UNIT 3 DRILLING AND BLASTING OPERATIONS

Structure

3.1 INTRODUCTION

Drilling and blasting are required on almost all large construction jobs to quarry the rock or remove for disposal and especially in tunneling. The various operations involved in drilling and blasting are discussed in this unit.

Rock excavation is usually done through the drilling and blasting in which suitable sized holes are drilled in the rock at proper intervals, and loaded with explosive. The explosive in then ignited with the result that the energy released due to the explosion shatters the rock. Drilling of holes in the rock, and blasting of explosive in the holes are very important operations in rock excavation. Drilling is done through air operated rock drills and explosion through blasting devices.

Objectives

After studying this unit, you should be able to

- familiarise with different rock drills,
- classify the various types of drilling jumbos,
- explain the blasting patterns for bench blasting and tunnel excavation, and
- discuss various types and applications of delay detonators.

3.2 HANDHELD DRILLS

Himdheld drills are percussion drills consisting of a hammer and replaceable steel drill bit. Drilling is done by hammering at the rate of 1800-2500 blows/min on the drill steel and turning it in the hole at one revolution per 30 blows so that the bit does not strike at the same spot each time. Exhaust air or water (in wet drilling machines), passes through a hole in the drill steel which removes the rock cuttings from the hole and cools the bit. These machines operate at 6.5 kgf/cm^2 air pressure.

The various types of handheld drills are :

(a) Jackhammer,

(b) Stopper, and

(c) Air leg or feed leg drills.

3.2.1 Jackhammers

Jackhammers are handheld air-operated percussion-type drills which are used primarily for drilling down holes in quarries or foundations or structures. For this reason, they are frequently called sinkers. They are classified according to their weight, such as 20 or 22 kgf. A complete drilling unit consists of a hammer, drill steel and bit. As the compressed air flows through hammer, it causes a piston to reciprocate at a speed up to 2200 blows per minute, which produces the hammer effect. The energy of this piston is transmitted to a bit through the drill steel. Some of the air flows through a hole in the drill steel and the bit to remove the cuttings from the hole and to cool the bit. For wet drilling, water is used instead of air to remove the rock cuttings. Figure 3.1 shows a sectionalised jackhammer with the essential parts clearly indicated. The drill steel is rotated slightly following each blow so that the points of the bit will not strike at the same spot each time.

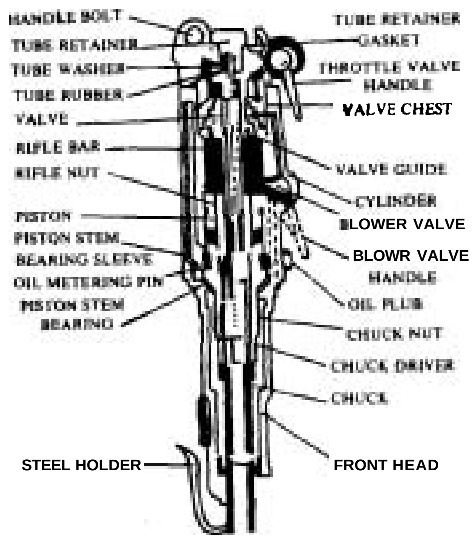


Figure 3.1 : Section through a Jackhammer

Although jackhammers may be used to drill holes in excess of 6 m depth, they seldom are used for holes exceeding 3 m in depth. However, there are instances where they have been used to drill foundation grout holes to depths of 60 m using suitable techniques. Jackhammers are not used on production work except in special cases, but they are restricted to drilling oversize muck and for spot work in reducing high grade. The heavier jackhammers will drill holes up to 62 mm dia. Drill steel usually is supplied in 600 mm length variations, but longer lengths are available. Table 3.1 gives the representative specifications for jackhammers.

Table 3.1 : Representative Specifications for Jackhammers

Weight (kgf)	14	22-25	22-32
Overall length (mm)	511	1594	1635
Cylinder bore (mm)	60	67	70
Size of steel recommended (mm)	22	22-25	22-32
Size of air hose recommended (mm)	19	19-25	19-25
Size of water hose recommended (mm)	12	12	12

3.2.2 Stoper Drills

It is a smaller surface drill that can be used in close quarters by one man with no drill mounting required. It has a thrust end to hold the drill against the work and is used for overhead drilling.

3.2.3 Air Leg or Feed Leg Drills

Air leg or feed leg drills are commonly used in small tunnels. They consist of a pneumatic drill supported on a telescoping pusher leg (Figure 3.2). Drills of this type are generally used in pairs, since, although they can be operated by one man, it takes two men to get one started. Air leg drills are also used in large diameter tunnels, but a platform or a drilling jumbo will be required or else the muck pile will be retained while drilling the upper holes.

