SHAFT SINKING

CHAPTER 4

SHAFT SINKING

After a mineral bed has been proved, if its extraction is considered economic, a decision is taken by the planning engineers whether the mineral is to be extracted by opencast mining or by underground methods of working. To extract mineral by underground methods of working, the access may be by an incline (a tunnel from surface to the mineral bed), by an adit, or by a well which is called shaft or pit in mining terminology.

Shape and size of a shaft

Shafts are circular in shape and rectangular shafts are rare in this country, the exceptional cases being some of the shafts in metal mines. A circular shaft is best able to resist heavy side pressure and for a given cross-section, offers the least rubbing surface to ventilating air current. It is easy to sink and line with bricks or concrete. The finished diameter of a shaft varies from 4.2 m to 6.7 m.

A rectangular shaft sunk in recent years is the main shaft at Mochia Magra Mines, Zawar, Raj as than (Hindustan Zinc Limited). It is of 5.2 m x 3.8 m cross-section, vertical, 321m deep from the shaft collar with 30 cm thick concrete lining.

Shaft sinking is costly operation. The mining companies pay to the shaft sinking contractors amounts varying from Rs. 50,000/- to Rs. 75,000/- per metre of overall depth of the shaft sunk and this amount includes sinking, lining with concrete, head gear winding engine, compressors and all the machinery required for sinking and lining upto the final depth (A turnkey job). The high cost involved demands much care in selecting the shaft site. It is, therefore, a standard practice to bore a pilot hole at the proposed shaft site to have a core of the rocks. Such hole need not be at the shaft centre, but may be within 50 m radius of the shaft centre and often only one hole would serve for twin shafts. The hole gives an idea of the rocks to encounter during sinking and provides data essential for—

(1) confirmation of shall site,
(2) selection of water control methods,
(3) estimation of sinking time and costs,
(4) Design of shaft and permanent lining.

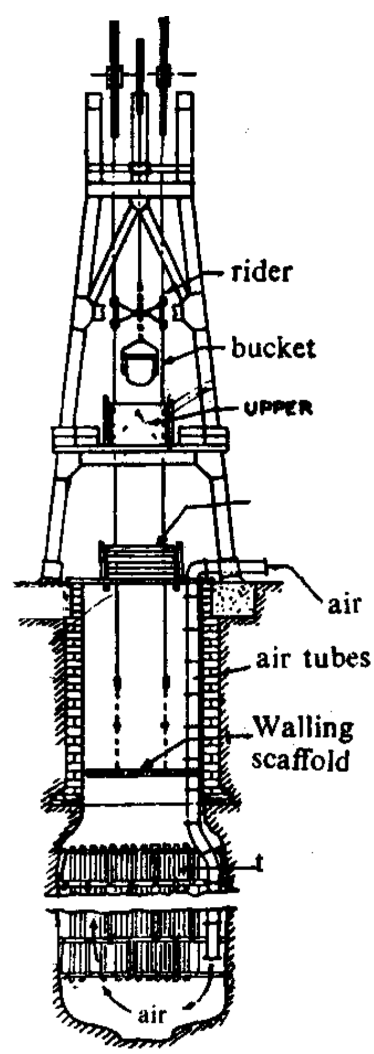
The present practice prefers holes with cores of 100 mm diameter. Such large diameter cores and holes are preferred for reasons of deviation control, good core recovery, satisfactory laboratory strength and permeability tests.

Surface plant and equipment

The surface plant and equipment required for sinking' is as follows:

1. Steam boilers or diesel engines for 'winding engine, pumps, etc. unless electric power is available.
2. Winding engines and winders fitted with locked coil ropes.
3. Steel headgear. The headgear may be of temporary nature and after the sinking is over, it is replaced by a permanent headgear and permanent winders to suit the output
4. Double drum winches for walling scaffold, and otter winches for lighting cables, shot-firing cables, pump suspension ropes and pump cables.
5. Air compressors for jack hammer drills used for drilling into rock and other compressed air operated equipment.
6. Fan of nearly 300 m3 per minute capacity.
7. Generator with diesel or steam engine for lighting.
8. Folding doors to cover the shaft top
9. Shaft centering arrangement.
10. Signalling arrangements from pit bottom to Pit top and from pit top to winding engine.
11. For disposal of debris, chutes, buckets, and tipping tubs with tramline, etc.
12. Workshop including smithy shop, mortar mill and other usual machines.
13. Lamp room, first aid room, magazine, stores, office, etc.

Special difficulties encountered during sinking would require use of additional equipment.



General Arrangement of Sinking Shaft.

The centre of shaft is marked by concrete pillars, each having u plate with centre line scribbled on it. These pillars are required always as reference marks when sinking. They should, therefore, be so placed as not to be damaged by sinking operations or covered by debris.

The strata through which a shaft has to be sunk may be divided into three groups.

(i) Sub-soil or alluvium

(ii) Hard rocks below the alluvium and above the mineral bed (generally consisting of sand stone, shale, thin coal seams, etc. in coal mining areas).
(iii) The coal seam, or the mineral bed.

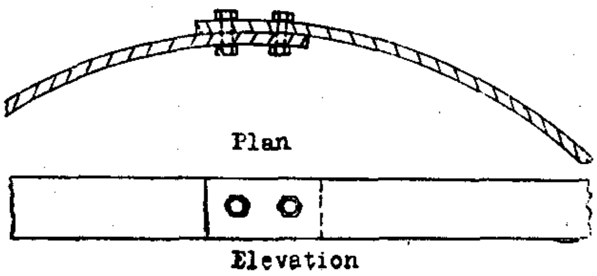


Fig. 4.1. Wrought iron curb

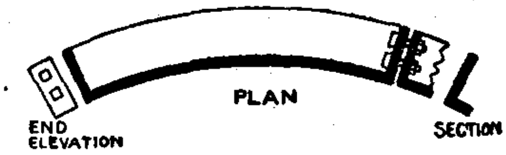


Fig 4.3. Segment of walling curb.

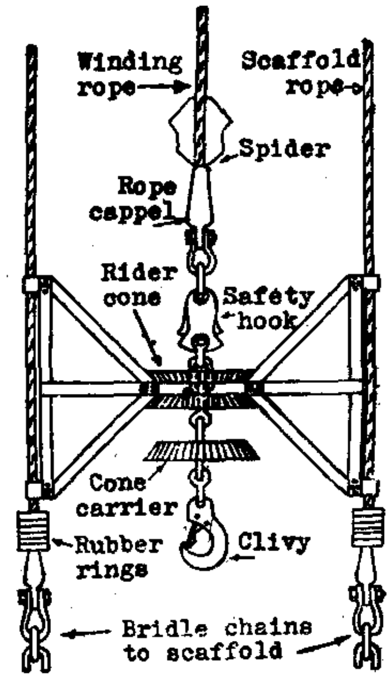


Fig. 4.6. Rider as used during sinking

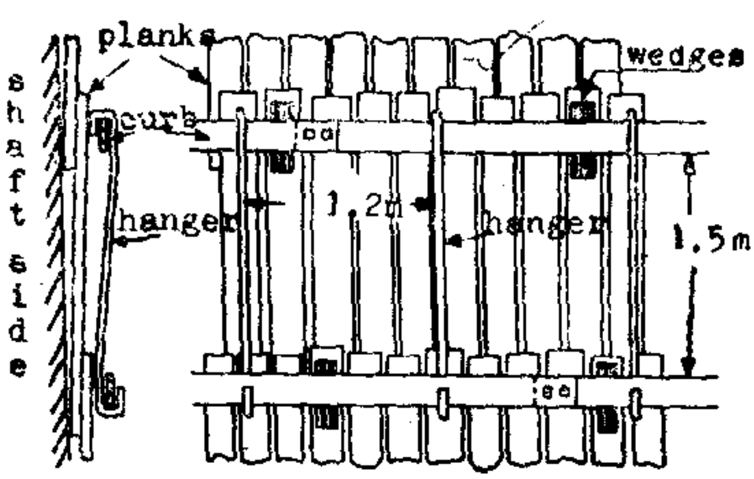
The perimeter of excavation at the surface is marked by pegs. The radius of such excavation is equal to finished radius of shaft + thickness of brick or concrete lining + a clearance of 230 to 300 mm.

