Chapter 25

Methods and patterns of charging blastholes

25.1 INTRODUCTION

After all the blastholes to be detonated in one blast are drilled, they are loaded with explosive. Even with the use of modern safe explosives, this has remained most dangerous operation in a mining cycle.

In large surface mines most of the blasthole charging is done through mechanical means. The equipment used for the purpose differs depending upon the type and quantity of explosive.

Some idea of the manner in which a blasthole is loaded with explosive, has been given in an earlier part of this book.

This chapter deals with such topics in greater detail.

25.2 MECHANIZED BLASTHOLE CHARGING SYSTEM

Even the smallest amongst large surface mines use blastholes of diameter 200 mm or larger. When such a blasthole of 10 m depth is loaded with ANFO the weight of the explosive works out to about 267 kg. Some of the largest blasts in the largest mines have detonated more than 1000 tons of explosive within a short time span of 1 min.

Such huge quantities of explosives can only be handled by mechanical means. Further, charging blastholes through mechanical means is advantageous in several ways, some of which are:

1 Fewer persons required for the operation
2 Very fast charging operation
3 Ability of using bulk explosives
4 Use of full blasthole volume
5 Possibility of attaining highest charge density
6 Possibility of increasing charge density in certain parts of the blasthole.
7 Ability of adding certain sensitizers in certain parts of the blasthole.

All these advantages lower the cost of the charging operation so much that it easily offsets expenditure in investment and maintenance of the fleet of bulk loading equipment.

Usually the storage depot of the explosives is situated at a long distance from the mine bench.

The only means of bringing the explosive to the mine bench is through trucks.

The most commonly used explosives in large surface mines are:

ANFO and Heavy ANFO
Bulk Slurries and Emulsions.

The equipment for charging blastholes with the above explosives differ from each other.

The following sections gives details of the equipment.

25.2.1 Trucks for loading ANFO or heavy ANFO

In the very early stages there may have been trucks that merely transported ammonium nitrate bags and fuel oil drums to the work site. However, modern trucks have the facility to carry all the components of the explosives safely in different compartments, enable their mixing at the site and pump them into the blasthole.

A typical truck used for charging a blasthole with ANFO is shown in Figure 25.1.

The internal construction of the charging truck is as shown in Figure 25.2.

Ammonium nitrate, in the prill form, is stored in three or more compartments on the truck. A fuel tank on the truck stores an adequate volume of fuel oil. All these compartments or tanks are coated with specialized materials for long corrosion-free life. Ammonium nitrate is pushed into the mixing chute by the main augur. The rotary speed of the main augur is controlled and set by the operator depending upon the requirement of the explosive. Thus, ammonium nitrate flows at a predetermined rate. The fuel oil jet sprays fuel at the appropriate rate to match the flow of ammonium nitrate. As the mixture moves into the discharge arm by use of the discharge augur the fuel is well absorbed into the AN prill.

Figure 25.1 Charging of a blasthole by use of explosive mixed by a delivery truck.

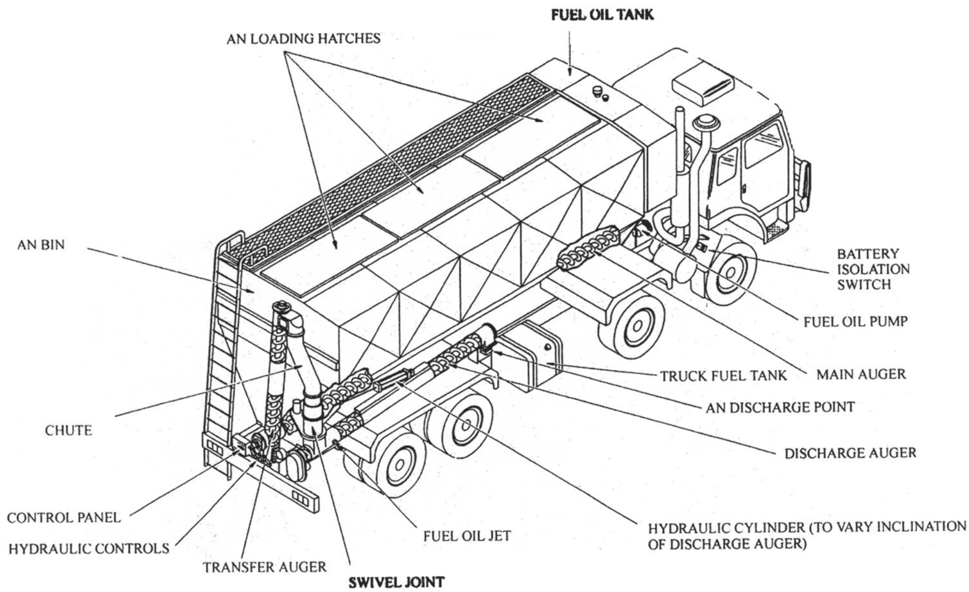

Figure 25.2 Internal construction of a charging truck.

The discharge arm can be swung by a hydraulic cylinder provided for the purpose so as to bring the discharge point above the blasthole mouth. This ensures that all the ANFO is poured directly into the blasthole.

Stemming of ANFO-filled blastholes can be done immediately after the blasthole is charged.

25.2.2 Trucks for loading slurry or emulsion

A typical truck meant for delivering slurry and emulsion explosives is shown in Figure 25.3.

Trucks used for loading slurry or emulsion into the blasthole have many chambers to store the ingredients needed for making the explosive slurry. Typically the chambers store fuel, oxidizer, aluminum, sulfur and trace ingredients. These ingredients are pumped by the pumps provided for respective chambers into a mixing chamber in appropriate proportions as set by the blaster on the control panel. After mixing, the slurry explosive formed in the process is made to flow through a long hose by a screw pump.

Some slurry explosive charging trucks have two cabs. The charging cab located on the rear side has the main control unit. The panel on the control unit has counters and totalizers to monitor the quantity being delivered.

The calibration of the unit is made at the manufacturer's plant to ensure that the slurry explosive has the advertised properties.

Most of the units are capable of making slurry with viscosity up to 60000 centipoise.

Figure 25.3 Truck for charging a blasthole by slurry explosive.

When the blasthole to be charged has a significant quantity of water, the slurry delivery hose is lowered to the bottom of the hole. This ensures that the slurry explosive starts getting filled from the bottom and the water in the blasthole is lifted out from the blasthole mouth.

Slurry explosive pumping units have discharge rates normally ranging to 300 kg/min. For the gassing and gelling to be completed it may take about 5 to 10 minutes in the case of most of the explosives. For this reason stemming of the slurry-charged blastholes is started after waiting for about 10 minutes for each blasthole.

The trucks used for charging slurry can also be used for charging emulsions into the blastholes. The delivery settings have to be appropriately adjusted for such changeover. Since emulsions take as much as 40 to 50 minutes for gassing and gelling, it becomes necessary to wait for nearly an hour before stemming of the blasthole can be started. In the case of emulsion explosives, the gassing process can be accelerated by using acetic acid.

