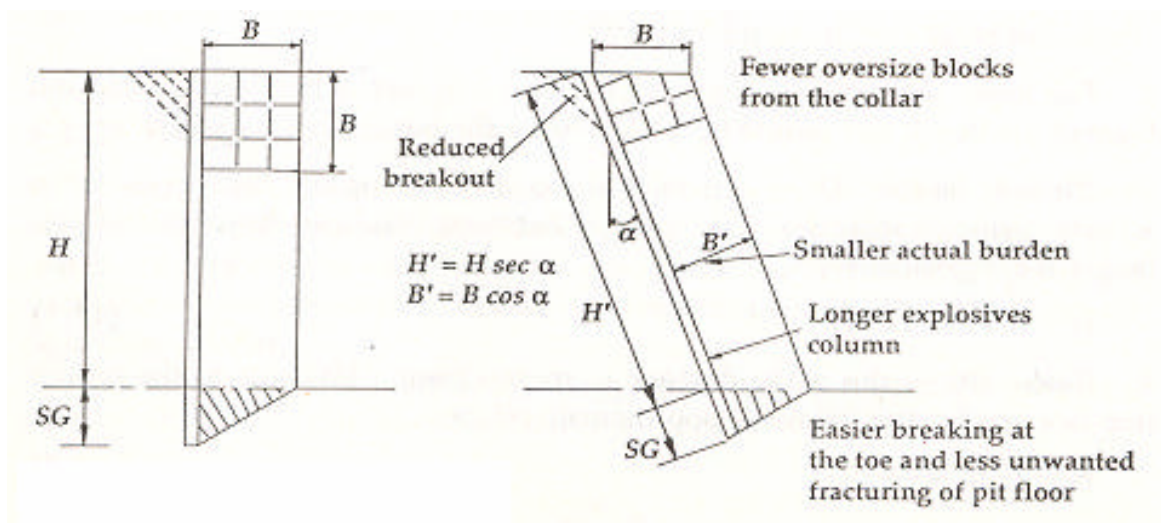


Figure 2: Angled versus vertical blastholes (after ICI)

Inclined blastholes are very effective in eliminating 'toe' (which is a hump of solid rock between the free face and the bench floor), and backbreak.  $\alpha$  varies between  $0^\circ$  and  $30^\circ$  from the vertical plane.

*Subdrill (subgrade drilling or overdrilling) (U)* : This is the extra depth drilled below the grade level to assure that the full face of the rock can be broken to the desired excavation level.

Usually  $U = 8$  to  $12D$ ; alternatively it equals to  $B/3$ .

*Charge length (L)*: This is the explosive column in a blasthole and should be at least  $20D$  in order to utilize fully the explosion-generated strain in the rock.

*Stemming (T)*: This is the inert material filled between the explosive charge and the collar of the blasthole to confine the explosion gases.

The stemming material could be water, drill cutting, sand, mud or crushed rock. The best is the dry angular crushed rock ( $<30\text{mm}$ ) as it tends to form a compaction arch, which locks into the blasthole wall, increasing its resistance to ejection.

The optimum stemming length can be found from the following formula:

$$T_s = \frac{12Z}{A} \left( \frac{QS}{100} \right)^{1/3} \dots\dots\dots (1)$$

- where
- Z = Flyrock factor ( 1 for normal blasting and 1.5 for controlled blasting)
  - A = Rock factor (6 for very soft and 14 for hard rock (see table 1))
  - Q = Mass (kg) of explosives in 8 hole diameters or if the charge length is less than 8 hole diameters, the total mass of explosives
  - S = Relative weight strength of explosives (ANFO) = 100

A stemming length shorter than 20D usually causes flyrock, cut-offs and overbreak problems.

It is also suggested that the stemming length should not be less than the effective burden B.

*Powder factor or specific charge or blasting ratio:* This is the ratio between the mass of explosives required to break a given quantity of rock and is normally expressed in kg/m<sup>3</sup> or kg/t<sup>3</sup>.

Table 1 is a guide to the powder factor for a given type of explosive in various types of rock.