The starting point of a vertical shaft at the ground surface is called collar or shaft collar. The sub-soil or alluvium and weathered rock are excavated upto the strong rock by earth cutting picks, chisels and hammers, without recourse to blasting. In most cases the thickness of such sub-soil varies from 3 m to 20 m. The excavated material is lifted to the surface through buckets hoistcd by manila rope in the same manner as practised for sinking ordinary water wells. A crane with a long jib or a grab is sometimes used for clearing the debris; a crane can be used upto a depth of 30 m.

During sinking the shaft sides are kept vertical and truly circular by a radius rod which is used to measure the radius, from a plumb wire suspended from the surface in the centre of the shaft.

Temporary lining

It is necessary to support the sides of the excavation to prevent their collapse. A heavy wooden frame or a frame of steel girders is built across the shaft top from which the first (topmost) ring of temporary lining is suspended. Alternatively the temporary lining may be suspended from strong iron spikes embedded on the surface round the periphery of the shaft. The temporary lining consists of skeleton rings (also called curb), hangers, planks of sal wood and tightening wedges. The skeleton rings are of mild steel, made in segments of 3 m in length and shaped to the circumference of the shaft. The segments are 100 mm x 25 mm in section and are joined together by fish plates or by lap joints as shown in Fig. 4.1 Before taking these rings in the excavation for support the segments are assembled at the surface and each segment numbered for assembling in its proper place in the excavation. The first skeleton ring to be inserted is suspended by chains from the steel girder frame or heavy wooden frame at the surface. The wooden planks are of sal, 2 m long, 215 mm wide and 38 mm thick and are securely held against the sides of the excavation by wedges driven between the rings and the planks (Fig. 4.2). Each ring is suspended from the ring above by hangers or S-shaped iron hooks of 25 mm diameter placed at intervals of about 1.2 m around the shaft circumference. The rings are hung at intervals of 1.2 to 1.5 m and every fourth or fifth ring is supported on plugs driveTi"7ntb"TioTes drilled horizontally into the shaft sides. Friction with the ground keeps the planks in position and cavities behind the planks are packed with wood.



Blasting should be avoided in the area where temporary lining is essential.

Permanent lining of shaft sides

When strong rock is reached, the excavation is reduced to the finished diameter of the shaft and continues thus for 3 to 4 m below. Arrangements are then made for construction of permanent lining which may be of brick, concrete or special steel tubbing. Brick walling is a common practice for ordinarily compact and moderately wet strata. Ordinary bricks of first class and well burnt quality of a size 225 mm length x 115 mm breadth x 75 mm height are used. Usual thickness of brick lining varies from 0.4 m to 0.6 m.

The hard rock from where the permanent lining- has to be commenced is made level only with picks and chisels (and not by explosives, to avoid shattering of the strata) with a projection inside the shaft side as shown in fig. 4.5 at the ledge. Sinking is usually stopped when walling is in progress. A 150 mm layer of concrete is then laid to form a level bed, the inside edge of the concrete being the finished diameter of the shaft. A bricking curb (also called crib) made of cast iron is then placed on the hardened concrete floor. The curb is made in segments as shown in Fig. 4.3 shaped to conform to the finished diameter of the shaft. Before lowering the curb segments down the shaft they are assembled-on the surface and each segment numbered. In the shaft the curb segments are assembled on the 'concrete floor, correctly centred, levelled, and bolted together, each joint being wedged against the sides of the shaft to hold it in correct position. Brick walling is then Marled above the curb and the inner surface of the brick wall is kept vertical and true to the circumference of the shaft by plumb wires suspended from 4—5 reels at the surface. As the brick walling proceeds the temporary fining is dismantled in stages. The space between the brick lining and the excavation is filled with ash, sand or loose bricks. If water percolates from the strata which have been lined, the packing allows the water to percolate and this prevents build-up of hydrostatic pressure behind the brick wall. Weep holes are left in the brick walls at the curb level during their construction for escape of such water which is collected in the water garlands at the curbs. The water is then piped down the shaft from the water garlands. The bricking curb comprising the water garland is of a special construction as shown in Fig. 4.4 and is called a "garland curb" which is required only where water percolates from the strata. Is is made in segments and one or more of the segments are provided with an outlet hole into which is screwed a nipple for 50 mm diameter drain pipe.

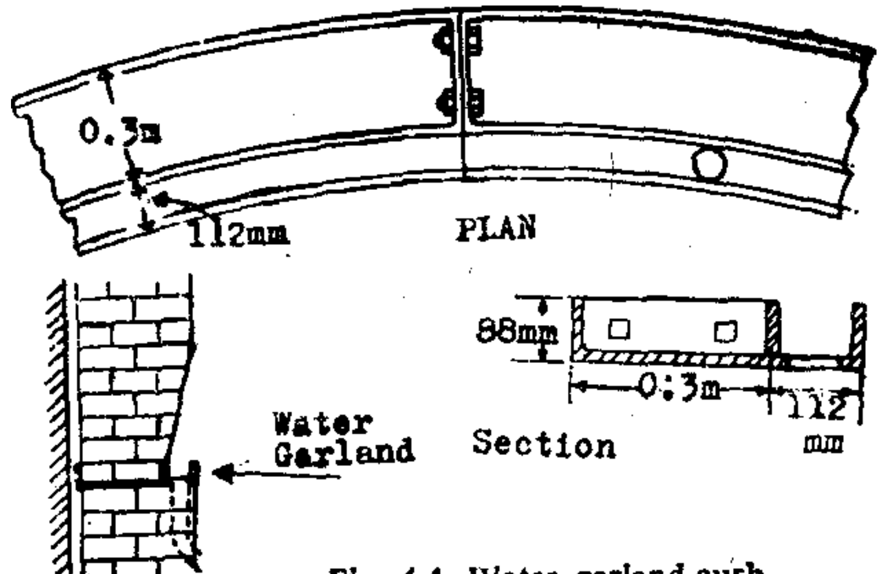


Fig. 4.4. Water garland curb

Permanent lining is generally not required where the shaft sides are of strong rock but the shafts sunk at Sudamdih and Monidih collieries and Jaduguda mine have permanent linings of concrete from the surface to the bottom of the shaft.

Walling scaffold

Construction of brick wall is carried out from a walling scaffold or platform (Fig. 4.5). This consists of a frame of sal wood having 0.3 m x 0.3 m square members covered with stout sal planks. It has an opening 2 m x 2 m square for passage of the sinking bucket. The scaffold is suspended by chains from two ropes hanging in the shaft, one on each side of the winding rope, and it is raised or towered by a double drum winch (or alternatively two winches) to which the scaffold ropes (locked coil) are taken. The diameter of the scaffold is slightly less than the finished diameter of the shaft. Four sliding bolts are used to keep the platform steady when use, and the bolts are pushed on to the top of the brickwork or into vertical recesses cut in the brickwork. About 1.3 m of walling is completed from one position of the scaffold.

