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Indian Standard

CODE OF PRACTICE FOR
CONSTRUCTION OF TUNNELS
CONVEYING WATER

PART II UNDERGROUND EXCAVATION IN ROCK

Section 3 Tunnelling Method for Steeply Inclined Tunnels,
Shafts and Underground Power Houses

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CODE OF PRACTICE FOR
CONSTRUCTION OF TUNNELS
CONVEYING WATER
PART II UNDERGROUND EXCAVATION IN ROCK
Section 3 Tunnelling Method for Steeply Inclined Tunnels, Shafts and Underground Power Houses

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AMENDMENT NO. 2 MARCH 1993
TO
IS 5878 (Part 2/ Sec 3) : 1971 CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER
PART 2 UNDERGROUND EXCAVATION IN ROCK
Section 3 Tunnelling Method for Steeply Inclined Tunnels, Shafts and Underground Power Houses

(Page 4, clause 0.4) — Insert the following at the end:

'Part 7 Grouting'

(Page 4, clause 0.5) — Delete and renumber 0.6 as 0.5.

(Page 4, clause 3.1) — Substitute 'IS 4756 : 1978' for 'IS : 4756 - 1968'

(Page 4, foot-note) — Insert '(first revision)' at the end of the foot-note marked with '†' mark.

(Page 10, clause 7.5.2) — Substitute 'IS 807 : 1976' for 'IS : 807 - 1963'.

(Page 10, foot-note) — Insert '(first revision)' at the end.

(RVD 14)
0. FOREWORD

0.1 This Indian Standard (Part II/Sec 3) was adopted by the Indian Standards Institution on 15 March 1971, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The construction of tunnels involves a large number of problems because of the great longitudinal extent of the work and many kinds of conditions are encountered which for maximum economy should be treated differently. In view of this it has been appreciated that it should be futile to prepare a rigid set of rules or procedures which can be enforced without leaving any latitude for the exercise of discretion by the site engineer. The aim of this standard is to summarize the well known and proved principles and to describe the commonly used procedures and techniques for providing guidelines which would permit the site engineer to use his discretion. This section deals with special features involved on tunnelling steeply inclined tunnels, shafts and underground power houses. The Indian Standard code of practice for construction of tunnels (IS: 5878) is being published in parts and Part II in sections.

0.3 Sometimes vertical or inclined shafts are required to be constructed to serve as construction adits or as permanent works, such as approach tunnels, pressure shafts, ventilation tunnels and cable tunnels for underground works like power station. Tunnelling operations described in Part II, Section 1 are generally applicable to such shafts and tunnels. However, some special features are involved in construction of steeply inclined tunnels, shafts and underground power stations and only such special features are covered in this section. Inclined shafts are also termed as inclined tunnels.

0.4 Other parts of this standard are as follows:
- Part I  Precision survey and setting out
- Part III  Underground excavation in soft strata
IS: 5878 (Part II/Sec 3) - 1971

Part IV Tunnel supports
Part V Concrete lining
Part VI Steel lining

0.5 This standard is one of a series of Indian Standards on tunnels. Other standards published so far in the series are:

IS: 4081-1967 Safety code for blasting and related drilling operations
IS: 4137-1967 Safety code for working in compressed air
IS: 4756-1968 Safety code for tunnelling work
IS: 4880 (Part II) -1968 Code of practice for design of tunnels conveying water: Part II Geometric design (Since revised).
IS: 4880 (Part IV) -1971 Code of practice for design of tunnels conveying water: Part IV Structural design of concrete lining in rock

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS: 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part II/Sec 3) deals with special features involved in tunnelling operations on steeply inclined tunnels, shafts and underground power houses. However, the tunnelling operations described in Part II, Sections 1 and 2 of this standard are generally applicable to such works also.

2. SETTING OUT

2.1 Setting out of works shall be done in accordance with IS: 5878 (Part I)-1971†.

3. SAFETY PRECAUTIONS

3.1 Adequate safety precautions shall be taken in accordance with IS: 4756-1968‡.

*Rules for rounding off numerical values (revised).
†Code of practice for construction of tunnels: Part I Precision survey and setting out.
‡Safety code for tunnelling work.
4. METHOD OF ATTACK FOR VERTICAL SHAFTS

4.1 Vertical shafts may be sunk usually from top to bottom but when access at the bottom is available the following methods may be more beneficial for excavation. The method to be used will also depend upon geology, size and seepage of water:

a) A small pilot of about 2 to 3 m dia may be first excavated from top to bottom and then the shaft may be widened throwing the muck down the pilot shaft, which may be mucked from the bottom by suitable mucking equipment.

b) Instead of sinking a pilot from the top, an 8 to 10 cm dia hole may be drilled from top to bottom. Through this hole a cage may be suspended to the bottom by installing a winch at the top. With the help of this cage, a small riser of about 2 m diameter may be excavated upwards to serve as a pilot shaft. Then as in the method given at (a), the shaft may be widened and the muck thrown down.

c) Burn type pattern of long holes may be drilled throughout the entire depth of the shaft by powerful wagon drills and by using guide tubes to see that deviation of holes is minimum. After drilling, these holes may be blasted by charging them from top and blasting progressively upwards.