Table 1: Guide to powder factors and rock factors for various rock types

General Category	Rock type	Powder factor (kg/m <sup>3</sup> )	Rock factor A
Hard (+200)	Andesite Dolerite Granite Ironstone Silcrete	0.70	12 -14
Medium (100 – 200)	Dolomite Hornfels Quartzite Serpentinite Schist	0.45	10 -11
Soft (50 – 100)	Sandstone Calcrete Limestone Shale	0.30	8 - 9
Very soft (-50)	Coal	0.15 – 0.25	6

Example: A quarry is planned to be working on a rock of Andesite with an estimated production of about 120,000 tonnes per month. What is the estimated requirement of explosives per month? Assume that the SG of Andesite is 2.7 and the powder factor for andesite is 0.7 kg/m<sup>3</sup>.

Solution:

Volume of andesite to be produced =  $120,000 / 2.7 = 44,444 \text{ m}^3$

Explosives required =  $44,444 \times 0.7 = 31,111 \text{ kg}$

*Backbreak or overbreak:* This is when the rockmass behind the row of blastholes farthest from the face is broken or cracked.

Backbreak is an undesirable phenomenon because it makes the crest of the face unsafe and often presents problems in drilling the first row of holes for the next blast

*Decoupling ratio* can be defined as the ratio of the diameters of an explosive column and the blasthole and is usually expressed as a percentage.

For example, if an 88 mm diameter hole is charged with 64 mm diameter cartridges,

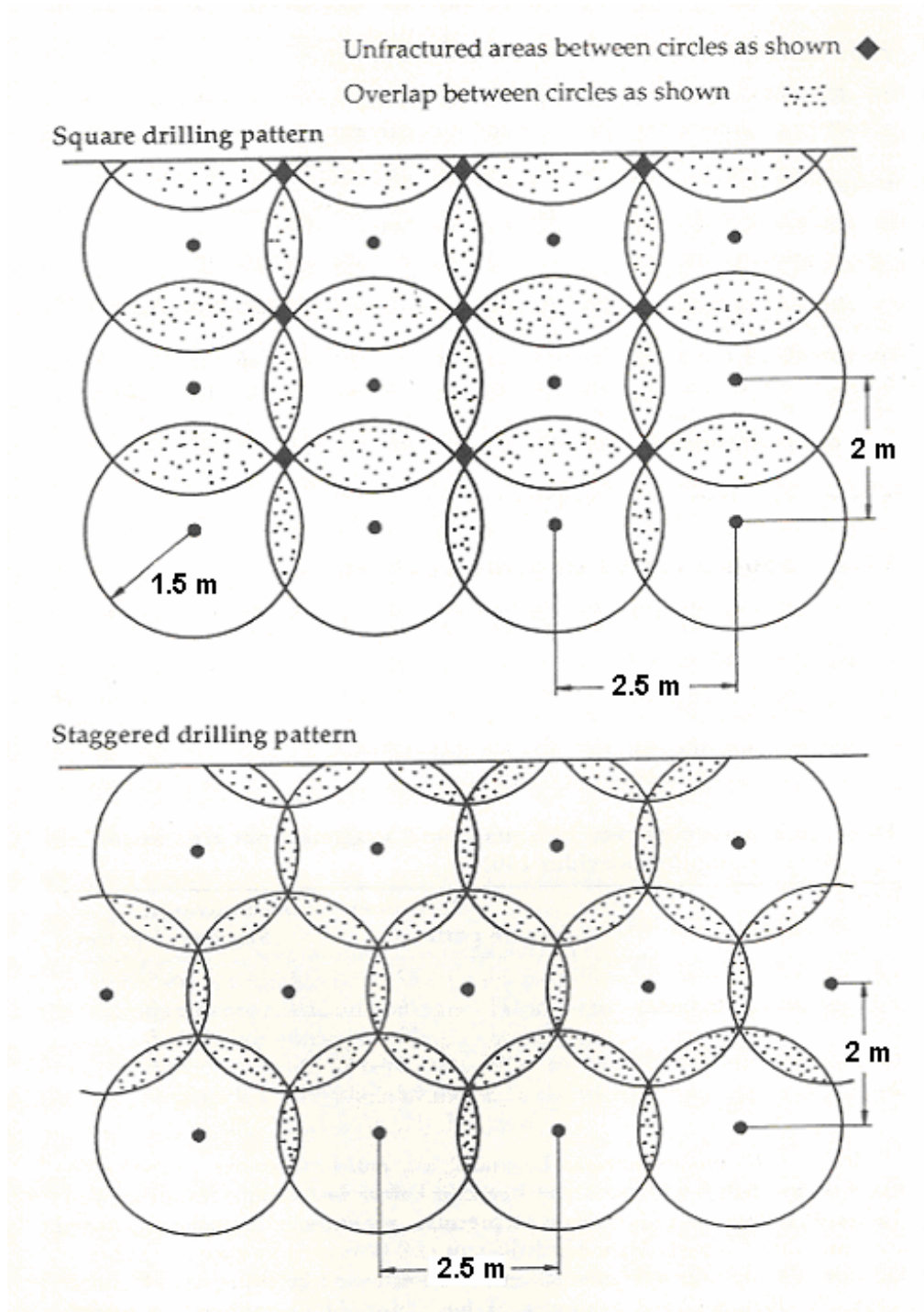
$$\text{The decoupling ratio } R_D = \frac{64}{88} \times 100 = 73\%$$