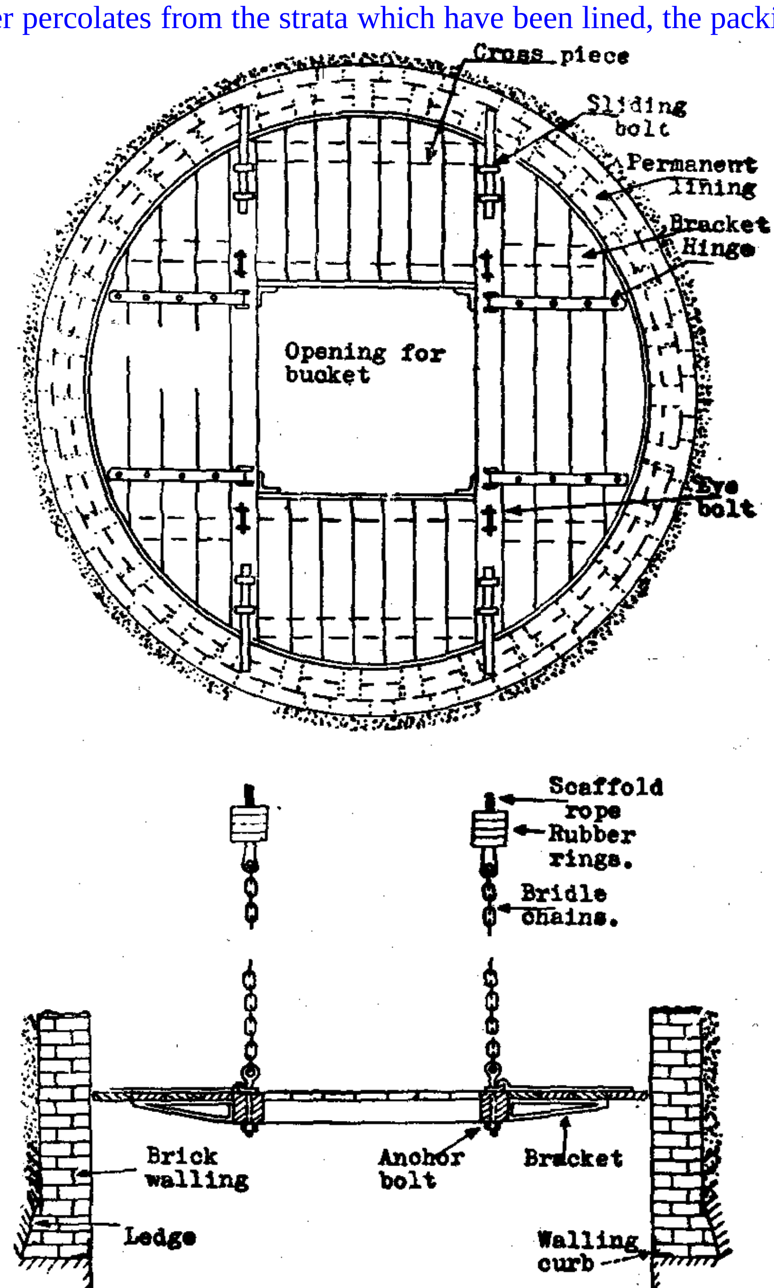


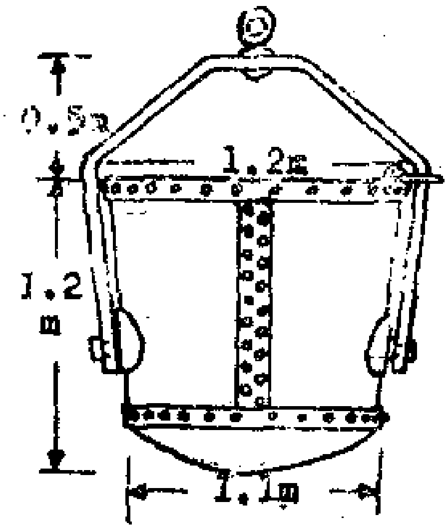
Fig. 4.5. A bricking Scaffold

In the shaft sides buntons have to be fixed at intervals of 9 m to 16 m for support of cables, water delivery pipes, compressed air mains, etc. The position of buntons where they are to be fixed in the permanent lining is marked by plumb wires suspended from the surface and holes are left in the lining for fixing the buntons.

Walling scaffolds have been designed which allow sinking and walling operations at the same time. These were used in the shaft sinking at Sudamdih and Monidih collieries, described later.

Rider

It is not a common practice to use guide ropes in a sinking shaft, and to prevent undue swinging of the bucket during its travel, a rider is used in addition to the use of a locked coil rope for winding (Fig. 4.6). The rider runs on the ropes supporting the walling scaffold and guides the bucket during its travel. The rider cone is so through it. When the bucket has to be lowered below the walling scaffold, the rider rests on the cappels of the scaffold ropes, and the rope passes down through the rider cone, guided by a loose guide sheave called the spider. The spider is so constructed as to collapse when passing through the detaching plate at the headgear in case of an over wind. The rider serves its purpose only between the bricking scaffold and the surface. It enables a bucket to be raised and lowered at a much greater speed and with greater safety than if no rider is used.



Drilling and blasting in a sinking shaft

The bard rock in a sinking pit is blasted with explosives after holes are drilled. The shot-holes are arranged as shown in the fig. 4.7. As a thumb rule it may be stated that the number of holes in a ring is three times the diameter of the ring in metres. The holes are drilled by hand-held jack hammer drills operated by compressed air. A jack hammer operates at air pressure of nearly 6 kgf/cm^2. The supply of compressed air to the drill is by rubber hose pipe connected to the compressed air main which is nearly 100 mm diameter and supported at intervals in the shaft, Usually 2 to 3 drills, each consuming nearly 3 m3 of free air per minute work at a time in a shaft of 6 m diameter. The holes are 38 mm diameter and 1.2 to 1.5 m deep. A hole, after it is drilled, should be plugged with wooden plugs to prevent entry of sludge. Gelatinous high explosives like Ajax G are used in sand stones and shales and special gelatine may be used in very hard rock like that of a sill. A hole 1.2 to 1.5 m deep, may require 0.6 to 0.9 kg of explosive charge.

Low tension detonators are employed for blasting. The holes need no stemming as the water in each hole acts as a good stemming material, though sometimes the drill cuttings are utilised for more effective stemming.

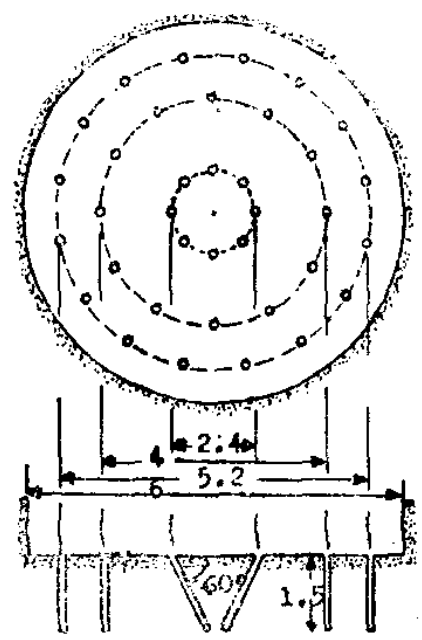


Fig. 4.7.

Blast holes in a sinking shaft.
(All the dimensions are in metres)

Blasting of the inner ring is to be carried out first and all the shots in the ring are connected in series. Before blasting, the equipment, lights, etc. which are likely to be damaged, are removed to the surface or raised high above the bottom of the shaft. The shots are connected to a shot firing cable which is suspended from a reel at the surface. Alf men are withdrawn, the folding doors closed, and the shots are fired electrically from the surface by a hand operated heavy duty exploder. Blasting by tapping current from electric power lines is permitted by DGMS under certain conditions and was practised in Sudamdih shaft sinking.