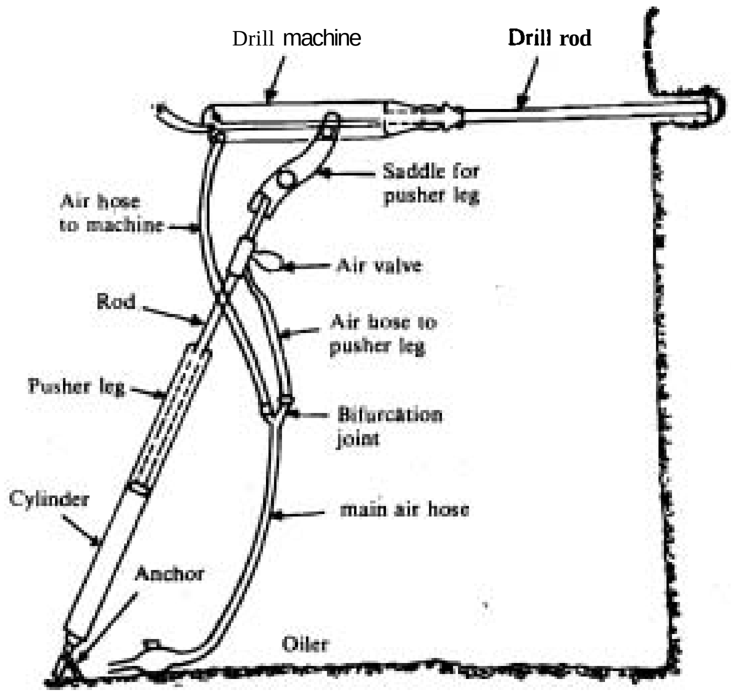


Figure 3.2 : Rock Drill with Air Leg

SAQ 1

(a) What are the different kinds of handheld drills?

(b) What are jackhammers and where are they used?

(c) What are stoper drills and where are they used?

3.3 DRILLING JUMBOS

4 drilling jumbo is a portable structure made of steel members in a shape and size such that it is capable of moving in and out of a tunnel. The jumbo provides one or more working platforms on which rock drills of the drifter class are mounted and operating

staff is able to stand and move during drilling operation. The platform decks are adequately spaced depending upon the size of the tunnel.

The jumbo is equipped with electricity feeding cables wound on suitable drums, electric lights, air receiver and connecting air lines, drill lubricators, water lines, pneumatic concrete placers and such items as hand tools, bolts and nuts, wooden wedges, steel ribs, precast concrete sleepers, etc. Proper layout of lines, electric cables and control points, as also good housekeeping on the various decks are necessary to avoid bottlenecks and delays from building up.

Air supply to the drills mounted on the jumbo comes from a compressor installation placed outside the tunnel. Compressed air mains are laid along the tunnel wall and these can be quickly connected to the distribution system of the jumbo. The lengths of the rubber hoses are usually limited to about 5 m in connecting the distribution system with the drill.

There are three types of drilling jumbos commonly used in tunnel construction :

(a) Main line drilling jumbo,

(b) Straddle type drilling jumbo, and

(c) Truck mounted drilling jumbo.

3.3.1 Main Line Drilling Jumbo

The main line type drilling jumbo (Figure 3.3) has collapsible platforms on the sides which are raised into horizontal position for drilling, charging and setting tunnel supports. The platforms are dropped to allow other equipment to pass when it is moved back from the face, and it is parked at a siding during mucking in case of it being rail type. After mucking, the mucker is moved to a siding before the main line jumbo is moved to the face.

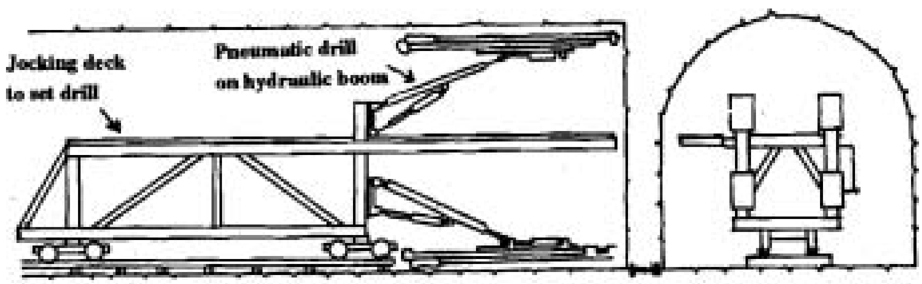


Figure 3.3 : Main Line Type Drilling Jumbo

3.3.2 Straddle Type Drilling Jumbo

The straddle type drilling jumbo (Figure 3.4) rides on wheels moving on wide track rails near the sides of the invert of the tunnel. The central platforms may be dropped to allow other equipment to pass through. Before blasting, the jumbo is moved away from the face and after mucking is over it is moved back to the face.

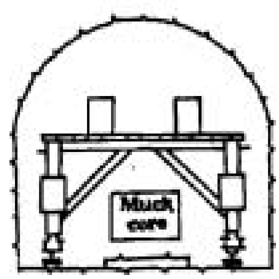


Figure 3.4 : Straddle Type Drilling Jumbo

The rail mounted jumbos, both mainline type and the straddle type, are provided with air motors for moving them with case.