25.2.3 Safety features of bulk delivery system

Bulk delivery systems generally have the following safety features.

The ingredients of the explosives are nonexplosive in nature. They can, therefore, be transported very safely. The chambers used on the trucks for storage of the ingredients are coated with resins that have high insulation properties.

The diameter of the delivery hose is kept below the critical diameter which is of the order of 100 mm.

Since explosive is directly charged from the bottom of the blasthole, and on the top of this a considerable depth of the hole is filled with stemming material, it

Figure 25.4 Lowering of slurry explosive hose to the bottom of the blasthole.

is cannot be easily scooped from the surface of the ground. This ensures that the explosive cannot be stolen.

The truck unit is equipped with a few chains that roll on the ground and carry static electricity from the truck components to earth.

In case of slurries or emulsions the gassing process is slow and the mixture poured in the blasthole takes some time to acquire the explosive properties.

25.3 BLASTHOLE CHARGING PATTERN

The most fundamental form of charging a blasthole with ANFO is shown in Figure 20.1. As briefly explained there, the detonator, primer, booster and main explosive are the four components of a charged ANFO blasthole. Some more information about these components is also contained in Chapter 22.

When the main explosive detonates, the energy released is in two forms viz. strain energy ET and bubble energy EB. The total energy TE released by the explosive is TE = ET + EB. For any explosive, TE depends upon its composition and characteristics and as such it is constant.

However, if the confinement of the explosive is very tight and without any air gas in it, the strain energy component is larger. On the contrary, if the confinement is tight but with some air gap, the bubble energy component is larger.

Thus, when very strong and brittle rocks are to be fragmented, confinement without any air gap is more suitable. Addition of Al is also desirable.

For fragmentation of relatively weak rocks confinement in the blasthole with an air gap is more desirable. In fact recent research indicates that use of an air gap is beneficial in every type of blast.

The technique of leaving air gaps in explosive columns is called air decking. Since every air gap causes a discontinuity, the explosive column gets divided into more than one zone.

When the length of a blasthole is more than 10 m or when the blasthole is in a rock mass that has many layers, there is a possibility of water seeping into the blasthole. Such water inflow makes a part of the explosive column very weak and the detonation may not continue from one side of such a weak zone to the other side. For this reason, it becomes necessary to divide the explosive column into two or more zones.

The components of an explosive column are a detonator, a primer, a booster and the column of main explosive.

25.3.1 Type and placement of primer

To properly charge a blasthole with ANFO as the main explosive, the arrangement, positioning and other relevant characteristics of the above components must be determined. In this regard the following points are of great importance.

The most important objective of a primer cartridge is to start detonation of the ANFO column with maximum attainable velocity of detonation for the diameter of blasthole (i.e. explosive column), right from the point of detonation.

This objective can be achieved only by using the primer cartridge with diameter close to the diameter of the ANFO column, and by using the primer that generates maximum detonation pressure in a confined state. Both these hypotheses are supported by Figure 25.5 and Figure 25.6.

Table 25.1 gives the velocities of detonation that can be achieved for ANFO densely filled in blastholes of different diameters.

As stated earlier, the primer is usually made of pentolite which is a mixture of PETN and TNT in equal proportion. Pentolite primer cartridges are available in different sizes.

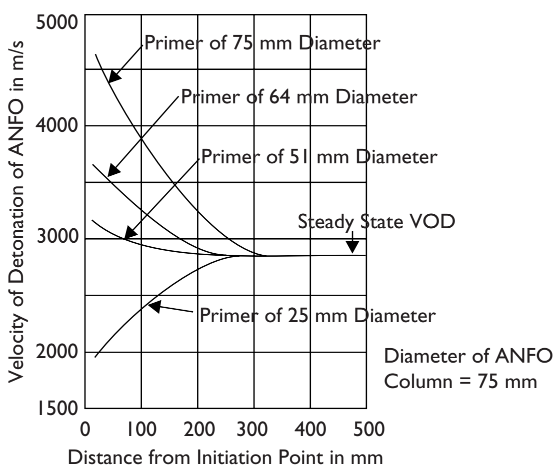

Figure 25.5 Effect of diameter of primer cartridge on velocity of detonation of ANFO.

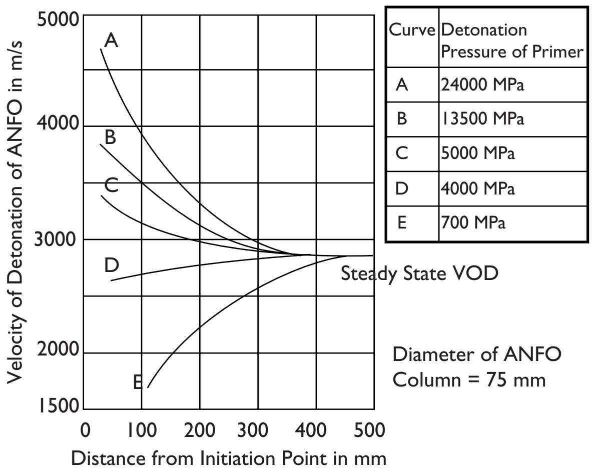

Figure 25.6 Effect of detonation pressure generated by primer cartridge on velocity of detonation of ANFO.

Table 25.1 Velocities of detonation for ANFO columns of different diameters.

Diameter of ANFO	*Column VOD (m/s)*
50	3000
100	3600
150	4000
200	4250
250	4400
300	4570
350	4650

For very large blastholes a primer of slurry or emulsion can also be used in conjunction with the primer cartridge. Such primers are made in plastic bag form as shown in Figure 25.7. They must be assembled by correctly inserting a detonator within their body as shown in the figure. The primer cartridge must not be tamped nor dropped into the blasthole.

Run up distance is the distance in the explosive column from the point of initiation of detonation to the point where maximum velocity of detonation is achieved. For convenience it is measured in terms of the diameter of the explosive column. As shown in Figure 25.8, it is about 8 diameters for an ANFO column. Therefore the length of primer cartridge or bag should be equal to about 8 times the blasthole diameter.

The quantity of primer is also important. As a general rule it can be said the weight of the primer in g should be equal to diameter of blasthole in mm.