5. METHOD OF ATTACK FOR INCLINED SHAFTS OR TUNNELS

5.1 Inclined shafts or tunnels may be sunk from top to bottom or if access is available, from bottom to top or from both top and bottom. If the depth of the shaft is more than 300 m generally an intermediate adit may be provided for opening additional working faces. The method to be used will also depend upon geology, size and seepage of water.

5.2 The following are the general methods for sinking inclined tunnels and/or shafts:

a) From bottom upwards with full face,

b) From top downwards with full face, and

c) From bottom upwards with pilot heading and widening from top downwards.

5.2.1 From Bottom Upwards with Full Face — This method consists of raising the shaft from the bottom and as such the muck after blasting rolls down by gravity. Therefore, proper arrangements shall be made to protect the air and water mains and ventilation ducts. The shafts may be usually divided into two parts as shown in Fig. 1 so that the services are kept in the top part, while the muck rolls down from the other part. Drilling platform and other things shall be winched up by some suitable
arrangement and drilling shall be carried out from a platform. Drilling shall be done with rock drills and pushers and blasting may be done as usual. This method has the following advantages and disadvantages:

a) **Advantages**
   1) Muck slides along the slope and collects at the bottom from where it is loaded by leaders.
   2) The quantity of explosive required is slightly less than what is required for the other method.
   3) If there is underground water no pumping is necessary.

b) **Disadvantages**
   1) Hoisting the material up the raise every time and going up is more troublesome, as every thing has to go on a steep slope against gravity.
   2) Scaling after blasting is more difficult.
   3) Ventilation has to be very powerful, otherwise the gases after blasting take more time to go out as they have tendency to go upward.

![Diagram](image)

**Fig. 1** **Partition in Bottom Upwards Excavation with Full Face**

5.2.2 **From Top Downwards with Full Face**—In this method, all the operations are carried out from top downwards, as in sinking a vertical shaft (see 4.1). The sinking of the inclined shaft is more difficult than sinking a vertical shaft. Drilling and blasting may be carried out as
usual. The general arrangements may be as shown in Fig. 2. This method has the following advantages and disadvantages:

a) **Advantages**
   1) Going down the shaft and taking the equipment is easier.
   2) Regular trolley track can be laid at the bottom so that the material and men can be winched up easily after every operation.
   3) Removal of gases takes less time.
   4) All the services are not liable to be damaged by mucking or blasting.

b) **Disadvantages**
   1) The muck is to be loaded manually, as such the progress will be slower than by the method given in 5.2.1.
   2) If underground water is met with, dewatering will be difficult.

![Diagram of excavation from top downwards with full face](image)

**FIG. 2** **EXCAVATION FROM TOP DOWNWARDS WITH FULL FACE**

5.2.3 **From Bottom Upwards with Pilot Heading**—This method is adopted when the size of the shaft is quite big. First a pilot heading at the lower level is driven from bottom upwards as shown in Fig. 3. After the pilot is complete, widening is started from top and carried down. Thus, in both the operations the muck is allowed to fall down so that it can slide along the slope by gravity up to the bottom of the shaft, from where it is removed by loaders. This method has most of the advantages of the methods given in 5.2.1 and 5.2.2 besides the overall cost might work out cheaper.

**Note**—With the development of special rigs which climb along the tunnel/shaft from bottom upwards and are capable of drilling large diameter holes the bottom upward method is becoming easier. The long hole method given in 4.1 (c) can also be used.
6. DRILLING

6.1 Drilling pattern for the shaft does not vary as much as for the tunnel. The following drilling patterns may be used:

   a) The most commonly used is centre wedge cut for square and rectangular sections (see Fig. 4);

   b) For circular sections, sometimes wedge cut or pyramid cut is also used; and

   c) When shafts are very large, drilling may be done in alternate steps (see Fig. 5).