When the debris resulting from the blasting of inner ring is being cleared up, holes of outside sumper ring are charged and in this manner the blasting of all the rings is carried out. Blasting and clearing up debris of all the rings gives a progress of nearly 1.2 m if the inside sumper holes are 1.5 m deep.

Clearing up debris

The debris is removed to the surface by a bucket (also called kibble, bowk or hoppit) (Fig. 4.8) A fork catch in the shape of a U keeps the bucket upright relative to the bow. The trunion axis is low so that when the loaded bucket is suspended and the fork catch turned back the bucket tilts itself discharging the contents. The bucket is attached to the detaching hook of the winding rope through a clivy and bridle chains. Two buckets are generally in use, one at the pit bottom for getting loaded and the other which may be in transit, or at the pit top, getting unloaded.

The debris is cleared at the surface through a chute into which it is unloaded from the bucket. V doors are sometimes used at shaft top so that the bucket, when hoisted slightly above the opened doors and then lowered to rest on the closed doors is automatically tilted if the fork catch is turned back. In another method a worker with a long hook stands on a platform built in the headgear over the chute. When the bucket comes to the surface, he catches the clivy with the hook and the winding rope is slightly slackened as the worker pulls the bucket with the hook towards the chute. In this case the chute is not above the shaft opening but to one side.

Shaft centering arrangement

The vertically and radius of the shaft are checked from lime to time, usually once every day. At the time of such checking plumb wire is suspended from the surface in the shaft and the radius is measured by a light wooden radius rod. The usual arrangement is as shown in fig. 4.9.

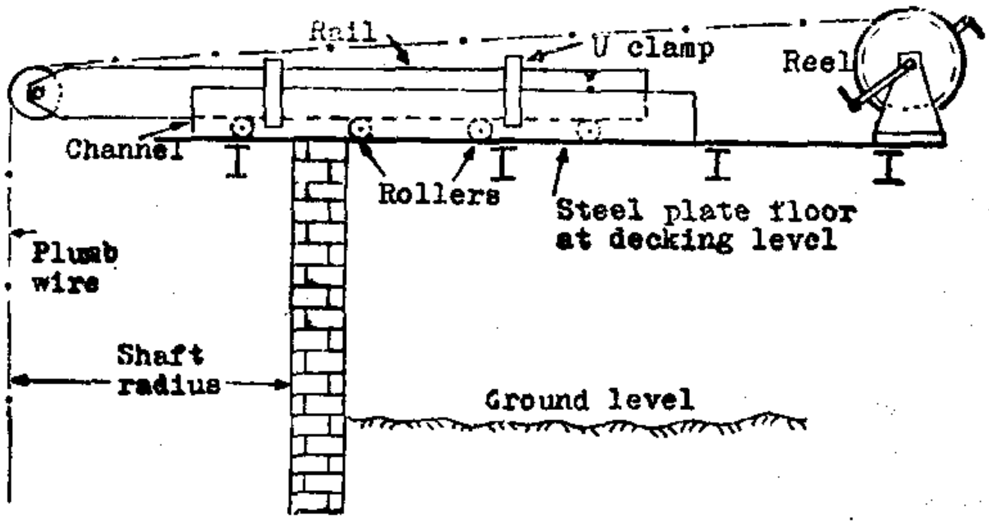


Fig. 4.9. Shaft centering arrangement.

At the decking level, riveted to the steel plates of the floor, is a channel with clamps in which a light section rail can slide on rollers. The clamps prevent overturning as well as lateral movement of the rail. At one end of the rail is a pulley over which piano wire from a reel can pass. On the rail and the channel there are two marks which coincide when the wire on the groove of the pulley attached to the rail is exactly in the centre of the shaft. When lowering the plumb wire, a light plumb bob is attached to it but it is replaced by a heavier one of nearly 18 kgf at the shaft bottom.

When checking of verticality and radius is completed, the plumb bob is raised to the surface and the rail withdrawn. The whole arrangement may be provided at the ground level where there may be no disturbance due to sinking operations.

Dealing with water

Where the make of water in the shaft exceeds about 100 litres per minute, pumps are used. For smaller make of water the bucket used for debris may be convenient. It is filled by a small pump and then emptied at pit top. Centrifugal pumps are commonly used to dewater the shaft and pump may discharge water right at the surface. The common practice, however, is to install a semi permanent pump in the excavation in the shaft side (called inset) and the small pump at the shaft bottom delivers the pit water to it. This arrangement is adopted when some of the permanent lining of the shaft is completed as the delivery column of the main pump (installed in the shaft side) can then be supported on permanent buntons.

Sinking pumps which are suspended from the surface by power-operated winches are also used. These are of the centrifugal type with a maximum of eight stages. In the initial phase of sinking only one or two stages are utilised and the rest replaced by dummy impellers. As the depth increases, further stages are added. For a deep shaft, the delivery column of a sinking pump is supported on buntons fixed permanently in the shaft sides and the bottom-most connection to the delivery range from the pump is made by a flexible hose pipe. The suction of the pump is a flexible armoured hose fitted with a retaining valve and a strainer.

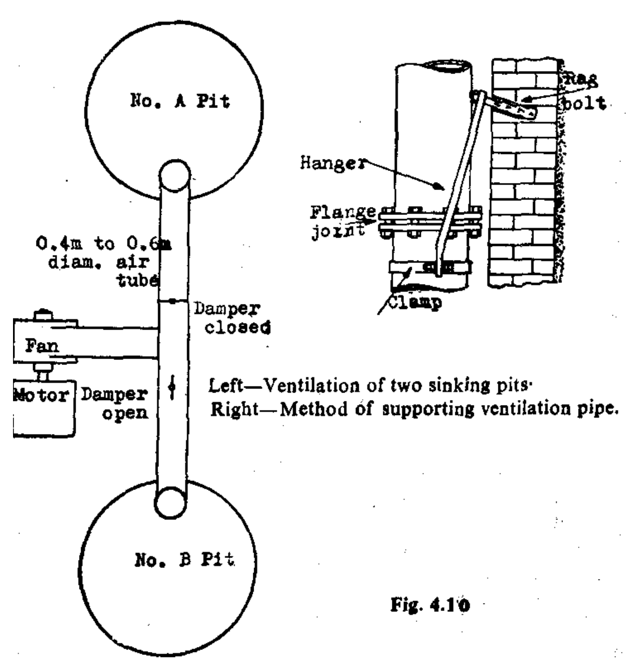
Ventilation.

In a shaft exceeding nearly 25 m in depth, ventilation during sinking is produced by a mechanical Ventilator which is commonly a forcing fan of 300 m3 per minute capacity. The air tubes are of sheet iron, nearly 0.6 m diameter, suspended from the shaft side, as shown in Fig. 4.10. The bottom-most length of air tubing is a canvas hose.

Lighting

The workers use electric cap lamps, but the shaft bottom is illuminated by a cluster of 4 to 6 bulbs, each 100 watts and 110 V.

The cluster is supplied power through an armoured cable suspended from a cable reel at the surface.



Left—Ventilation of two sinking pits.
Right—Method of supporting ventilation pipe.