ANFO is also available in pressure-packed bags. In these bags the density of ANFO is about 1.1 kg/L rather than 0.8 kg/L in the case of poured ANFO. These ANFO bags

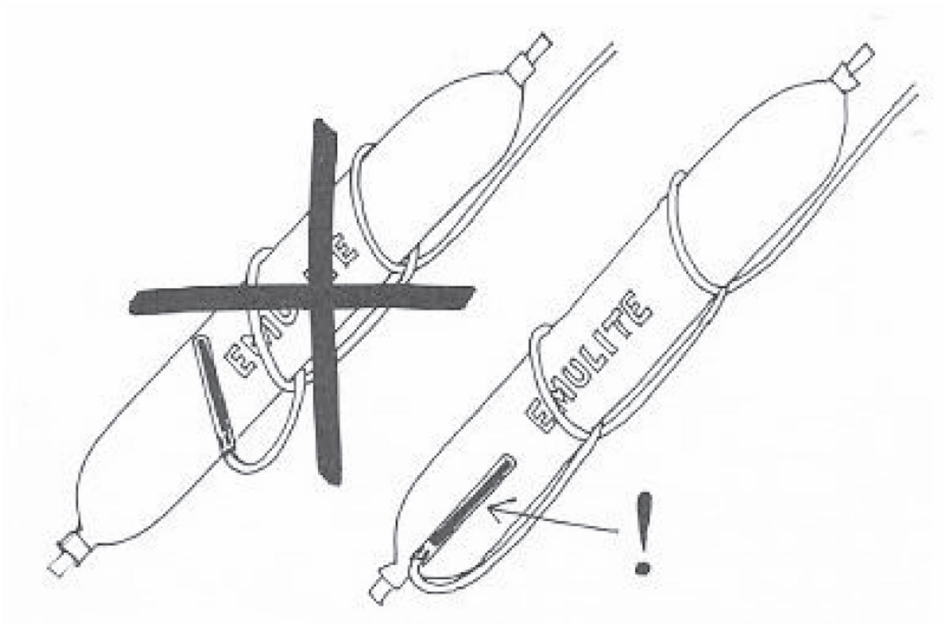

Figure 25.7 Primer made from emulsion in bag form.

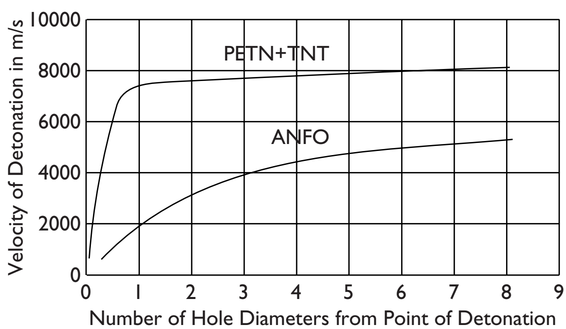

Figure 25.8 Run up distance for ANFO and PETN + TNT.

are used in blastholes where water seeps inside the blasthole. Initiation of detonation in such watery blastholes is done by cast primer.

While placing the bags one above another in a blasthole with only one primer in the bottom, as shown in Figure 25.9A, one of the bags may rupture and the explosive in the bag may desensitize. In such cases only a part of the explosive column gets detonated. To avoid such a situation a larger number of cast primers are introduced as shown in Figure 25.9B.

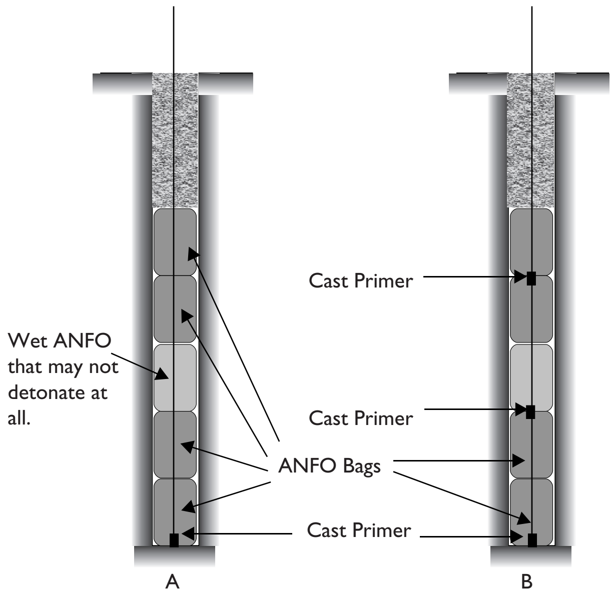

Figure 25.9 Use of pre packed ANFO bags.

In waterlogged blastholes, use of poured slurry or poured emulsion is most appropriate. When these explosives are detonated by a primer cartridge, as the detonation front travels, the explosive in viscous or semi viscous state gets compressed to the point that it becomes insensitive. Naturally, the detonation does not propagate beyond this zone. In such instance more than one cast primer has to be used.

For determining the number of cast primers an empirical equation as under is used.

$$N_b = L/(30 * D) + 0.73$$

where

N_b = Number of primers
L = Length of explosive column in m
D = Diameter of blasthole in mm

Thus, in the case of a blasthole of 200 mm diameter and 20 m depth excluding 1.8 m subdrilling the number of cast primers to be used can be found as below.

As will be explained in the next chapter, the stemming length presumed for this blasthole works out to 25D i.e. 25 * 0.200 = 5 m and required subdrilling works out to 8D i.e. 8 * 0.2 = 1.6 m.

Therefore, L works out to 20–5.0 + 1.6 = 16.6 m. This gives N_b = 16.6/6 + 0.73 = 3.49.

Therefore, to be on the safer side 4 cast primers should be used.

While placing the primers, the lowermost primer should be kept at a distance of 4D from the bottom of the blasthole and the topmost primer should be kept at a distance of 4D from the bottom of the stemming column. In the rest of the column the primers should be equidistant.

Thus in the above example the lowermost primer should be at a height of 0.8 m from the blasthole bottom. The depths of other three primers from the blasthole bottom should be 5.8 m, 10.8 m and 15.8 m.

In very heavily waterlogged blastholes, use of emulsions in bagged form is most suitable. In charging these blastholes, bags are lowered into the blasthole and remain in stacked form. In such blastholes the likelihood of desensitization of explosive due to water contamination is virtually non-existent but the danger of desensitization due to explosive compression remains. For this reason, the blastholes do need more than one primer. These primers should be placed at a distance of 30D after the lowermost primer which is to be kept at a height of 4D from the blasthole bottom.

25.3.2 Direction of propagation of detonation

The position of detonator and primer in the column of main explosive determines whether the detonation travels from bottom to top or from top to bottom or in some other manner. The three types recognized on this basis are:

1 Top Priming
2 Bottom Priming
3 Multi Point Priming

All the three types are important and one of them is to be chosen depending upon the condition of the rock mass on the basis of the following details.

In surface mines till some two decades ago top priming was practiced to a larger extent but this trend is now reversing, and in many instances bottom priming is preferred. This, of course, largely depends upon the ground conditions.

The most important factor in bench blasting is the pressure exerted at the toe by the blast of explosive in the blasthole.

When the detonation propagates from the top to bottom the velocity of detonation is insignificantly less than that when the detonation propagates from bottom to top. With a velocity of detonation of 4000 m/s about 4 ms are required for the detonation wave to travel from bottom to top or top to bottom in a blasthole of 20 m depth and 4 m stemming.

In bottom priming the point of initiation of detonation is never at the bottom but at some distance above the bottom. Due to this, actually two detonation zones, one traveling upward and other traveling downward as shown in Figure 25.10A, simultaneously exert pressure at the toe.

In the case of bottom priming, where the detonator is some distance below the top of the main explosive column, the upper wave detonation zone quickly reaches the bottom of the stemming column and results in venting off of the detonation pressure built up in the blasthole. The lower detonation wave travels downward and when it reaches the floor level, pressure is exerted in the toe region.