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**Fig. 3** Excavation from Bottom Upwards with Pilot Heading

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**Fig. 4** Central Wedge Cut

**Fig. 5** Steps for Drilling Large Shafts
7. MUCKING

7.1 There are various methods of hoisting muck through shafts. The selection of method depends on the size of the shaft and the progress desired. The mucking through the shaft may be divided into two categories, namely (a) mucking for sinking the shaft and (b) mucking of the tunnel driven through the shaft.

Note — In the first case, actual blasting takes place in the shaft and, therefore, no equipment can be kept in the shaft during blasting. Therefore, the arrangements of mucking have to be done accordingly. In the latter case, as the blasting takes place in the tunnel, the shaft is free and, therefore, permanent type of equipment can be installed in the shaft for mucking.

7.1.1 General design and layout of hoisting plant is influenced by many factors, such as size, depth of shaft, space available on the top surface, size and length of the tunnel, type of ground and method of hoisting muck.

7.2 Mucking of Vertical Shafts — For sinking shaft, the muck may be removed manually in the beginning for about 3 m or so. Thereafter, muck may be hoisted by temporary mechanical arrangements, such as three-legged derrick or crane, till other permanent arrangements, such as headgear, fixed or movable crane, sliding skip are installed.

7.3 Mucking of Inclined Shafts or Tunnels — When sinking is being done from top to bottom, winches have to be used for hauling muck into suitable skips running on trolley track. If the shaft is being raised, the muck may be pushed down which may be achieved by gravity by using a scrapper.

7.4 Special Methods and Equipment — Sometimes special methods and equipment may be used for working from bottom upwards. In vertical shafts a central hole may be drilled through and a cable is passed through the hole to support the platform (cradle). This platform may be hauled up and down as required by means of a winch. During blasting the cradle shall be removed to a safe place.

Note — For inclined and vertical shafts a travelling unit has been developed. This moves on a mono rail supported from the top (or side) by means of removable rock bolts.

7.5 Precautions

7.5.1 Head Frame — The head frame (including hoists, cables, etc) shall be preferably of steel structure and properly designed with sufficient head room and strong enough for possible overload and impact due to sudden drops.
7.5.2 Hoist Equipment—It shall be thoroughly inspected at least once a week and maintained in first class condition. Suitable standby power supply arrangement or alternate means of working the hoist mechanically (see IS: 807-1963*) shall be provided. A limit switch or automatic brake shall be provided on the hoist to control speed.

7.5.2.1 There shall be a fencing round the shaft opening at least 90 cm high and it shall comprise two rail guards and also a top board, 15 cm high to prevent material from falling in. The gate provided there shall be closed except when used for entering or leaving the shaft or emptying the buckets. The gate should preferably be automatic.

7.5.3 Access Through Shafts—Persons shall not be lowered or raised in bucket used for mucking.

7.5.3.1 A special cage or a bucket shall be used for lowering or raising personnel during the sinking of a shaft. For emergency use, strong ladder made out of wire rope shall be provided on one side of the shaft. After the shaft is sunk, a suitable arrangement for the workman shall be made in the shaft for access to the shaft and the tunnel.

7.5.4 Signals—Reliable means of communication, such as bells or whistles or electric signals shall be maintained at all times between the bottom of the shaft and the surface and telephones used, wherever possible.

7.5.4.1 Any code of signals used shall be kept conspicuously pasted near workplace or entrance.

8. TUNNELLING METHODS FOR LARGE TUNNELS

8.1 The tunnelling methods described in other sections shall be generally applicable.

8.2 The methods of attacking the faces or tunnel depends on the type of rock strata available, size and shape of tunnel and the equipment available. The following methods may be generally used:

a) Full Face—When the rock strata is hard and massive, the tunnels may be attacked full face.

b) Top Heading and Benching—This method may be used when the quality of the rock is less satisfactory. After driving top heading to the full section, the arch may be concreted if found necessary to support the rock before taking out the bench.

c) Multiple Draft—This method may be used when the strata of rock is poor.

*Code of practice for design, manufacture, erection and testing (structural portion) of cranes and hoists.

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9. TUNNELLING METHODS FOR UNDERGROUND POWER HOUSE

9.1 For starting work in underground power station, invariably one or two access tunnels may be provided. The position, location and the number of access tunnels will depend on the topography of the area, the size of the power station and time available for its construction; while their sizes will depend on the mucking equipment to be used and machinery to be taken inside for installation.

9.2 As the width and height of a power station will be bigger than most tunnels, the normal practice is to excavate first the top portion of the power station up to the arch and concrete the arch. This is necessary to render the whole working area safe from any rock falls, which are likely to take place due to wider and flatter arches. After the arch is concreted, the benches may be removed in one or more operations, depending on the height of power house and the nature of rock.
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