Fig. 4.10

Permanent concrete lining

Concrete lining used for support of shaft sides is of two types:

1. Reinforced concrete lining, and
2. Monolithic concrete lining.

Reinforced concrete lining is costly and is used where high pressures have to be resisted. Concrete lining is stronger than brick work, offers less frictional resistance to air current, and can be erected rapidly. It is, however, difficult to repair and due to its rigidity may crack and collapse with slight earth movements. For monolithic concrete lining, concrete in the proportion of 1:2:4 (fresh cement:sand:coarse aggregate) is suitable for dry shafts. For wet shafts, richer mixture is preferable.

To construct monolithic concrete lining, the hard rock from where lining is to commence, is dressed and levelled in the same manner as for brick lining to provide a base. When erecting the lining it is necessary to retain the wet or plastic concrete in position by a shuttering. This consists of segments of sheet steel nearly 1 m high, curved to suit the circumference of the shaft and having angle iron riveted to them for bolting together adjacent segments. The first ring of shuttering is carefully centered and levelled. Back side of the shuttering which will be in contact with concrete is greased for easy withdrawal after setting of concrete which is poured and ramded hard behind the shuttering.

Further shutterings are added and the concrete poured and rammed hard till the process builds up the lining upto the base of walling constructed higher up. Temporary lining is removed as the successive rings of shuttering are built up. The shutterings have to be left in position for several days until the concrete sets. Where the percolation of water from the strata is not insignificant, precautions have to be taken to prevent the water from washing the cement out of the concrete before it has time to set and this may be done by use of C.G.I, sheets as back sheeting. The C.G.I, sheets may be bolted or nailed on strips of wood about 40 mm thick which act as distance pieces to keep the sheets away from the shaft sides. The water percolating behind the back sheeting is taken through vertical pipes and discharged into the shaft. The space between the shaft sides and the back sheeting is filled with gravel. Once the concrete sets, holes are drilled into the gravel through pipes left in the concrete for the purpose. Liquid cement is then injected to seal off the water completely.

The concrete used for lining is sent down the shaft in a specially constructed bucket which has a bottom door for discharging the concrete on to a chute fixed over the walling scaffold. Through the chute the concrete gravitates into the place behind the shuttering.

Cast iron tubbing

A cast iron lining known as tubbing is used as a permanent watertight lining of shaft sides in case of water bearing strata containing water at high pressure. The water bearing strata may have several feeders of water at various depths and these have to be sealed by several independent lengths of tubbing, each made watertight at the top and bottom. It is also used as a permanent lining where running sand is encountered during sinking.

There are two types of cast iron tubbing:

1. English tubbing, and
2. German tubbing (Tubbing plate shown in Fig 4.11)

In both of these types the tubbing is built up of C.I. rings and each such ring consists of a number of flanged segments, shaped to suit the curvature of the shaft. A tubbing plate is strengthened with cast ribs and flanges. The German tubbing is preferred. The thickness of tubbing depends on the water pressure it has to withstand.

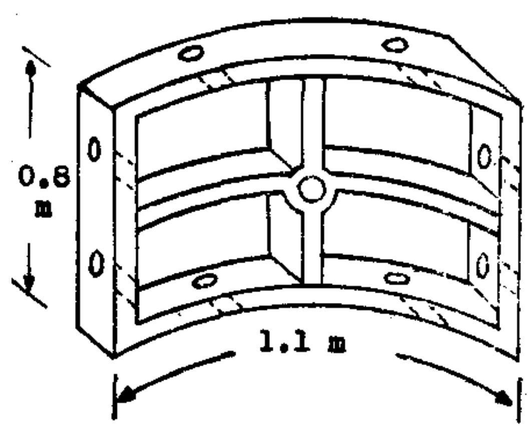


Fig. 4.11 German tubbing plate

Construction of German tubbing upwards

A base for a wedging curb is prepared in good, strong levelled ground over which a cast iron wedging curb is carefully laid. It is carefully centered, levelled and wedged in position. The tubbing plates are then lowered, one at a time, by the winding rope, and slewed by the workmen into position on top of the curb. Each plate is bolted to the wedging curb. When a complete ring of plates is placed at site the position of each joint is measured from the centre line and the plates suitably adjusted to conform to the circumference of the shaft. The gap between the flanges is packed tightly with lead sheeting and the bolts of the flanges tightened. Quick setting concrete is poured and rammed behind the tubbing and another ring is built on top of the previous one. Additional curbs are laid, according to the nature of the strata, at intevals of nearly 20 m.

Construction of German tubbing downwards

German tubbing constructed from top downwards is known as "Underhung Tubbing". For building underhung tubbing an inverted wedging curb or anchor ring is placed above the waterbearing strata and the tubbing suspended therefrom (Fig. 4.12). A ring of tubbing comprising the required number of tubbing plates to suit the circumference of the shaft is inserted as soon as sinking proceeds sufficiently below the wedging curb to accommodate the ring. As the sinking proceeds, the tubbing can be constantly maintained within 1.5 to 1.8 m of the shaft bottom. Each plate' has a hole cast near the bottom (or at the centre) for pouring cement or concrete to fill up the space behind the next lower ring of tubbing. A horizontal retaining plate, made up in segments, is bolted to the lower flange to retain the cement or concrete in position until it sets. After the concrete sets behind the complete ring of tubbing a drill is inserted to clean out the hole which is then utilised for filling the space behind the next lower ring of tubbing. The process continues till the water bearing strata are passed through.

With underhung tubbing the advantages are:

1. Tubbing is done downwards. No temporary supports are, therefore, required.
2. No scaffold is required for its insertion.
3. Simultaneous sinking and strata support are possible.
4. Feeders of water can be promptly sealed by tubbing as they are met during sinking. This reduces pumping cost.

The thickness of tubbing plates is increased after every 13 to 15 m. Tubbing plates of special construction are used for reception of bunions where they have to be fixed in the shaft sides.

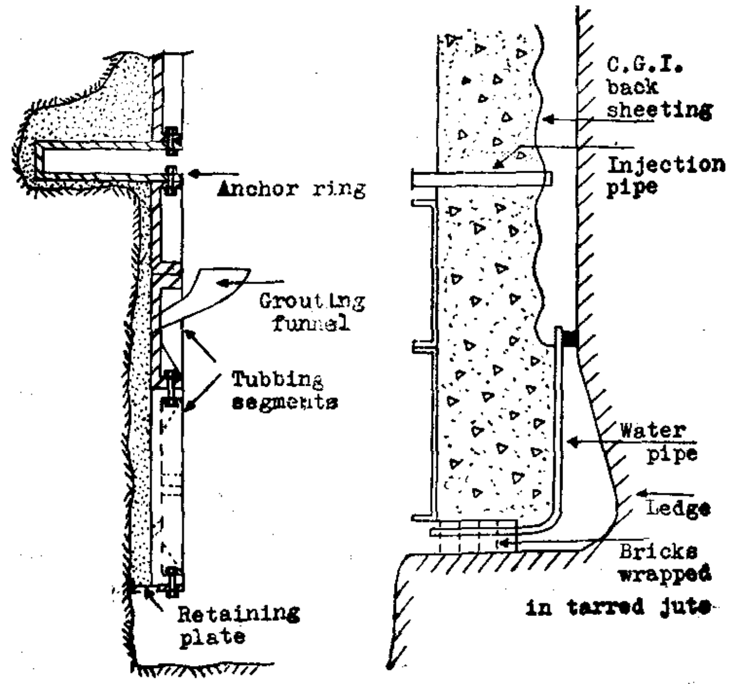


Fig. 4.12. Left—Underhung tubbing
Right—Concrete lining of a sinking shaft.

Upward drivage of shaft

It is sometimes necessary to drive a shaft upwards and such occasions are common in metal mining practice. Upward drivage may be carried out for a distance of upto 15 m and because of the difficulties involved, great care and experience are necessary to execute the work. A vertical shaft which joins two underground roadways but does not extend upto the surface is known as a staple pit.