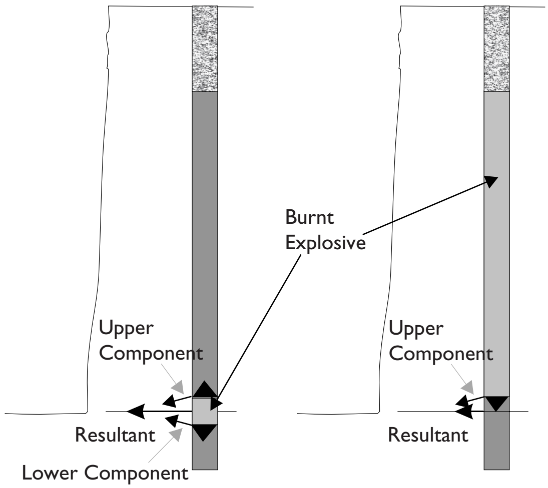

Figure 25.10 Top and bottom priming.

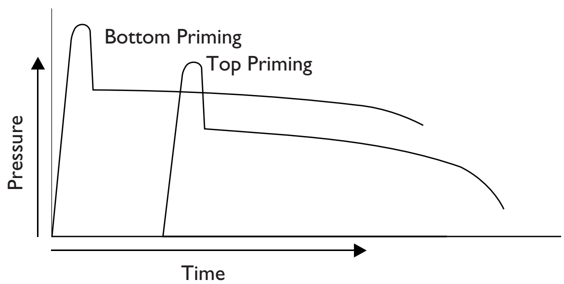

Figure 25.11 Curves of pressure at toe for bottom and top priming.

If very precise measurements of the pressure at the toe are taken by some means, the indicator curves for the pressure at the toe, in case of bottom and top priming, will look like those shown in Figure 25.11.

25.3.2.1 Top priming

The main advantage of top priming is that it is safer than other types of priming. This is so because the detonator is introduced in a charged blasthole at much later stage. At the same time the stemming in top primed blastholes is somewhat casual and weak. Therefore, venting of explosion gases starts rather easily.

When blasting is carried out in coal mining or similar sedimentary formations where one layer is to be fragmented by leaving the adjacent layer intact, there exists an inherent weak plane at the toe. In such circumstances the likelihood of toe problems is very low. For such blasts top priming can be equally as effective as bottom priming.

Similarly, in a rock mass of low compressive strength, top priming can be resorted to without any particular disadvantage.

25.3.2.2 Bottom priming

In hard rock formations, where the likelihood of toe problems is greater, bottom priming is practiced. In some instances use of a booster placed in the vicinity of the primer at the bottom of the blasthole is also advisable.

It has been estimated that the peak strain level at the toe is about 37% higher in the case of bottom priming as compared to top priming.

The need for shorter subdrilling length is also likely in bottom primed blastholes.

25.3.2.3 Multi point priming

When two detonation fronts travel towards each other and collide at a point the pressure built up is highest. It is noticed that the pressure magnitude at the point of collision is as much as 46% higher than that from one-way traveling detonation.

This fact can be utilized with advantage in blasting of rock masses that contain many layers with varying weakness.

One such example is shown in Figure 25.12, where one pair of primers is placed at the level of each of the two surfaces of hard rock layer. The detonation zones collide within the hard rock layer and create heavy stress in the hard rock layer to shatter and fragment it very effectively.

The other place where two primers can be used is at the floor level as shown in the figure. This primer placement reduces toe problems in hard rock.

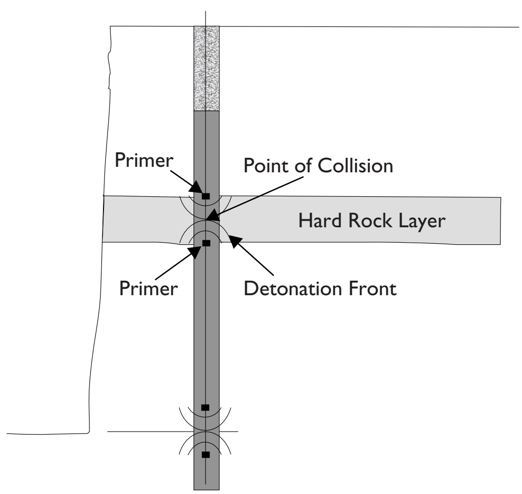

Figure 25.12 Multi point priming.

25.3.3 Continuous side initiation

By placing the detonating cord near the wall of the blasthole it is possible to initiate the detonation from one side of the explosive column rather than in the center of it. Such detonation propagates at low velocity and produces more bubble energy as compared to strain energy. For this reason, this type of initiation is more suitable in fissured rock masses where more bubble energy is necessary.

25.3.4 Air decking

Air decking was first introduced in Russian mines as early as the 1940s but remained forgotten until it was revived by Melnikov and Marchenko in the 1970s.

The principle behind air decking is that in some parts of the explosive column the explosive is replaced by atmospheric air. This is achieved by using one of the many available devices.

The air gaps surely increase fragmentation size but at the same time the quantity of explosive is reduced to a much greater extent. Thus, there is an overall cost saving by adopting the air decking technique. Some idea about the advantage of air decking can be gained by reviewing Figure 25.13.

It can be easily concluded from the figure that even if 40% of the explosive column is replaced, the increase in the mean size of the fragments yielded by the blast is only 9% or so. In most cases this increase in fragment size does not affect the loading and hauling operations and affects the crushing only to a very small extent.

The above indirectly means that a saving of about 30% cost is possible by using air decking of 40%. The difference of 10% is due to the cost of additional consumables and accessories required for air decking and extra efforts required in charging the blasthole.

For creating an air deck in the explosive column, some consumables are needed to be firmly placed at appropriate places in the blastholes. These consumables are available in two forms, viz. gas bags and hard plastic plugs.

In the early days of air decking gas bags were lowered into the blasthole to the required depth and were inflated by a compressor or gas cylinders from the surface of the ground. Such types of gas bags did not develop strong friction between their

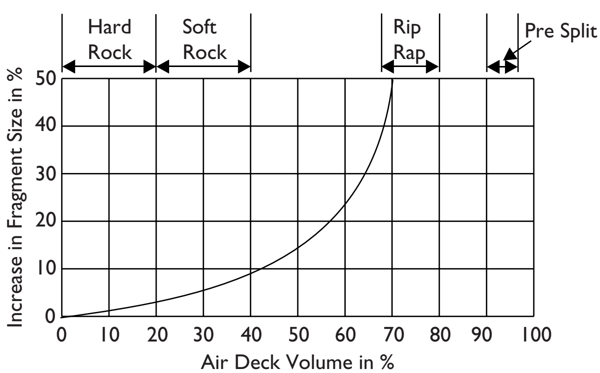

Figure 25.13 Advantage of air decking.

outer surface and the blasthole wall so as to bear the load of the explosive column and stemming material. They could be used only near the surface.

