Underground Mining of Metalliferous Deposits
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Lecture No. 17
Shaft – III (Continued)

SHAFT SINKING (Shaft boring systems)

The SBS is a development for the mechanised excavation of deep vertical blind shafts in hard rock conditions.

The semi full-face sequential excavation process is based on the use of a **rotating cutting wheel excavating** the full shaft diameter in a two stage process for one complete stroke.

The excavation process is divided into two steps:

1. **Trench excavation** to a depth of one stroke with the **cutting wheel rotating** around its horizontal axis and being pushed downward in the shaft direction.
2. **Excavation of the entire bench** (face) area by slewing the rotating cutting wheel 180° around the shaft vertical axis.

The SBS machinery consists of three major areas of equipment and operation which are (starting from the bottom):

1. **Shaft boring machine** with excavation, muck transport and gripping system as well as equipment for primary rock support and probe drilling.
2. **Primary platform decks** for SBS supply infrastructure and power packs.
3. **Secondary platform decks** for final lining installation, muck handling and services extension.

The SBS machine can be separated into the main functional areas (starting from the bottom):

Excavation chamber with **cutting wheel**, cutting wheel drive assembly, mechanical machine support structure, shotcrete and probe drilling equipment (1)

Figure 1. Shaft boring system

Adjustable **front support with slew bearing/drive** assembly cutting wheel support and dust shield (2).

Regular rock support area for rock bolts (3).

SBS mainframe with **gripper carrier**, gripper system and thrust cylinders (4).

Rear alignment system (**secondary gripper**) and the muck handling system (5).

The cutting wheel circumference and periphery of both sides are equipped with appropriate **cutting tools to excavate** the rock and **remove the cuttings while rotating**.

Excavation and muck removal is a continuous process. The cuttings are guided along **internal muck channels and discharged by gravity onto a center arranged secondary conveying system**.

All reaction forces of the excavation process are transferred into the **shaft walls by grippers arranged** in the rear.

During the **gripper reset operation after each excavation cycle**, the machine can be adjusted along its vertical axis for alignment control.

SHAFT SINKING (Advantages)

High sinking rate is achieved with SBS technology.

High level of safety is possible with this system.

Integrated system of excavation, mucking and rock support in this method.

Fully accessible face.

Dedicated drills rigs come with it for probing and pre-excavation grouting.

The finished diameter of the shaft is as per the desired standard.

SHAFT SINKING (Special method)

- Ordinary methods of shaft sinking are not suitable in some cases and special methods have to be adopted under the following conditions:
- **Loose or unstable ground**, such as sand, mud, etc.
- Excessively **watery** strata.
- A combination of the above two.
- The special methods are:

1. The Piling System
2. Caisson Methods
3. Freezing Method
4. Cementation Process

SHAFT SINKING - The Piling System

This method is known as simply “piling” or “sheet piling and is suited sinking through loose deposits of sand, mud, or alluvium near the surface upto a depth of 20 m.

Interlocking steel piles, 6 m to 10 m long, are used and they are practically water-tight. Additional lengths may be available by welding or riveting two or three lengths of piles.

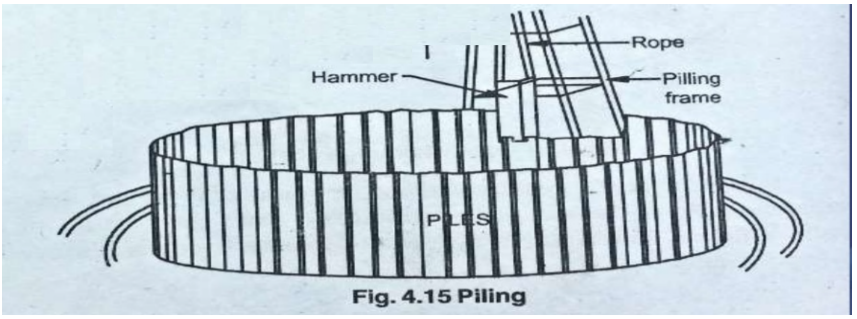

Figure2. Shaft sinking by piling system

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 meters at a time by a direct-acting steam piling hammer.

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.

SHAFT SINKING - Caisson Methods

The methods can be divided into three classes:

(i) Sinking Drum Process or Open Caisson Method

(ii) Forced Drop Shaft Method

(iii) Pneumatic Caisson Method

<u>Sinking Drum Process or Open Caisson Method</u>

This consists of a **cylindrical well of brick** work, 0.3 m to 0.4 m in thickness over a mild steel 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.

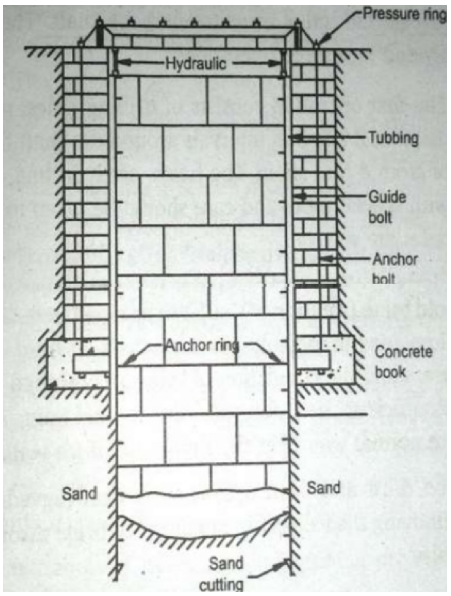

Figure 3. Shaft sinking by open caisson method

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.

Forced Drop Shaft Method

- This is commonly **adopted** where the strata consists of **alternate tough and loose ground** arid 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.

Pneumatic Caisson Method

- This method is **adopted** when there is a danger of ground filing 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 material.
- The limit of the pressure of the air is 4 kgf/cm^2 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 strata with heavy inrush of water**, or sand connected with inflow of water.
- This method 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**:
- (i) **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 another 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.
- The whole process can be divided into three operations:
- (ii) **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.
- The whole process can be divided into three operations:
- (iii) **The third and final operation is thawing** (warming up) which consists in removing the ice wall by sending hot brine through the existing holes.
- This method is never used in India.

SHAFT SINKING - 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 lose 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:

(i) To stabilize the collapsing ground,

(ii) To reduce the inflow of ground water,

Treatment of ground around the shaft is carried out to achieve one or more of the following objectives:

(iii) To avoid flooding,

(iv) 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 unfavorable ground conditions. – **Consolidation grouting**

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 – **Injection grouting/curtain grouting.**

Otherwise humidity in the underground excavation would create serious ventilation and corrosion problems.

The method consists in drilling the holes 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/cm^2** but it has been proved that high pressure of the order of **300 kgf/cm^2** can be used successfully. The water cement ratio can be changed according to the requirements.

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 “product-hole” and their number is usually three times that of cementation holes.

Chemicals used in injection grouting are - **Polymers such as polyester, epoxy, vinyl ester, polyurethane and acrylic resins**

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