## **Blasthole Patterns**

### 1. Square versus staggered pattern

Blastholes can be drilled in either square pattern or staggered pattern.

A staggered pattern produces a more uniform distribution of explosive effect



The blastholes form equilateral triangle

Figure 3: Square versus staggered pattern. Optimum coverage is achieved in staggered pattern.

Optimum fragmentation can be achieved by firing each blasthole separately by using (Figure 4) trunk line delay (TLD) units on the surface.

This system has particular application where ground vibration problems put restrictions on the charge mass detonated per delay.

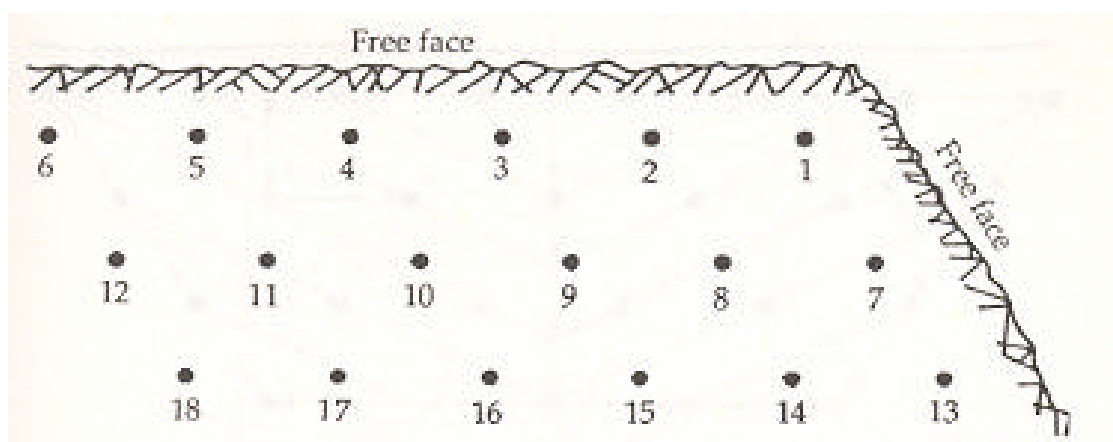


Figure 4: Design of each blasthole detonating separately (After AECl)

## 2. Chevron patterns

A closed chevron pattern (Figure 5) produces a high profile rock pile with a possible secondary fragmentation due to impacts between rocks projected from opposite directions.

An open chevron patterns gives evenly spread rock piles particularly suitable for front-end loaders and may produce less toe problems.