In the improved version of gas bags, the bag contains a specific quantity of vinegar in a sachet and sodium bicarbonate. When the gas bag is lowered at desired depth the sachet is broken. As the vinegar comes in contact with sodium bicarbonate, carbon dioxide is evolved. It fills up the bag and expands it to firmly adhere to the walls of the blasthole.

In yet another form of gas bag, an aerosol is contained in the bag. Just before the bag is lowered into the blasthole the aerosol cap is pressed down. The aerosol starts slowly releasing air and expanding the bag. A time of about 20 s is available to the blaster to lower the bag to the requisite depth before it catches on the blasthole wall and grips well with it.

Some manufacturers have made expandable plastic plugs made from a special type of hard plastic. These can be used in place of gas bags.

In general all these consumable accessories allow air decks to be created in a satisfactory manner.

In some blastholes water cannot be completely removed and a column of water always remains inside it. In such blastholes, decks are created by using air bags or plastic plugs. The water decks contain water instead of air.

Depending upon various conditions of blastholes and surrounding rock mass, many suitable air decking patterns have evolved. Patterns shown in Figure 25.14 are based on the experience of air decking practice described in a technical publication by Mintech, Australia.

As will be seen from the patterns shown in all the figures, there are no specific distance markings. This is because it is not possible to definitely define what percentage of explosive can be replaced by an air or water column to give acceptable fragmentation. For coming to a conclusion about the percentages, field trials need to be carried out. The best way to carry out field trials is to reduce the explosive by 10% and replace it with air deck volume without any change in stemming height. If the fragmentation is much below the acceptable size of fragments, then increase the air deck volume to 15% by reducing the explosive to 15%.

Some benefits that accrue by using air decks in blasting practice are summarized here below.

1 Considerable reduction in explosive quantity
2 Better confinement of explosion gases
3 Less ejection of stemming material
4 Better fragmentation at bench surface
5 Huge reduction in ground vibration level
6 Less air blast
7 Better charging efficiency
8 Reduction in explosive cost
9 Possibility of increasing concentration of explosive in hard rock layers
10 Less backbreak
12 Better heave
13 Consistent fragmentation level
14 Possibility of using ANFO in place of emulsion
15 Less fine generation
16 Clean and stable bench face with no toes or overhangs.

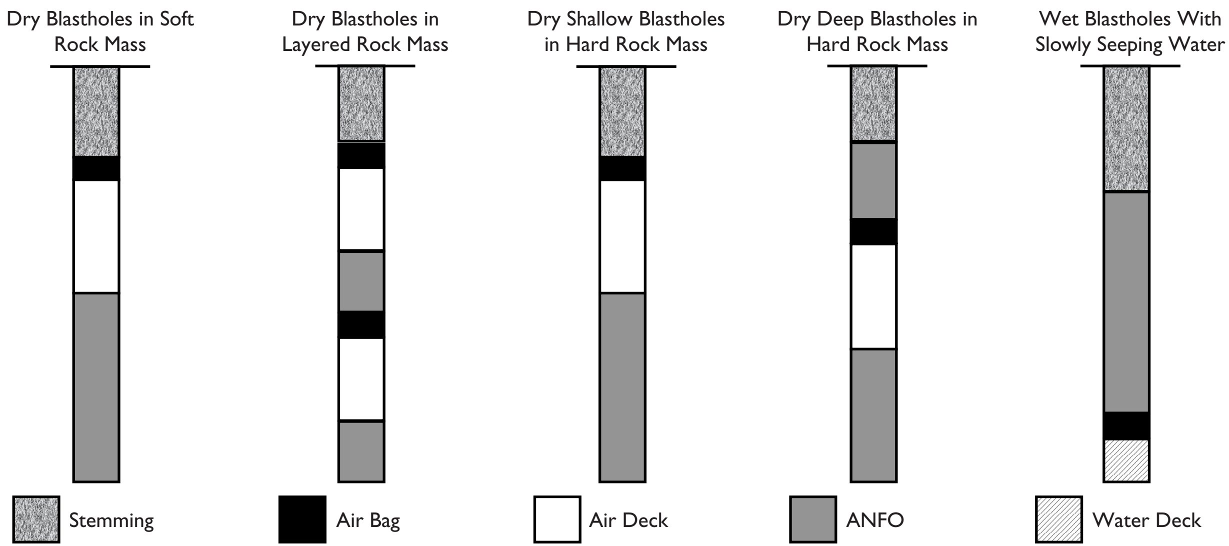

Figure 25.14 Air deck pattern different rock mass conditions.

25.3.5 Priming under special rock mass conditions

Some geological conditions of rock mass need special considerations while priming the blastholes drilled in the benches. The conditions can be titled as below.

1 Well Defined Ore Layer
2 Heavy Water Seepage in Blasthole
3 Hard Boulder in Soft Bed
4 Cavities in the Rock Mass

The following elaboration deals with the ways in which such conditions can be tackled while priming the blastholes.

25.3.5.1 Well defined ore layer

This condition often arises in mines of the minerals that are found in sedimentary rock masses.

In most surface coal mines there is a well defined coal layer separated from the overburden by a surface as shown in Figure 25.15. In such coal mines the overburden is removed by using a dragline, whereas the coal is excavated by using shovels as shown in Figure 26.4. One of the primary needs of blasting in such a rock mass is that by blasting in the overburden, the coal layer should not get disturbed. If coal gets fragmented along with overburden, quite a large portion of coal mixes with overburden and gets wasted.

To accomplish this objective, blastholes are always drilled only down to the top surface of the coal layer. While charging the blastholes the bottom one or two meter portion is filled with stemming material before charging the blasthole. The blasthole is charged as per conventional priming practice.

25.3.5.2 Heavy water seepage in blasthole

When water seeps profusely into the blasthole, dewatering fails. In such circumstances a thick but flexible plastic tube can be lowered into the blasthole with some steel

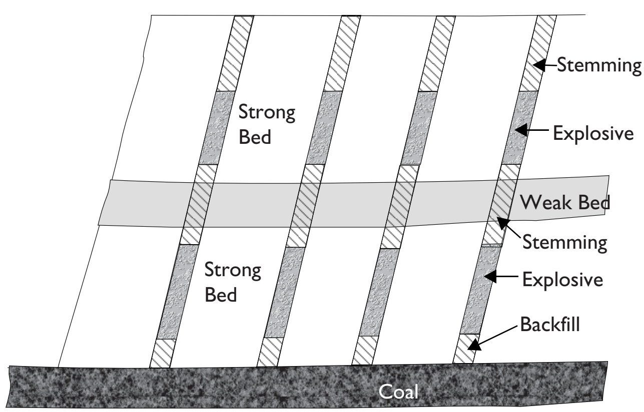

Figure 25.15 Pattern of blastholes charging in coal mines.

ingots at the bottom of the tube. A charging hose is also placed into the tube while it is being lowered. ANFO can be charged in the blasthole. It may be necessary to use a pneumatic charging method.

Such blastholes can also be charged with emulsion explosive because this has excellent resistance to water.