3.3.3 Truck Mounted Drilling Jumbo

For short tunnels, truck mounted jumbos (Figure 3.5) which have fixed or collapsible decks are moved away after each blast to permit access for other equipment. On large tunnels, two truck-mounted jumbos, each covering half the tunnel area, are used for {drilling and are parked end-to-end during mucking to allow space for other equipment.

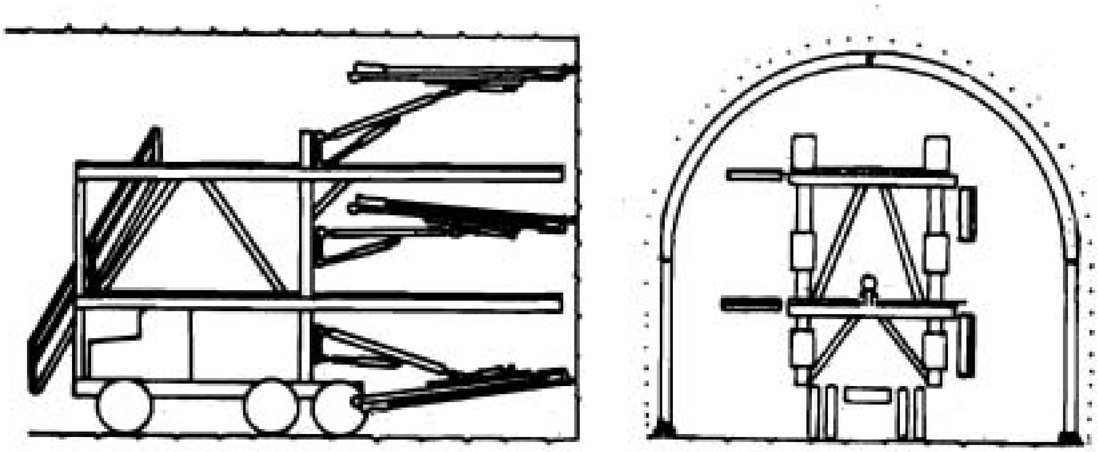


Figure 3.5 : Truck Mounted Drilling Jumbo

Rock drills have to be mounted on all the three types of drilling jumbos.

Table 3.2 gives the suitability of the three types of drilling jumbos.

Table 3.2 : Drilling Jumbos

Sl. No.	Type of Jumbo	Suitability
1.	Main line type	On small tunnels where rail mounted equipment are used
2.	Straddle type	On large tunnels where rail mounted equipment are used
3.	Truck mounted type	On very large tunnels where motorised units are used

SAQ 2

(a) What are the drilling jumbos?

(b) What are the different types drilling jumbos used in tunnel construction?

(c) What is the advantage of a straddle type drilling jumbo?

(d) Where would you recommend the following drilling jumbos?

 (i) a main line jumbo;

 (ii) a straddle type jumbo; and

 (iii) a truck mounted jumbo in tunnel construction?

3.4 DRILLING TECHNIQUES

Rock blasting is carried out by drilling holes in a particular pattern and loading them with detonators and explosives. The holes and ignition or blasting sequence are arranged according to a pattern, which is prepared in advance depending on the nature of the rock, size of tunnel or quarry, equipment in hand and the method of excavation of blasted rock. The entire planning aims at breaking the rock in a sequence that creates a surface or opening towards which the rest of the rock is successively blasted in a certain order from all sides, so that fine fragmentation of rock takes place due to mutual collision of the blasted rock against each other. In blasting rock at the ground level a free surface is already available for the rock to break free.

Thus, drilling patterns in open or surface excavation and sub-surface or underground excavation are different.

3.4.1 Drilling Patterns in Surface Works

Figure 3.6 shows a typical drilling pattern for a surface work.

(1) Bench height, K

(2) Free face

(3) Burden, V

(4) Spacing, E

(5) Powder column

(6) Stemming

(7) Sub-drilling

(8) Working floor of cut

(9) Collar

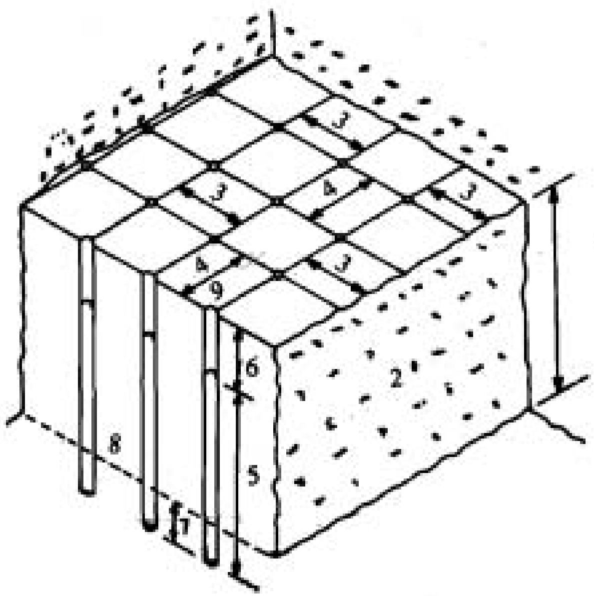


Figure 3.6 : Bench Drilling

The factors that determine the drilling pattern are :