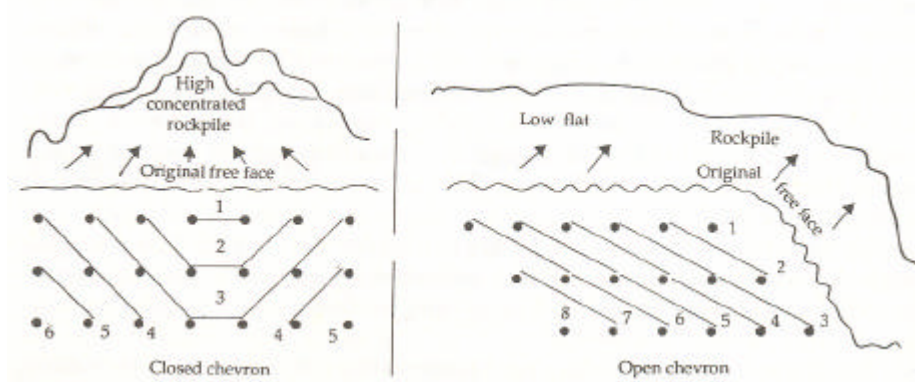


Figure 5: Chevron blast pattern

## Firing Patterns

In normal blasting all holes do not blast at the same time.

Bench blasting is normally carried out as short delay blasting. The firing pattern has to be designed so that each blasthole has free breakage.

The firing sequence of a chevron pattern can radically alter the drilled burden and spacing into the blasted or effective burden (Be)