At the proposed site of the pit a bypass is first driven (Fig. 4.13). The roof is then blasted down for a few metres and girders or wooden beams are placed across the gallery width to divide cross sectional area of the staple into three compartments, A_1, A_2 and A_3 The compartment A_1 which is larger than the others, serves the purpose of collecting rock dislodged after blasting and also as a platform on which the workers can stand. In the middle compartment A_1 thick wooden planks are attached vertically to the girders or wooden beams. Compartments A_2 and A_3, course the ventilating air current which is taken from one compartment, A_2 or A_3, across the top of the compartment A_1 and then to the other compartment,

In the compartment A_2 or A_3 a ladder of angle iron and mild steel rods is placed for the workers to ascend to or descend from their work site which is the top of compartment A_1; a winch is placed at the bottom of the staple for taking up materials to the top of the compartment A_1.

To maintain verticality of the shaft two iron plugs P_I and P_2, each marked with punch, are driven into the floor. A light wooden rod, slightly shorter than the diameter of the staple, is similarly marked and the centre of the shaft, which corresponds to midpoint between P_I and P_2 is also marked upon the wooden rod. When a pair of new wooden beams is placed in position the wooden bar is kept horizontally across them. Two plumb fines are suspended over the plugs P_I, P_2 and the midpoint of the wooden rod gives the centre of the staple pit which is then marked on the roof.

Figure 4.13 shows a staple in course of drivage. Holes 1 m deep are drilled by workers in the roof of the staple standing on the debris of compartment A_1. Before blasting, the top of the compartments A_2 and A_3 is protected by slanting timbers. Shots are fired electrically from a safe place in the roadway. The debris fills up the top of compartment A_I and the surplus debris is thrown by workers down the compartments A_2, A_3 for further disposal. A pair of wooden beams and vertical planks are fixed in position on top of A_1 when the place is sufficiently advanced.

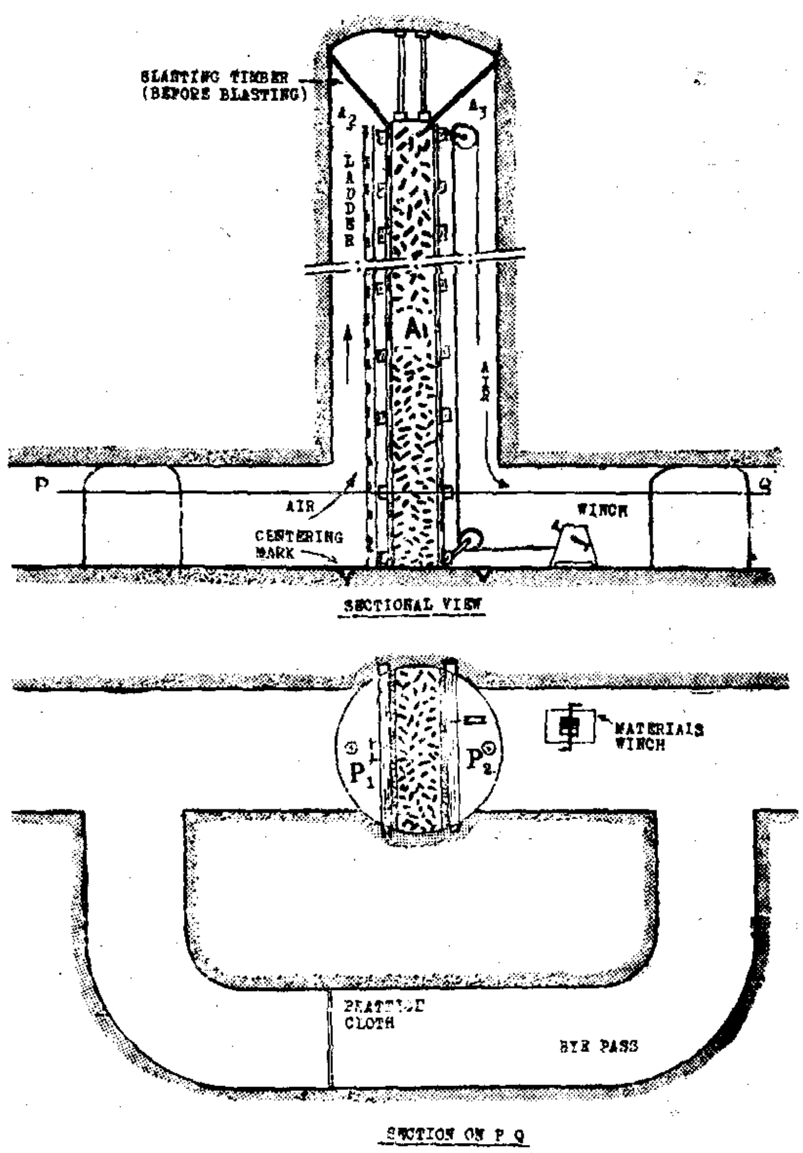


Fig. 4.13. Upward drivage of shaft

When the staple reaches the upper seam or level the debris in compartment A_1 is cleared up, commencing from the bottom of the column of debris. The wooden beams and planks are then removed to clear up the staple pit,

Special methods of sinking

Ordinary methods of shaft sinking are not suitable in some cases and special methods have to be adopted under the following conditions:

1. Loose or unstable ground, such as sand, mud, etc.
2. Excessively watery strata.
3. A combination of the above two.

The special methods are as follows:

The Piling system

This method is known as simply "piling" or "sheet piling" and is suited for sinking through loose deposits of sand, mud, or alluvium neat the surface upto a depth of 20 m. Interlocking steel piles, 6 m to 10 n long, are used and they are practically water-tight. Additional lengths may be available by welding or riveting two or three lengths of piles. At the surface, the piles are set up to form a ring and then they are hammered down in rotation, each member being driven a few metres at a time by a direct-acting steam piling hammer. {Fig. 4.14). As the piles descend in the loose ground, the latter, enclosed by the piles, is excavated and cleared up, but it should be remembered that the bottom ends of the piles are kept sufficiently ahead of the excavation to prevent inrush of water or loose sand. When the excavation reaches strong rock, permanent lining is constructed and the sinking then proceeds in the manner already described for normal conditions.

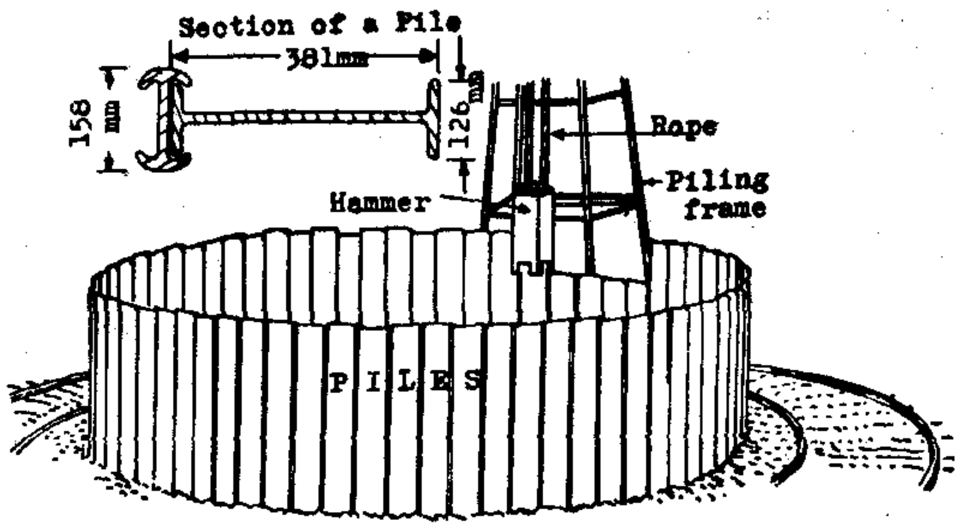


Fig. 4.14. Piling.