25.3.5.3 Hard boulder in soft bed

On rare occasions large boulders get embedded in a soft clay mass. A blasthole proceeds to the desired depth through this boulder. When explosive is loaded in the conventional manner the portion of the blasthole in the boulder many not have explosive at all as shown in Figure 25.16 A. When such a blasthole detonates, the energy is absorbed by the clay layer and the boulder remains intact. To avoid such situations the portion of the blasthole within the boulder is filled with explosive as shown in Figure 25.16B. This charge is called a pocket charge. In practice a boulder can be detected by careful study of the penetration logs of a group of adjacent blastholes. It can be seen by a blasthole camera.

25.3.5.4 Cavities in the rock mass

Some minerals, concentrated in the rock mass, can get leached to form a cavity in the ground. Such conditions can occur in iron ore or limestone rock masses. In such circumstances poured explosive will keep on filling the cavity as shown in Figure 25.17A and the blast may become a huge devastating explosion.

To avoid such consequences the blasthole has to be charged very carefully. The first step is to detect the cavity. This is possible by careful study of the penetration rate log. In most cases the drill string either gets quickly dropped in the cavity or the penetration rate increases to disproportionate magnitude. A cavity can also be seen by using a blasthole camera.

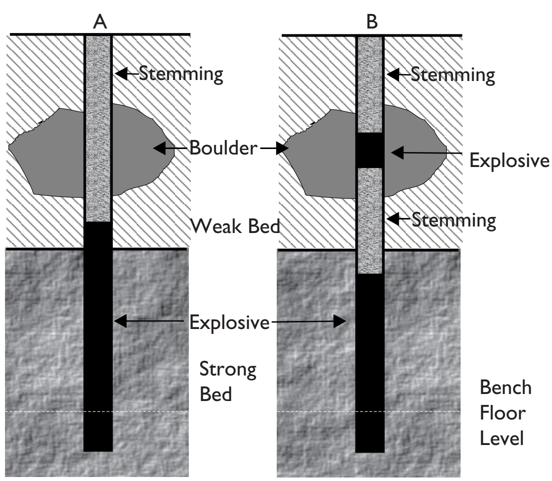

Figure 25.16 Fragmenting a boulder in clay mass.

Such a blasthole can be charged at the bottom up to a level a little lower than the cavity bottom and then a hard plastic plug can be firmly fixed into the blasthole. After this some wooden props are lowered into the blasthole and another hard plastic plug is fixed in the blasthole on the top of the props in the manner shown in Figure 25.16B. After this the blasthole is charged with explosive to the requisite height and the remaining upper portion is filled with stemming material.

25.4 DRILLING AND FIRING PATTERNS

Some information on delay elements introduced in the detonators was given earlier. Sequential delay in the timings of initiation of explosive in the blasthole is an important aspect of every blast.

If blastholes in two or more rows are fired at the same instant i.e. without any delay, then the rock mass in the portion lying between the first row and the bench face gets sufficient space beyond the free face to move the fragments horizontally. However, since the fragments formed from the rock mass portion between the first and second rows also try to move in a horizontal direction, they have much less space to move horizontally. The energy released by the blast then tries to move the fragments upward to produce long-traveling flyrocks in huge quantity. Further, when detonation of explosive in all blastholes is simultaneous, the hazard of airblast and ground vibration is also excessively large. Most importantly, simultaneous detonation of explosive in all the blastholes gives very poor fragmentation of the rock mass and requires considerable secondary blasting.

This is quite evident from the photograph shown in Figure 27.18, where the left side half of the bench was blasted by appropriately delayed detonation whereas the right hand half was blasted instantaneously.

When looked at from the bench surface the blastholes have collaring points at specific locations. This layout is termed the "Drilling Pattern".

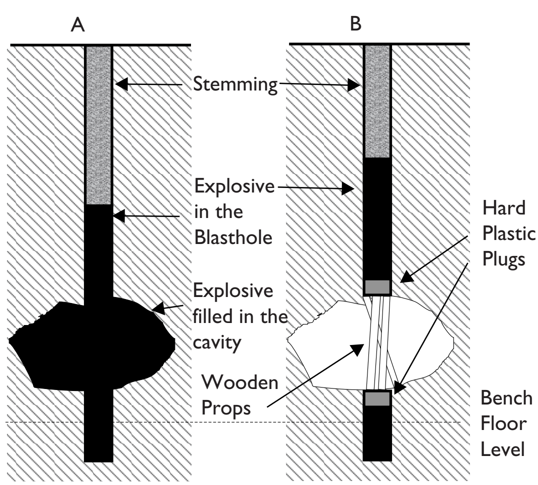

Figure 25.17 Charging a blasthole that passes through cavity.

By making intelligent use of delays, blastholes are also fired at different timings. This is irrespective of their layout. If a line connecting all the blastholes that detonate simultaneously is treated as a criterion, there are many shapes in which the blast takes place. The layout of such lines is called a firing pattern.

The sequence of detonation timing is called the firing sequence.

25.4.1 Drilling patterns

On the surface of a bench blastholes are drilled in one of the three patterns, viz. square, rectangular, and triangular. These are called drilling patterns and are shown in Figure 25.19. These should be distinguished from firing patterns.

When a blasthole is drilled in homogeneous and joint-free rock and is detonated after charging, the zone of cracking around the blasthole is circular as seen in Figure 25.20.

If such zones from two adjacent blastholes overlap, then such overlapped portion will have excessive cracking. On the contrary, if there is no gap between the two zones it will generate large pieces of rock mass. Both these situations are undesirable.

The upper drawing in Figure 25.21 shows four blastholes in square pattern. The dimensions of the square on which they are positioned are such that there is a zone of

Figure 25.18 Difference between fragmentation achieved by delay based blast and instantaneous blast.

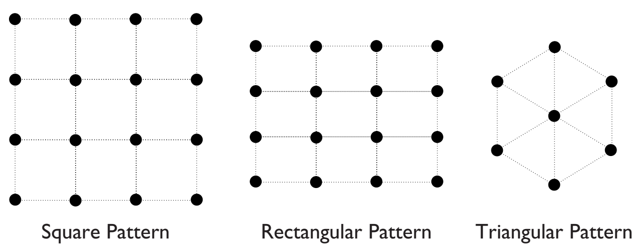

Figure 25.19 Blasthole layout patterns.