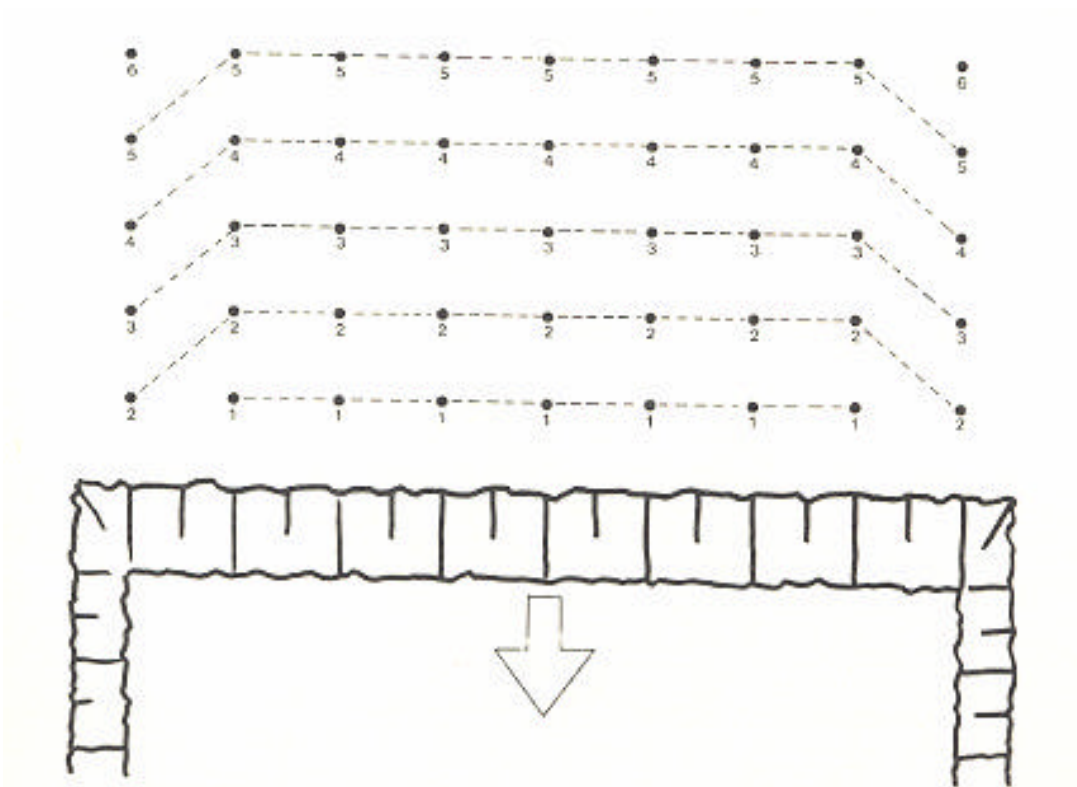


Figure 6: Firing pattern, multiple row blasting

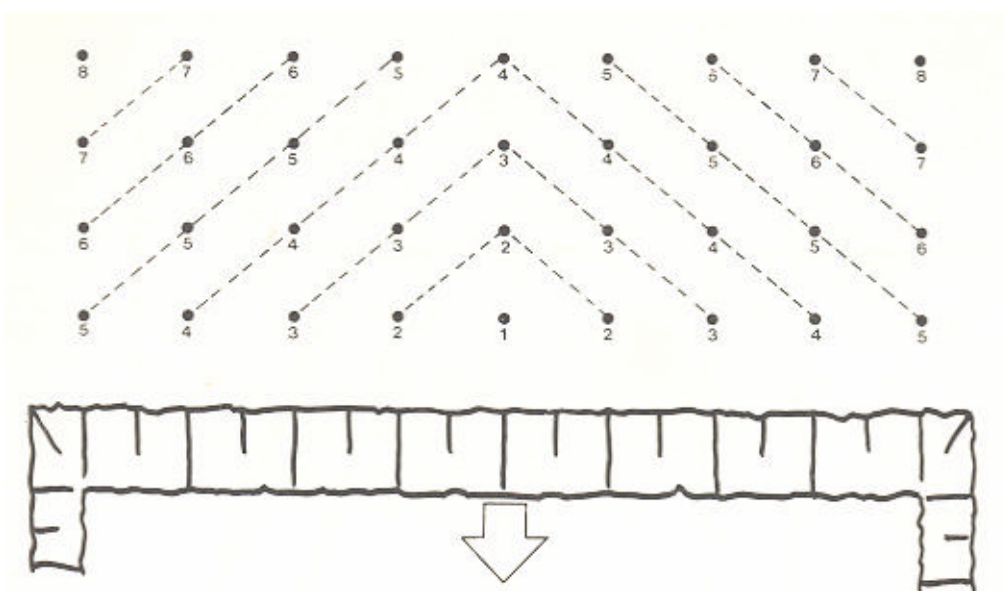


Figure 7: Firing pattern

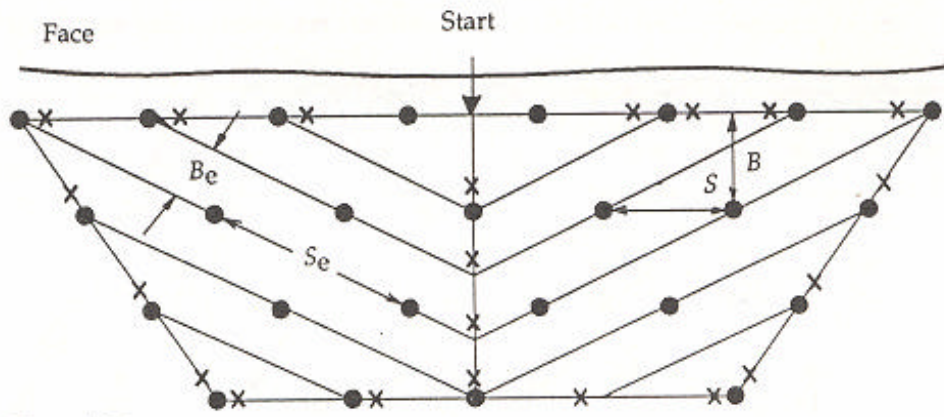


Figure 8: Drilled burden and spacing versus effective burden and spacing (after ICI)