(a) Burden,

(b) Degree of packing,

(c) Degree of fixation,

(d) Spacing of holes,

(e) Diameter of holes,

(f) Direction of drill holes,

(g) Depth of a hole, and

(h) Distribution of charge.

Burden, V

It is the most critical parameter (Figure 3.6). Its practical value depends on a combination of variable including rock constant, (C), charge per metre at the bottom and its height (h), weight strength of explosive, (s), degree of fixation, (*f*), and spacing of holes (E). The charge per metre depends on the diameter of the hole, (d), and the degree of packing (P). The relationship is given by :

$$V = \left[\frac{d_b}{33}\right]\left[\frac{Ps}{Cf\left(\frac{E}{V}\right)}\right]^{\frac{1}{2}} \quad \ldots (3.1)$$

where, V = Burden, m,

d_b = Diameter of hole at the bottom (mm), and = diameter of cartridge + 6 mm,

P = Degree of packing, kgf/dm^3,

s = Weight strength of explosive used expressed as a fraction,

C = Rock constant,

f = Degree of fixation, and

E = Spacing of holes, m.

Degree of Packing, P

As this may be 5-15% less than the true volume, the degree of packing is somewhat larger than the real density of the explosive in the hole.

Quantity of charge in kg/m of the hole,

$$l = P\left(\frac{d}{36}\right)^2$$

or

$$P = 1296\left(\frac{l}{d^2}\right) \quad \ldots (3.2)$$

where d is the diameter of the hole.

Degree of Fixation, f

It is expressed as a fixation % of charge required at **f** = 1. It is taken as 1 for full fixation, 0.75 for a free bottom. 0.8 for free face slope of 2 : 1 and 0.9 for free face slope of 3 : 1 for one row of holes (Figure 3.7).

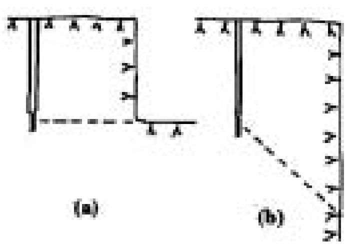


Figure 3.7 : Bench Blast with (a) Fixation at the Bottom; and (b) Free Burden at the Bottom

Spacing of Holes, E

It is dependent on the nature of rock, degree of fragmentation desired and the sequence of firing. For better fragmentation, E = 1.3 V. For considerably greater values, tearing is uneven and for considerably smaller values the throw is more. Where hole are fired singly, E = 2 V and if fired simultaneously or at very short intervals, E = 1.5 V, preferably, 1.3 V. In very hard and tough rock, spacing may be less than V. For smooth blasting or in presplit technique of blasting E < 0.8 V. ***For given conditions and charge, the value of E*** V is constant.

Diameter of Hole, d

The diameter of the hole does not in itself exercise any influence on the quantity of charge required for breakage. The diameter of the hole depends on the equipment available and on economics of drilling small size holes at closer spacing or larger size holes at larger spacing. Smaller diameter gives better fragmentation and reduces ground vibration as they require less charge. It also requires lighter equipment for drilling.

Direction of Drill Holes

Holes inclined at 10-40° to the vertical (advantageous in increasing order) have the following advantages over vertical holes in bench blasting :

(a) Greater safety,

(b) Height of bench can be increased which reduces the number of haulage levels,

(c) Increased blasting efficiency because

  (i) More energy is utilised for fragmentation,

  (ii) Resistance to breaking at the toe is reduced, and

  (iii) Percentage of bore hole which can be charged is greater.

(d) Increased burden and spacing possible,

(e) Back break is eliminated, and

(f) Causes less vibrations.

Depth of Hole, h

It depends on the capacity of the drilling equipment and the height of the bench. For manual loading in quarries, bench height is restricted to 3 m. For mechanical handling, economics of haulage levels and drilling should be worked out and the economical height of bench adopted. The depth of a drill hole should never be less than the burden, V. In practice, holes are drilled to depths varying from 1.5 to 4 times V, most common being 2.5 V. In case of nearby bedding plane, all holes' may be ended on the plane to take advantage of the weakness of rock.

Distribution of Charge, Q

For maximum blasting effect a certain minimum charge is required to be placed at the bottom of the hole and the rest as column charge (Figure 3.8).