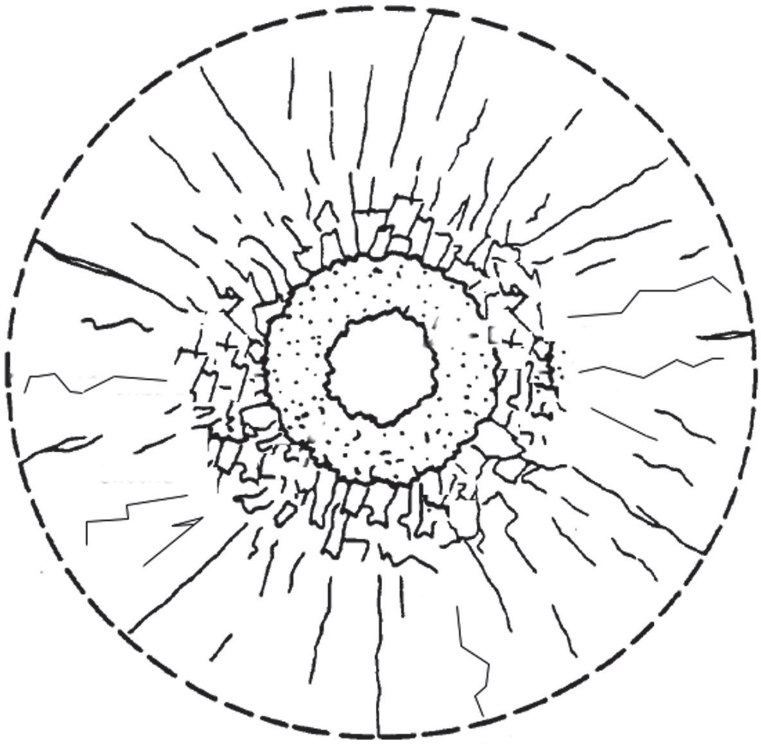

Figure 25.20 Cracking zone around a blasthole.

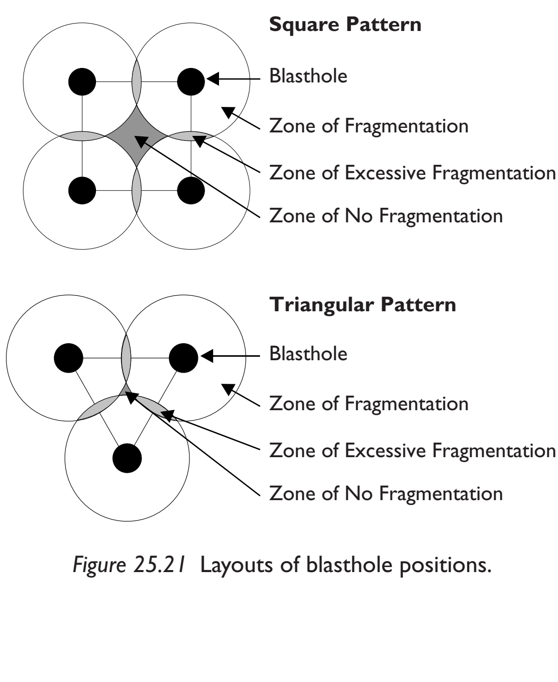

Figure 25.21 Layouts of blasthole positions.

excessive fragmentation as well as of no fragmentation. If the blastholes are brought near to each other the zone of no fragmentation will reduce and will disappear when the length of the square has a certain unique value. But simultaneously the zone of excessive fragmentation will increase. Similar is the case of a triangular pattern shown in the lower drawing in Figure 25.23. It can be geometrically shown that for each of the blastholes in square pattern the area of excessive fragmentation equals $0.570796 * r^2$ when the zone of no fragmentation disappears. Similarly in a triangular pattern the area of excessive fragmentation equals $0.181172 * r^2$ when the zone of no fragmentation disappears. This clearly means that blastholes in a triangular pattern will utilize the explosive in a better way.

Square and rectangular patterns are still used in practice, but to take advantage of the triangular pattern many times, an offset is given to the blasthole positions in adjacent rows. With this the position of blastholes becomes very similar to that of a triangular pattern as shown in Figure 25.22. Naturally, the advantages of a triangular pattern are achieved by this type of layout to a good extent.

With the ease of positioning a blasthole drill precisely by use of GPS systems, the choice of rectangular and square patterns is slowly waning away.

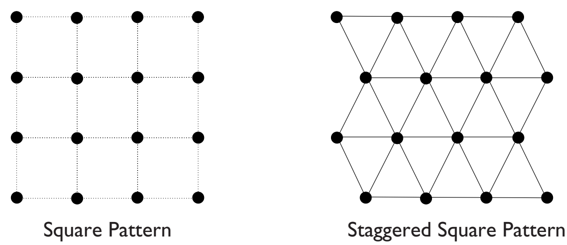

Figure 25.22 Blasthole layout staggered patterns.

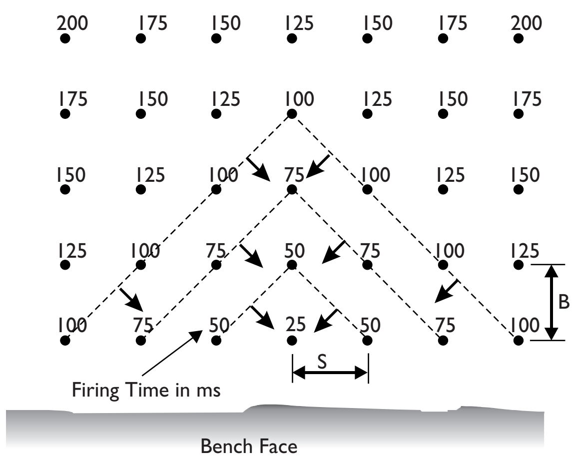

Figure 25.23 V pattern with two directions of throw.

25.4.2 Firing patterns

In large surface mines five commonly adopted firing patterns are used. They have been summarized below.

1 "V" Pattern
2 Echelon Delay Pattern
3 Flat Face Pattern
4 Channel Pattern
5 Sinking Hole Pattern

Following are the details of each of these.

25.4.2.1 "V" Pattern

This type of firing arrangement is made on either a square or rectangular drilling pattern. A typical V pattern firing arrangement is shown in Figure 25.23. The blastholes on two rows have the same delay timings. These rows make an angle of 45° with the bench face and 90° with each other. They are in V shape as can be seen from the figure and hence the name. This firing pattern is also called a chevron pattern.

V pattern is the most commonly used firing pattern in large surface mines because it has many advantages as listed below.

1 The fragments of rock are in the form of a tall heap. Material in such a heap can be easily lifted by shovels and loaded into the dumpers.
2 Since rock fragments are thrown towards each other in a 90° angle they collide with each other and further reduce in size.
3 The collision of fragments reduces the hazard of flyrocks. Sometimes, when the number of rows fired in the same blast is more than five, two centrally located blastholes in the first row are given the same delay time. The V shape arrangement of firing then takes a shape as shown in Figure 25.24. This firing pattern

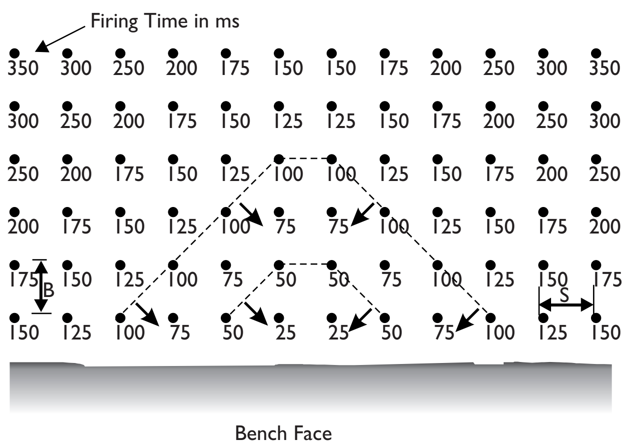

Figure 25.24 V pattern with three directions of throw.

increases the probability of collision to give even better fragmentation and throws the muck pile a little farther.