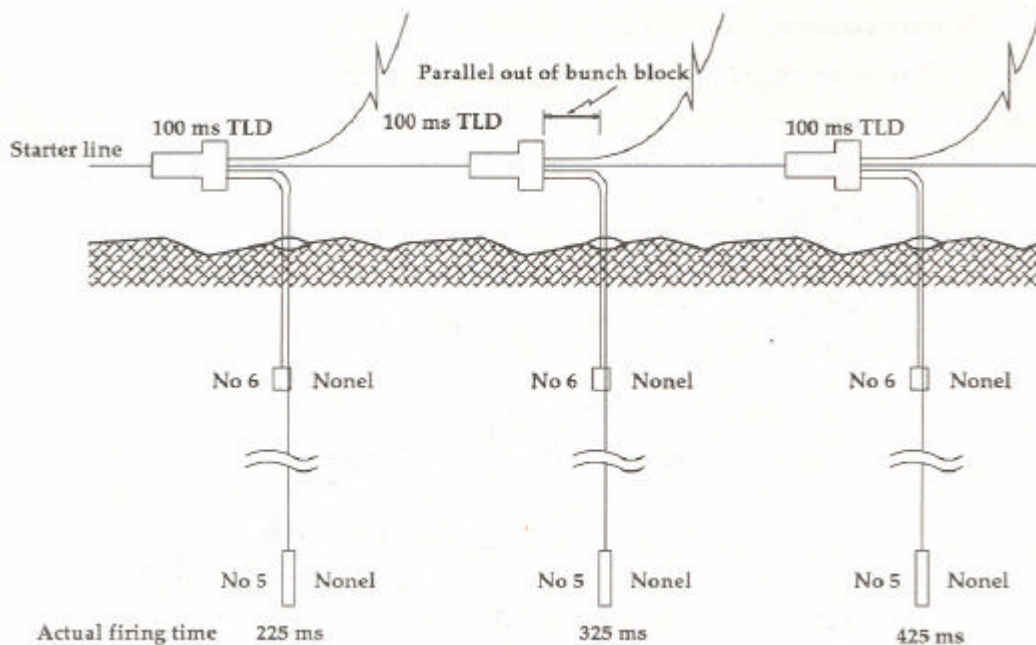
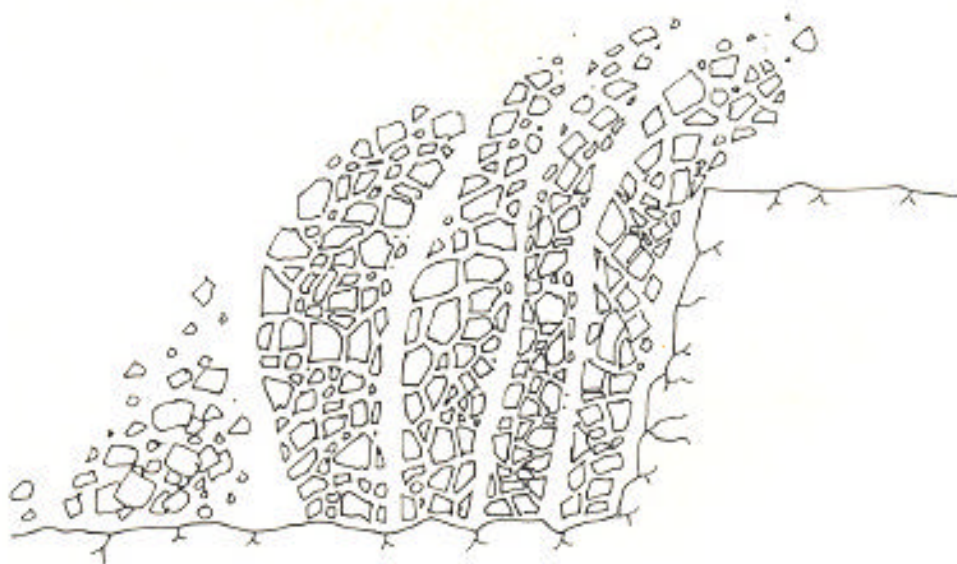