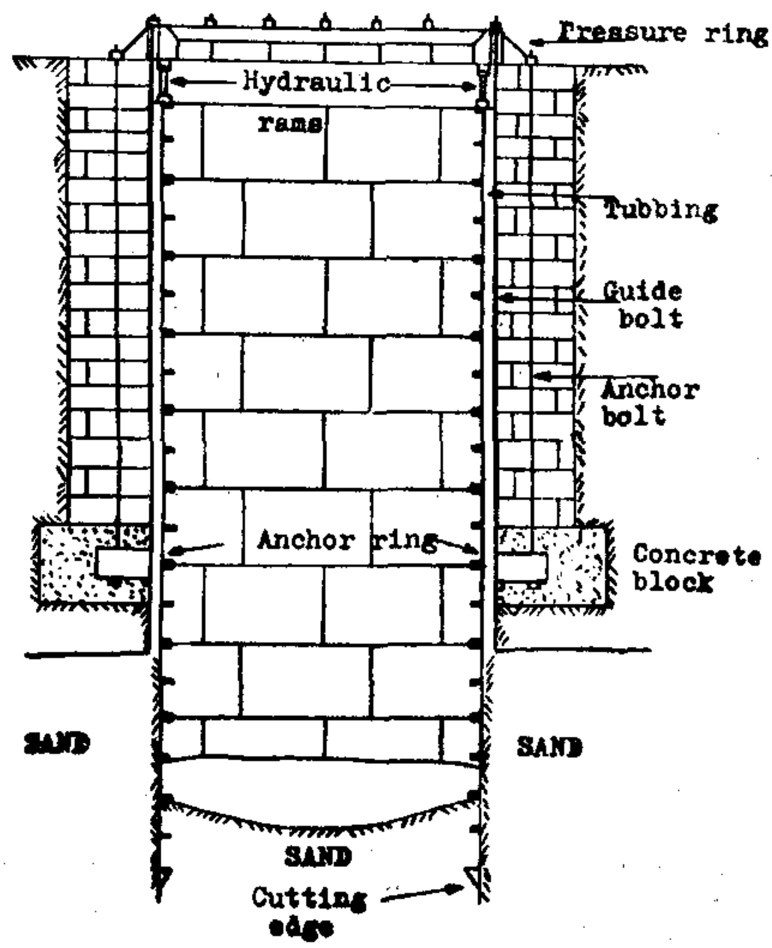


Fig. 4.15. Forced drop shaft

Caisson methods

The methods can be divided into three classes.

(1) Sinking drum process or open caisson method

This consists of a cylindrical well of brick work, 0.3 m to 0.4 m in thickness over a m. s. ring having a steel cutting shoe. The shaft is excavated and the drum sinks down gradually by its own weight. As the drum sinks down, further brick work is added on the top. A compound sinking drum consisting of brick work surrounded by 13 mm thick steel plates is sometimes used to resist uncertain tensile stresses. Concrete sinking drums also can be used. Care must be taken to see that the drum descends vertically and with this object additional weights may be placed over the drum.

(ii) Forced 'drop shaft method

This is commonly adopted where the strata consist of alternate tough and loose ground and also when the drop shaft refuses, to sink further due to very high skin friction. In these cases sinking is carried out with the help of hydraulic rams which force down the cast iron drums. This method can be used for depth upto 60 m (Fig. 4.15)

(iii) Pneumatic caisson method

This method is adopted when there is a danger of ground filling up the shaft or where there is considerable inrush of water under a small head. Compressed air is led into the chamber formed by means of a partition, 1.8 to 2 m above the cutting shoe, compressed air keeps back the water and sand. An air lock is mounted on top of the partition as a passage for men and material. The limit of the pressure of the air is 4 kgf/cm2 beyond which persons cannot work. This method cannot be used for depths of more than 30 m.

These caisson methods are commonly adopted for the construction of foundations for bridges, tall buildings, etc.

Freezing method

This method is used when the sinking is proceeding through an unstable or friable stratum with heavy inrush of water, or sand connected with inflow of water and "essentially involves the formation of a large block of frozen ground in the water-bearing strata. The frozen block prevents the influx of water into the shaft. The whole process can be divided into three operations.

1. The first operation consists of drilling holes, usually 150 mm diam. at 2.2 to 3 m intervals around the shaft from the surface or from a fore shaft. The holes, after drilling, are to be lined with special tubes and care should be taken to see that all the holes are vertical.

2. Inside the holes special small tubes are inserted to enable the cold brine (solution of $CaCl_2$) to be circulated. Cold brine, while circulating in the holes, extracts the heat from the surrounding strata and the circulation of brine is continued till a wall of ice of sufficient size is formed. Sinking and lining is carried out in the normal way after the formation of ice wall.

3. The third and final operation is thawing which consists in removing the ice wall by sending hot brine through the existing holes.

This method is very rarely used in India.

Cementation process,

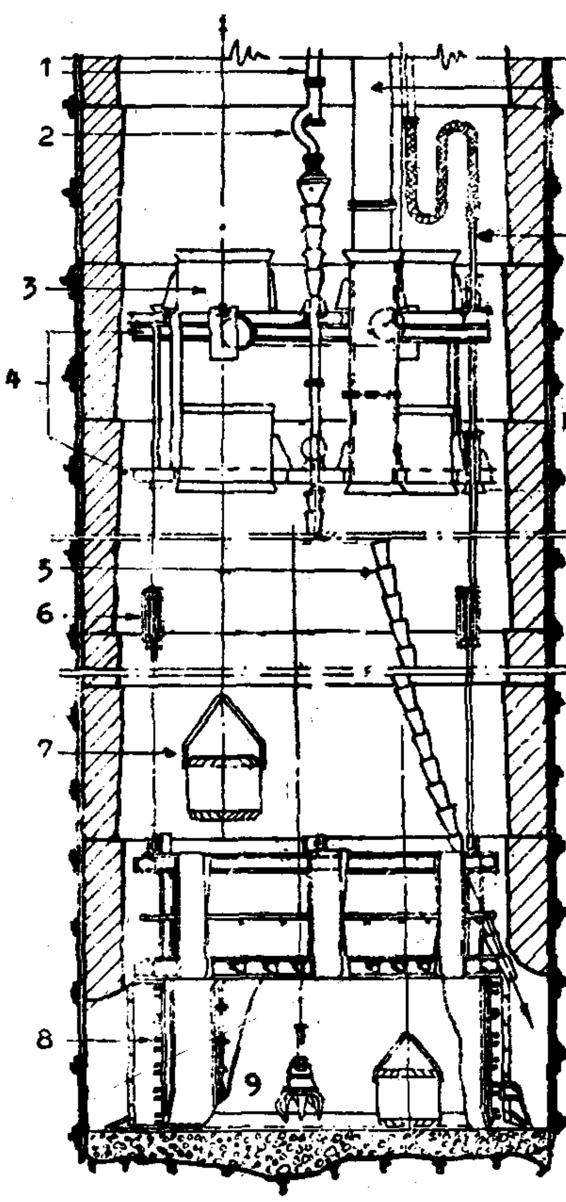
This process can be used in all cases of shaft sinking, particularly in any fissured water-bearing strata except in running sand or loose ground. It can be successfully applied in sinking even when the inrush of water is heavy.