25.4.2.2 Echelon delay pattern

Echelon Delay Pattern is shown in Figure 25.25. It is sometimes referred to as half echelon pattern. It is particularly suitable for mine benches which have two free faces. This firing pattern gives a muck pile that is not flat but well spread on the bench floor. Such muck piles are suitable for loading by wheel loaders.

25.4.2.3 Flat face pattern

The flat face firing pattern is adopted when the number of rows in the blast is five or less. The drilling pattern of the blastholes is usually staggered or triangular because with such a drilling pattern the fragmentation is within acceptable limits.

When the blast is meant for getting large stone pieces to be used in a dam or breakwater, a square or rectangular drilling pattern is better suited.

A typical flat face firing pattern is shown in Figure 25.26.

25.4.2.4 Channel delay pattern

Sometimes mining activities have to start from the side of a hill. In such case there is no bench and so no bench top or bench floor. A classic excavation of this type of operation is a channel cut for some distance, made before the entry into a large tunnel. The blasted material must be made to accumulate in the blasted area where shovels can approach from one side and the dumpers also approach from the same side. For the purpose of loading muck into the dumper the shovel must slew through a 180° angle rather than the usual 100° to 120°. Under such situations the most suitable firing pattern is the channel delay pattern shown in Figure 25.27.

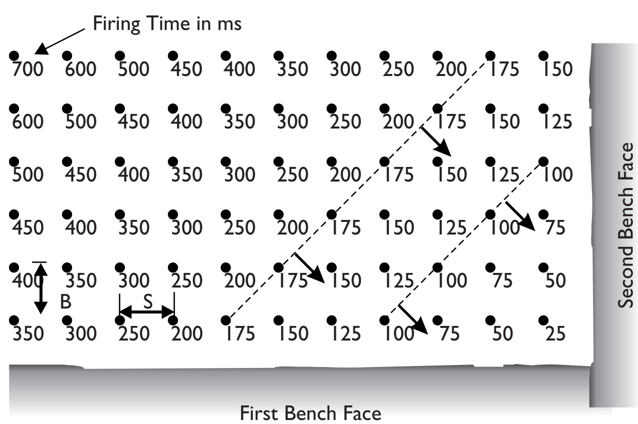

Figure 25.25 Echelon delay pattern.

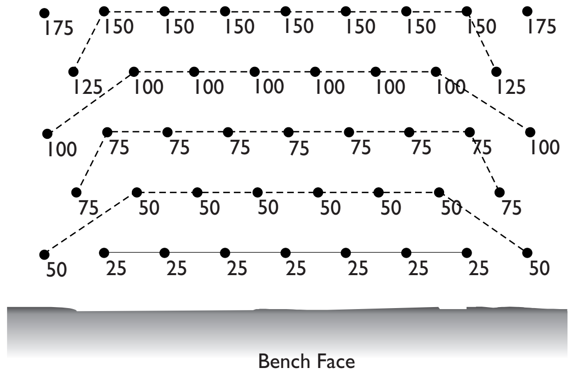

Figure 25.26 Flat face pattern.

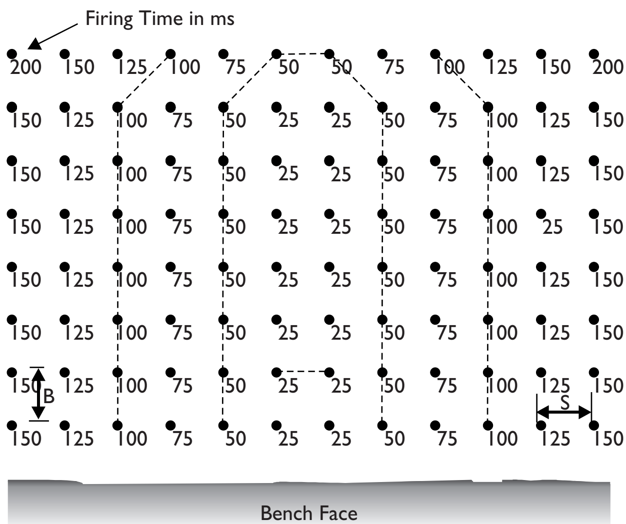

Figure 25.27 Channel delay pattern.

On many occasions in such situations the blastholes may have different depths and have to be charged very carefully. Further, the rock mass fragmented by the blast of one hole does not move to a significant distance to create space for blast of the subsequent holes. To remedy this drawback, at least to some extent, the delay interval between the rows of blastholes with the same delay is kept larger.

It is very usual to find small diameter blastholes made by small rotary percussion drills in such situations even if the mining project is to be worked with large rotary blasthole drills. Needless to say that almost all large mining projects do have small rotary percussion drills for miscellaneous jobs.

25.4.2.5 Sinking hole pattern

Many mines, particularly coal mines, are located on horizontal planes. To start a mine in such terrain, initially a huge excavation, much like the excavation for a foundation of a skyscraper, is started by blasting vertical holes. The pattern chosen for such blasts is as shown in Figure 25.28.

Blast starts with detonation of the explosives in centrally located blastholes. Later blastholes surrounding these holes, but which lie on the periphery of the diamond-shaped area, are detonated with the same delay. In this manner the blast spreads outward.

In such a blast the fragments do not move in a horizontal direction because there is no space for such movement. Naturally, movement of rock fragments in the upward direction is on a much larger scale. Ground vibrations and flyrock hazard of this type of blast is much higher than in other types of blasts with an equal quantity of explosive. To reduce both these hazards the delay intervals are kept large.

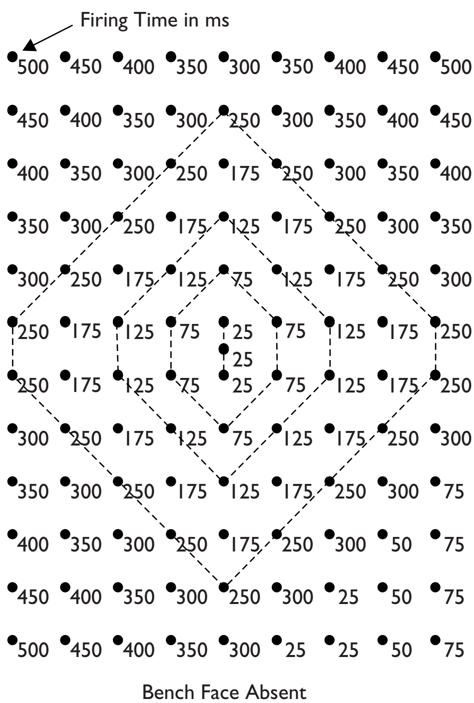

Figure 25.28 Sinking hole pattern.