Figure 9: Hook-up system with Nonel in surface mining

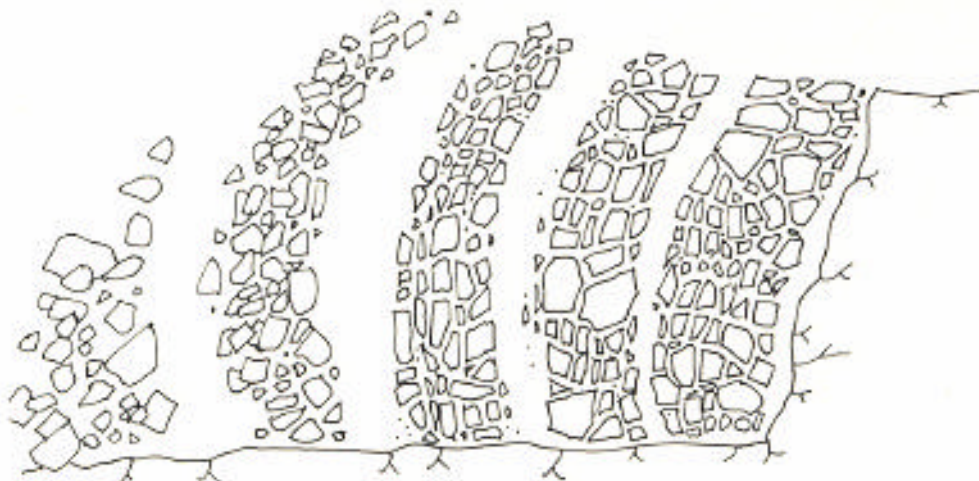
## Delay Intervals

Too short a delay causes the back rows to be initiated before the burden on the front holes has time to break away and to move. This may cause flyrock from rows at the back.

Too long a delay may also cause flyrock, airblast and boulders, as the protection from previously fired rows disappears due to too great a rock movement between detonations.



*Figure 10: Too short a delays between rows may lead to problem of flyrock from the back row*



*Figure 11: Perfect delays between rows*

## **Blast Size**

The blasted block should be such that the length is at least twice the width and preferably five times or more.

As the number of rows of blastholes increases, the overall rock fragmentation improves, usually up to 5 rows. However, if the loading equipment can handle a high profile of broken rocks the number of rows can be increased to about 8.

## **Blast Design**

The best use of explosives is made when a blast produces a clean break, giving good fragmentation, while avoiding excessive fly-rock. The success of achieving these goals depends significantly on good blast design.

If the blastholes are drilled as a staggered pattern on an equilateral triangular grid, the optimum distribution of the explosive's energy is achieved. Hence the following relation exists:

$$1.15B = S$$

Example:

A new iron ore deposit is to be worked by surface mining methods with 15 m benches using 150 mm diameter blastholes. Since the prevailing condition is dry rock, it has been decided to use bulk ANFO with emulsion cartridges as primer. Assume that the overall density of compacted ANFO and the primer as  $0.85 \text{ g/cm}^3$  and the powder factor of  $0.6 \text{ kg/m}^3$ . Find the appropriate burden and spacing for vertical holes and inclined bores. Assume that the drilled blastholes are in a staggered pattern forming equilateral triangles.

$$\begin{aligned}\text{Charge density} &= \frac{\pi}{4} \times \left( \frac{150}{1000} \right)^2 \times 850 \\ &= 15 \text{ kg/m}\end{aligned}$$

Since iron ore is hard rock, and referring to Table 1 the rock factor A can be taken as 11. Assuming flyrock has to be controlled,  $Z=1.25$ .

Using equation (1),

$$Q = 8 \times 0.150 \times 15 = 18 \text{ kg}$$

$$\text{Then, stemming length } T = \frac{12 \times 1.25}{11} \times \left( 18 \times \frac{100}{100} \right)^{1/3} = 3.6 \text{ m}$$

$$\text{Now subdrill } U = 10 \times 150 = 1500 \text{ mm} = 1.5 \text{ m}$$

Then blasthole length =  $15 + 1.5 = 16.5$  m, and

Charge length =  $16.5 - 3.6 = 12.9$  m

Hence one blasthole will have:

$$\begin{aligned}\text{Charge density} \times \text{charge length} &= 15 \times 12.9 \\ &= 193.5 \text{ kg explosives}\end{aligned}$$

Volume of rock blasted per hole =  $193.5/0.6 = 322.5 \text{ m}^3$

$$\begin{aligned}\text{So, } S \times B &= 322.5/15 \\ &= 21.5 \text{ m}^2\end{aligned}$$

$$1.15B \times B = 21.5$$

$$B = 4.3 \text{ m}$$

$$S = 5 \text{ m}$$

However, if the face is inclined to  $20^\circ$  from the vertical, the blastholes have to be parallel to the face and their new length will be:

$$\frac{15}{\cos 20^\circ} + 1.5 = 17.3 \text{ m}$$

Charge length =  $17.3 - 3.6 = 13.7$  m

Explosives mass per hole =  $13.7 \times 15 = 205.5$  kg

$$\text{Now, } S \times B = \frac{205.5}{15 \times 0.6} = 22.83 \text{ m}^2$$

$$\text{So, } 1.15B^2 = 22.83$$

Hence,  $B = 4.46$  m and  $S = 5.12$  m

## Secondary Blasting

Most primary blasting, whether on surface or underground, will leave some oversize boulders.