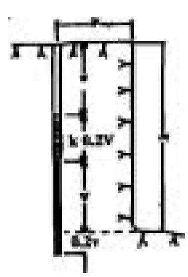


Figure 3.8 : Bottom Charge and Column Charge

SAQ 3

(a) Why does the drilling pattern differ in surface and underground excavations?

(b) What factors affect the drilling pattern in surface works?

(c) What is "burden" and what factors affect it?

(d) How is "degree of packing" defined?

(e) How would you explain "degree of fixation"?

(f) How does the spacing of holes vary with the different associated factors?

(g) What influence does the diameter of hole have in rock excavation?

(h) What advantages do inclined drill holes have over vertical holes?

3.4.2 Drilling Patterns for Underground Works

In tunnelling, a free surface has to be created known as a "cut" which is responsible in opening the rock to a depth depending on the features and the success of the cut. The holes of the cut are arranged in a definite pattern. The rock contours are maintained by using delay detonators. The main objective is to obtain proper fragmentation of the blasted rock to the full depth of the hole and the natural rock around the periphery of the intended contours is left undamaged.

A number of cuts are employed in tunnel excavation. They are – wedge cut, burn cut, fan cut, pyramid cut, V-cut, michigan or cylinder cut, line drilling, presplitting and smooth blasting

Wedge Cut

This cut removes a wedge of rock out of the face in the initial blast. The holes are placed at an angle to the face in a symmetrical wedge formation (Figure 3.9). The angle towards the working face is kept about 60°. The cut consists of 2 or 3 rows of holes forming a sequence of wedges arranged about the centre line, each breaking a similar burden of rock. In massive **unlaminated** rock it is sometimes **desirable** to drill short stab or burster holes into the face of the wedge to prevent it from coming out in large pieces. Wedge cut is generally suitable if space required is not restricted. The numbers (in the figure) denote the order of firing the explosive charge in the drill holes.

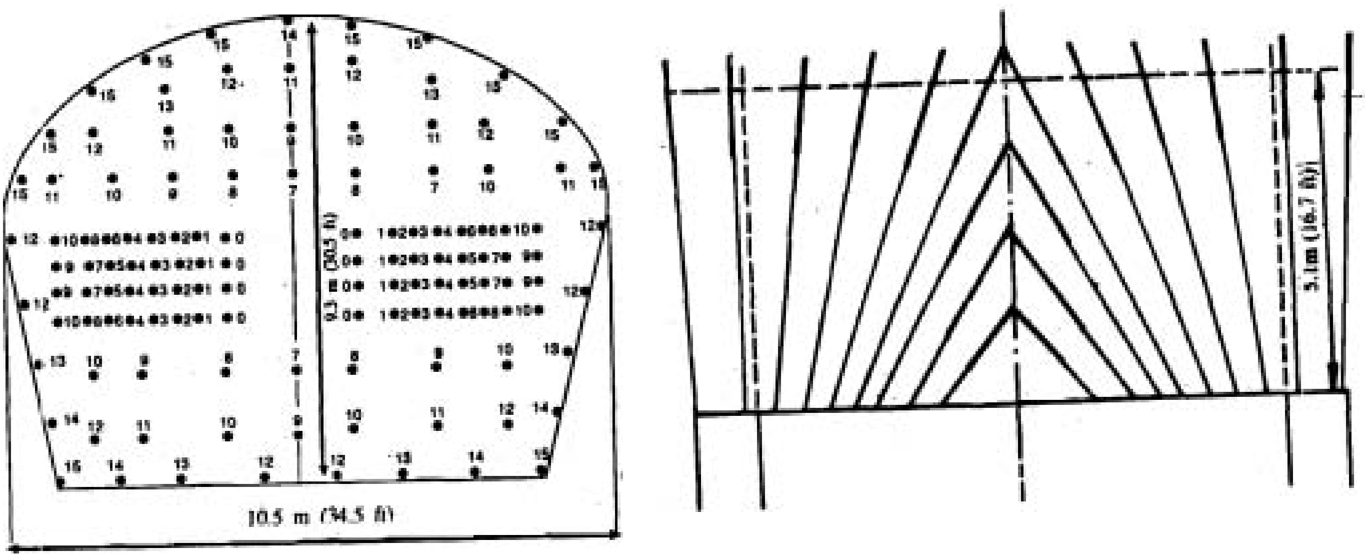


Figure 3.9 : Wedge Cut

Burn Cut

It consists of a series of holes generally spaced 10-15 cm and placed normal to the working face (Figure 3.10). A common practice is to drill 40-50 mm dia holes and charge them all. But where rock fractures readily or exhibits close jointing, it is often beneficial to leave 2 or more holes in the cut uncharged to form zones of weakness. Alternatively a larger diameter relief hole is drilled parallel and close to the normal holes and is left uncharged. It is more suitable for homogeneous rock. The total meterage drilled is more in a bum cut.