Treatment of ground around the shaft is carried out to achieve one or more of the following objectives: (1) To stabilise the collapsing ground, (2) To reduce the inflow of ground water, (3) To avoid flooding, (4) To prevent sand "boiling". The operation is usually carried out in 2 phases, one before the sinking and the other after shaft lining. Ground conditions usually dictate the pattern of treatment.

The pre-sinking treatment reduces the surprise-stoppages of the sinking due to unfavourable ground conditions. Further, by reducing the amount of water inflow it not only saves expenditure on the dewatering pumps but substantially enhances the rate of sinking and the quality of the work.

On occasions post-cementation treatment may be necessary to have improved working conditions in the mine. Otherwise humidity in the underground excavation would create serious ventilation and corrosion problems.

The method consists in drilling the holes as shown in fig. 4.16 and then injecting a slurry of water and cement under pressure through the" holes till they are completely sealed off. In the past injection was done at low pressures like 6 kgf/cm2 but it has been proved that high pressure-of the order of 300 kgf/cm2 can be used successfully. The water: cement ratio can be changed according to the requirements.



Simultaneous sinking and concrete lining
Excavation dia—7 m; Shaft dia—6.5 m.

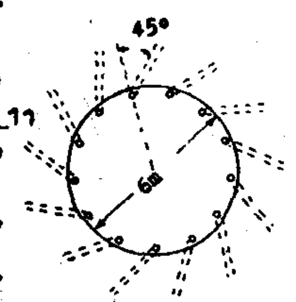


Fig. 4.16. position of holes in cementation process.

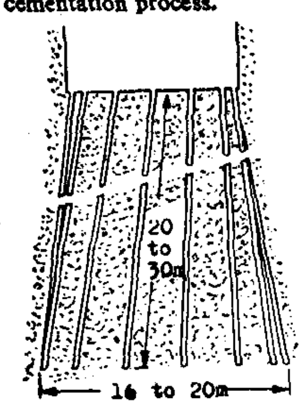


Fig. 4.17

1. Concrete pipe line
2. Kinetic energy damper
3. Opening for bucket
4. Two deck platform
5. Flexible portion of concrete pipe line
6. Pulley block for shuttering
7. Sinking bucket,
8. Steel shuttering
9. Grab loader
10. Ventilation tube, and
11. Compressed air pipe

A process known as pre-silicatisation, which reduces the friction of the rock to the passage of cement is necessary in certain types of rocks. Extra holes are drilled for the purpose and are treated first with silicate of soda and then with aluminium sulphate. This process of treating the holes with the chemicals is known as silicatisation. The holes to be treated with chemicals are known as "pfa3uct'-rtolesw and their number is usually three times that of cementation holes.

After cementation of holes the shaft sinking proceeds in the usual manner.

Shaft sinking at Sudamdih and Monidih collieries

Sudamdih was the first mine in India where two shafts were sunk in the early sixties with the help of Polish engineers in a manner that was completely new for the mining industry in the country. The distinctive features adopted for the first time in shaft sinking at Sudamdih, and later at Monidih, were:

1. Sinking was carried out with the help of one head gear and 2 winders, diametrically opposite to each other on either side of the shaft.
2. A double deck platform was used for simultaneous sinking and concrete lining.
3. Delay detonators were used.
4. Shot firing was carried out with the current from the electric power line at 550 V.
5. Grab loaders, suspended from the double deck platform, were used for loading of muck at shaft bottom.
6. High rates of sinking with completion of shaft lining were achieved. The average progress per month was 25 metres and the maximum was 50 metres.
7. Entire shaft depth was lined with concrete.

At Sudamdih No. 1 shaft is 450 m deep, finished dia. 7.2 m and the adjacent No. 2 shaft is 420 m deep, 6.5 finished dia. All the coal production comes from 400 metere horizon (400 m below M.S.L.) by means of skips in No. 1. pit. During sinking at shaft No. 1. a temporary head gear and two winders were installed but the headgear and winders were replaced later by permanent ones.

A general lime-study of different operations:

1. Drilling 3 to 4 hours.
2. Charging and blasting l '/2 to 2 hours.
3. Clearance of smoke & cleaning of D.D. platform '/2 to 1 hour.
4. Lowering of pipes, equipment & grab '/: to 1 hour.
5. Loading of much 18 to 21 hours.
6. Lowering the steel shuttering 45 min to 1 hour).
7. Placing & plumbing the shuttering 1 to l '/2 hours.
8. Extension of concrete pipe line (flexible portion '/2 to 1 hour.
9. Pouring concrete 3 to 4 hours.

Drilled shafts

The drilling of mine shafts by suitable machines is the most progressive method of shaft sinking adopted in Russia and other advanced countries of the west. The process is completely mechanised and all the sinking work can be carried out by sequence-controlled automatic machines so that there is no need to keep any men at the shaft bottom. Basically a shaft borer is similar to a large tunnel-boring machine. A cutting head equipped with roller bits continuously excavates the entire shaft cross-section at once. The removed fine muck is pumped as slurry to the surface or dropped through a pilot hole for underground removal. In many cases sprayed on concrete is used as initial lining. The machines used in Russia for such shaft sinking are suitable for shaft diameters 6.2 m to 8 m (excavated diameter) upto a depth of 800 m through rocks of medium strength like those available in coal mining localities. The average speed is 100 m per month. The shaft is drilled in 3 stages; a pilot hole 1.2 m dia. is drilled to the full depth with a tricone bit; thereafter the reamer enlarges the hole to 3.6 m and then to 6.2 m. The reamer is rotated by the drill pipe through a square section pipe at the surface, operated by electric motors. During drilling, the hole and shaft are full of mud-water mixture (mud flush) which exerts a pressure within the shaft and takes the place of temporary lining. It also flushes the reamers, removing the broken rock to the surface with the help of an air-lift pump. The permanent shaft lining is built after the entire length of the shaft has been widened to its full diameter.

Actual capital expenditure for boring per metre of shaft by the technique of shaft boring is higher than by the conventional drilling-blasting-mucking method and other special methods of sinking. But the cost is likely to be reduced with more knowledge of the 'knowhow* in handling of rigs.

Such machines are not used in Indian mining practice.

The current trends in the design of the shaft boring rigs are: (1) Drilling of shot holes to a depth of 6 m. (2) Increasing the hoist speed for deep shafts to 15-18 m/sec. (3) Automation of sinking process.

The progress available with shaft sinking machines may be appreciated from the following performance of a machine manufactured by WIRTH, a leading manufacturer in West Germany.

In early 1983, one 7 m diam. shaft was sunk in Alabama, U.S.A., completing the sinking of the shaft, 650 m depth, in 6 weeks. Sinking rate at one stage was 35 m/day. The period is inclusive of the time spent on shaft-lining.

The Company manufactures machines which have achieved sinking rates of 7 m in a 7-hr, shift. The machine is adopted for cuttings-removal system and works in conjunction with the company's pilot hole machines for sinking of blind shafts. The cuttings are removed upwards.

QUESTIONS

1. A shaft 6 m dia. is to be sunk to a seam 150 m deep. The shaft is to pass through 12 m thick alluvium at the surface and strong sandstone. Describe briefly the methods adopted for support of sides.
2. What are the special methods of shaft sinking? Under what circumstances are they followed? State their limitations.
3. A shaft 5 m dia. is being sunk through rock consisting of shale and sandstone. Describe the arrangement of shot holes, blasting and disposal of debris.
4. Describe a method of driving a staple pit from a bottom seam to a top seam, 10 m above.
5. Describe a. method of simultaneous shaft sinking and shaft lining.