The term oversize boulder may be defined as *any boulder produced from primary blasting, which cannot be adequately handled by the standard loading and crushing equipment used in an operation. Its size varies from one operation to another, depending on the type of loading, conveying and crushing equipment in use.*

In surface mining or quarrying, oversize boulders cause delays in loading operations. Boulders or oversize rocks have to be lifted out of the muckpile during digging and set aside for secondary breakage.

In underground mines oversize may cause hang-ups in the chutes and orepasses.

Oversize rocks may be broken by hydraulic impact breakers or drop balls. In smaller surface mines or quarries it is not economical to use these machines, so explosives have to be used.

However, secondary blasting is the most expensive type of blasting.

Appropriate blast design is important in order to lessen the production of over size.

Secondary blasting can be done by pop shooting (blockholing) and plaster shooting (mudcapping).

Shaped charges are sometime used in secondary blasting, but this is much more expensive.

## **Cast Blasting**

When overburden is removed from a coal or mineral deposit it is generally cast to a waste dump by draglines, or removed by loaders and trucks.

Cast blasting is the controlled placement of overburden into the previously mined cut resulting in a reduced volume or overburden material for the dragline to handle.

Cast blasting often results in improved fragmentation of the overburden material, causing improved productivity for the dragline or loader.

This type of blasting is sometimes called *throw* or *controlled trajectory* blasting.

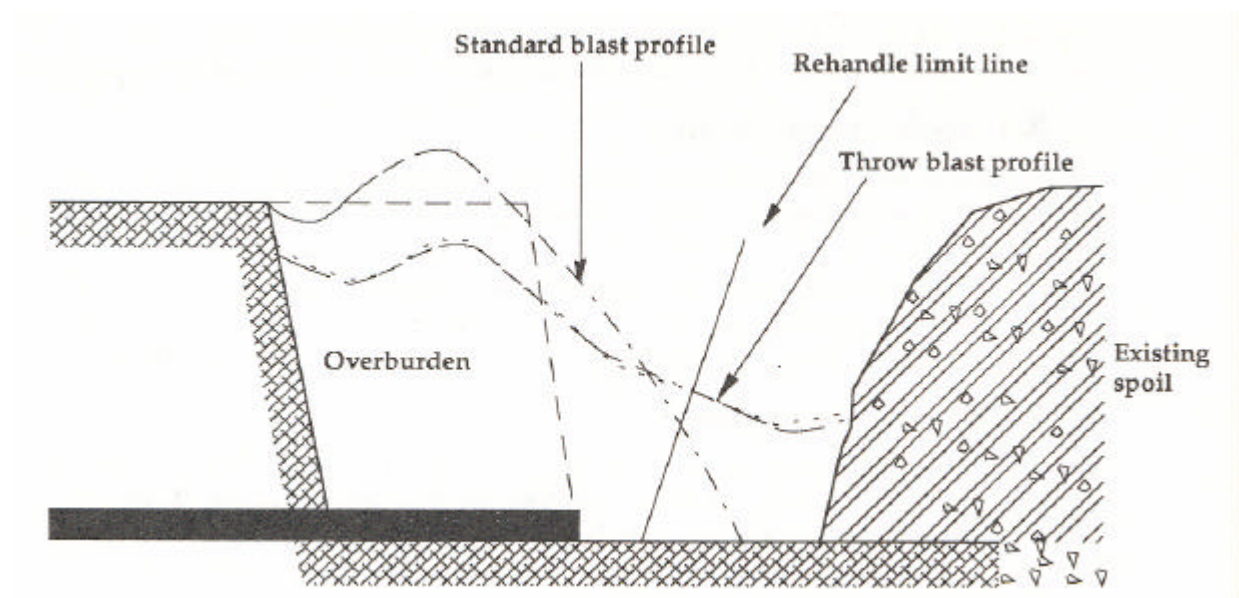


Figure 12: Standard blast versus throw blast profile