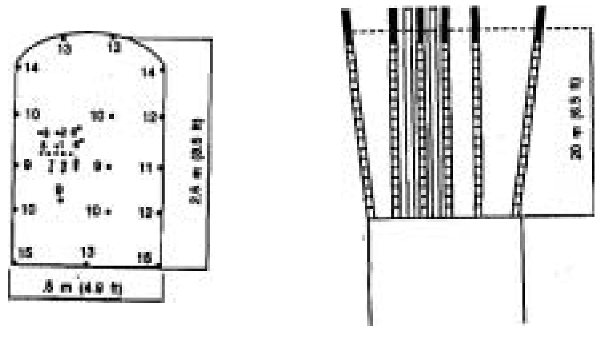


Figure 3.10 : Bum Cut

Fan Cut

It is a modified half wedge shifted to one side with cut and adjacent holes drilled into a fan shape (Figure 3.11). It is not widely used except where only one machine is employed in a narrow drivage or where the width for full wedge is insufficient, or rock is unsuitable for bum cut. It may be used in small tunnels.

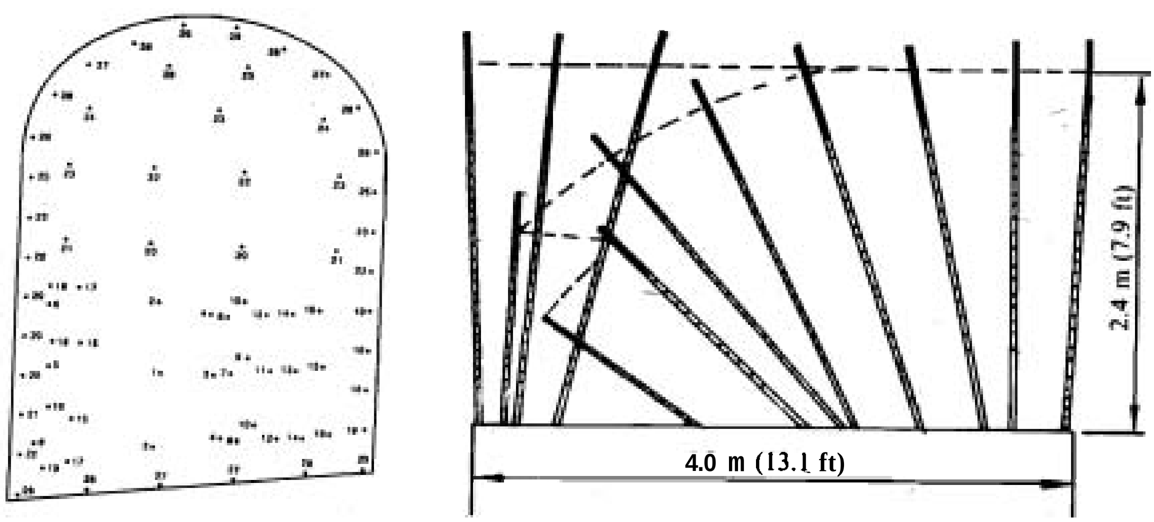


Figure 3.11 : Fan Cut

Pyramid Cut

It has the converging holes so directed that they meet at a point further in. This cut is generally used in small size shaft sinking.

V-Cut

It is similar to a horizontal wedge cut, but is suitable for tunnels of very large section – 30 to 100 sq. m. in cross-sectional area. The design of the drilling jumbo dictates the position of the cut holes.

Michigan or Cylinder Cut

In this type of dut a hole 70-100 mm dia. is drilled in the centre and left uncharged. Around and close to this hole, a series of holes forming two pentagons or two triangles are drilled. This cut entails the largest drilling meterage per cut and a heavier consumption of explosive than other types.

Line Drilling

This is done where damage to adjacent rock is to be avoided. In this the holes spaced at 10-20 cm in a line are drilled and left uncharged.

Presplitting

This is used to avoid overbreak. In this method holes spaced at 30 to 45 cm round the periphery are drilled and blasted first.

!Smooth Blasting

This is also used to avoid overbreak. It is similar to presplitting except that light charge is placed and blasted first.

SAQ 4

(a) Define a "cut" in underground drilling. What are the different types of cuts in underground excavation?

(b) How does a wedge cut remove rock from a tunnel opening?

(c) Where is a pyramid cut adopted?

(d) Where is a V-cut suitable?

(e) What is a Michigan cut?

(f) Where and how is line drilling done? .

3.4.3 Blasting Patterns

In single hole blasting the holes are drilled, charged with explosive and fired individually. This is a slow process on a large-sized project. There are more expeditious methods of blasting on large works.

In single row blasting, the choice between firing the holes simultaneously or in a sequence depends on the nature of the rock and the degree of fragmentation and throw desired. Delay firing or blasting of the series of holes gives following advantages.

(a) Better fragmentation,

(b) Reduced vibrations,

(c) Less back break, and

(d) Better control of the rock pile.

Single Row Blasting

It can be fired according to the above requirements. If delay detonators or detonating relays are used, the delay interval necessary is of the order of a few milli-seconds (Figure 3.12).

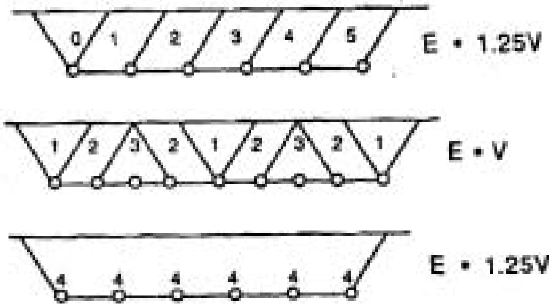


Figure 3.12 : Some Ignition Patterns for Single Row of Holes

Multi Row Blasting

In multi-row round of holes the same delay period should be taken into account while designing the ignition pattern so that every hole has a free breakage zone in its front (Figures 3.13(a) and (b)).

(a) 1 Delay per Hole **(b) 2 Delay per Row**

Figure 3.13 : Ignition Pattern in Multiple Row Blasting

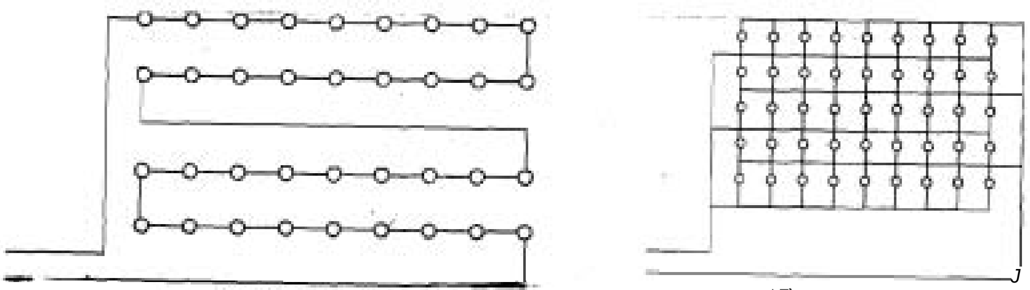
Firing the Shot Holes with Electric Current

The ends of the two lead wires of a detonator are connected with the shot firing cable. If several shots are to be fired simultaneously the electric detonators may be connected in 3 ways :

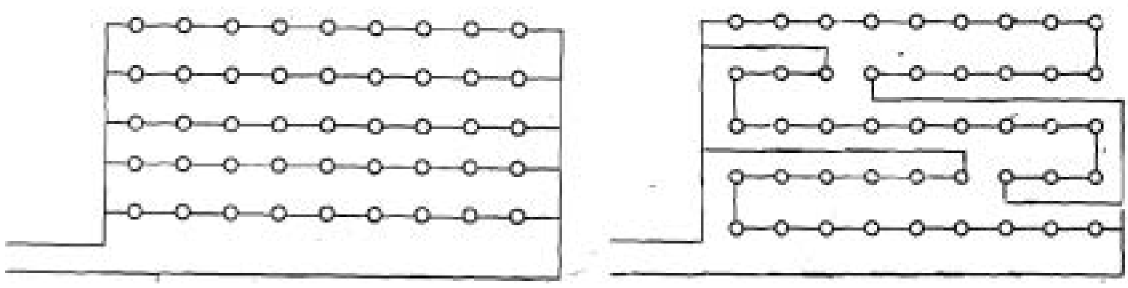
(a) Series circuit (Figure 3.14(a)),

(b) Series-parallel circuit (Figures 3.14(b) and (c)), and

(c) Parallel circuit (Figure 3.14(d)).



(a) Series Circuit **(d) Parallel Circuit**



(b) and (c) Series-parallel Circuit

Figure 3.14 : Firing the Shot Holes with Electric Current

The resistance of the firing circuit is tested with an ohm metre and if the connections are all right the shot firing cable is connected to the exploder. The key is inserted and the blast fired. The firing key is then removed from the exploder and retained by the shot firer as a precaution against accidental detonation.

SAQ 5

(a) What are the advantages of delayed firing of a series of holes?

(b) What are the two methods of blasting?

(c) In how many ways are shot holes connected and fired with electric current?

3.4.4 Delay Detonators

Detonators are accessories for a blasting operation. Detonators, also called blasting caps, are devices to produce detonation in a high explosive charge initiated by safety **fuse** or electricity. A spark **produced** by the safety fuse or electricity causes explosion of the detonator which in **turn** sets off the explosive. They are made in about 6 mm dia and 32 mm long copper or aluminium tubes closed at one end (Figure 3.15). The base of the tube has a conical shape which gives an intense local shock due to **"Murore effect".** They contain a base charge of penta-erythritol-tetra-nitrate or PETN for short. The detonator tubes are connected with 24 SWG tinned iron or tinned copper wire covered with PVC, tinned iron wire being used only **upto** 1.8 m length. The OVC is of different colours to distinguish aluninium tubes from copper tubes or short delays from long delays and so on. They are generally available in No. 6 (used in general) and No. 8 strengths. No. 6 detonators are for general purpose while No. 8 are used in cases where a more powerful detonation **effect** is required.

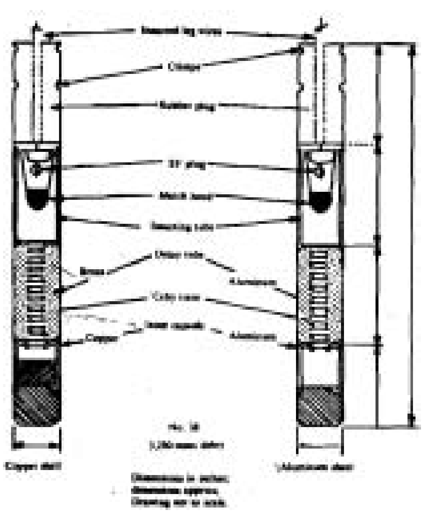


Figure 3.15 : Delay Detonator

Plain detonators store well for long periods. But, they are readily desensitised under **damp** or wet conditions. The detonators are of the following types :

(a) Plain detonators, and

(b) Electric delay detonators.

Plain Detonators

This type of detonator is the simpler one and is used for all general purposes under relatively dry non-gassy conditions and particularly where single independent charges are fired. It is detonated by a safety fuse, which is inserted into the open end as far as it will go and fixed in position by "crimping" the mouth of the tube to the fuse.

It contains a base charge with priming charge of ASA composition (lead oxide, lead sulphate and aluminium powder).

Packages contain 10,000 detonators and weigh about 20 kg.

Electric Delay Detonators

It is similar to plain detonator except that an electric bridge is provided, and the mouth of the detonator tube is sealed with a plastic plug through which pass the plastic covered leg wires (Figure 3.16).

Figure 3.16 : Electric Delay Detonator

On passing an electric current, the bridge wire becomes incandescent and ignites the priming charge. For all practical purposes, the detonator is fired instantaneously, that is, at the same time as the current is applied.

The two types of delay detonators are :

(a) Short delay, and

(b) Long delay detonators.

Short delay detonators provide a series of explosions at very short time intervals between each other. They are developed to meet exacting blasting requirements and by their use new methods of blasting techniques have been made possible. Some details of the detonators are given in Table 3.3.

Table 3.3 : Delay Detonators

Type	Delay Numbers	Normal Delay Interval (sec.)
Short delay	0 – 6	0.025
	0 – 12	0.025 between 0 and 4 nos. 0.050 between 0 and 12 nos.
	0 – 15	0.025 between lower nos. 0.075 between higher nos.
Long delay	0 – 10	0.05
	0 – 10	3.00

Electric detonators modified to suit different conditions are available in the following forms :

(a) Waterproof electric detonators which can'withstand a water pressure upto 2 kgf/sq. cm. for 2 hours,

(b) Submarine electric detonators which can withstand a water pressure upto 4 kgf/sq. cm. for 16 hours, and

(c) Seismic electric detonators which can withstand high hydrostatic pressure, having low initiation time and are manufactured in aluminium tubes.

SAQ 6

(a) Why do you require delay detonators?

(b) Where are delay detonator used?

(c) What are electric detonators? How are they advantageous over other types of detonators?

3.5 SUMMARY

Let us summarise what you have learnt in this unit.

Various drilling machines and their uses, as well as drilling jumbos, handheld drills, blasting patterns, explosives and delay detonators (used in construction practice) have been discussed. Calculations regarding bench blasting and stoping have also been discussed.

3.6 KEY WORDS

Bench Blasting : This is usually employed in quarries and while drilling downwards in large sized tunnels or other underground openings from a horizontal surface.

Bottom Charge, Q_b : It is the explosive charge at the bottom of the hole in a length of 1.3 V from the bottom.

Bulk Strength : It is the strength of a given volume of explosive compared with the strength of the same volume of blasting gelatine.

Burden, V : It is the perpendicular distance between the hole and the nearest free face in the direction in which movement is most likely to take place.

Degree of Fixation, f : It is the measure of fixity of rock at the level of the floor above which the rock is to be removed.

Degree of Packing, P : It is the quantity of charge in kgf/m^3 of the nominal volume of the hole.

Depth of Hole, h : It depends upon the capacity of the drilling equipment and the height of bench.

Fragmentation : It is breaking of larger pieces of rock into smaller pieces for convenience of handling.

Spacing of Holes, *E* : It is the distance between adjacent holes and depends on the nature of rock.

Stoping : It is drilling holes in the upward direction against gravity, charging and blasting usually employed in tunnelling.

Swelling : It is the increase in the volume of rock after being blasted.

Throw : It is the distance over which fragments of rock fly after a blast shatters the rock.

3.7 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.