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IS 4756 (1978): Safety code for tunneling work [CED 29: Construction Management including safety in Construction]



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Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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(Reaffirmed 1987)

Indian Standard

SAFETY CODE FOR TUNNELING WORK

(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Indian Standard

SAFETY CODE FOR TUNNELING WORK

(*First Revision*)

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Indian Standard

SAFETY CODE FOR TUNNELING WORK

(*First Revision*)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 3 March 1978, after the draft finalized by the Safety in Construction Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Tunneling work is widely carried out in the country in the construction of railway, road and hydel projects. The work involved is of a specialized and hazardous nature. Cramped working space in the heading, wet and slippery flooring, artificial lighting — all too often inadequate, difficult ventilation, obnoxious gases, unseen weaknesses in the rock, handling of explosives, leading and hauling muck, etc, might contribute to accidents. In order to avoid hazards, it is necessary to lay down the safety precautions for the use of machinery, electrical installations and labour in tunnels, during the construction period, and arrange for their compliance. This code has, therefore, been formulated to lay down the safety rules for tunneling in rocks and soft strata and underground excavations in rocks. This code does not cover tunnels made in connection with mining operations, gassy tunnels (*see 3.1.3*), and also tunnels made in running ground (*see 2.3*), where special methods like shield tunneling are adopted.

0.3 This standard was first published in 1968. In this revision, modifications have been made regarding warning signals, sanitation and drinking water facilities inside the tunnels and the concentration of various gases inside the tunnel. Modifications have also been made regarding the personal protective wear of persons entering the tunnel.

0.4 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.5 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 lays down the safety requirements for tunneling and underground excavations in rocks and soft strata.

1.2 This code does not cover tunnels made in connection with mining operations, gassy tunnels, and also tunnels made in running ground (*see* **2.3**), where special methods like shield tunneling are adopted.

NOTE — ‘Gassy tunnel’ wherever used in this code shall mean a tunnel in any part of which flammable gas is present or is likely to occur including a tunnel which is adjacent to or is approaching any such place.

1.3 Safety precautions to be observed during blasting and related drilling operations are covered separately in IS : 4081-1967†.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Soft Strata — It may be classified into three main categories, namely, soft ground, firm ground, and running ground, as defined under **2.1.1** to **2.1.3** [*see also* **3.1** of IS : 5878 (Part III)-1972‡].

2.1.1 Soft Ground — Ground where bridging period is so short that conventional supports cannot be installed. In some cases of this type it may be possible to increase the bridging time by methods like shot-creting. This type includes soft or squeezing clay, damp sand, certain types of gravels or soft earth, some formation of decomposed and/or treacherous rocks.

2.1.2 Firm Ground — Ground where reasonable bridging period is available for installing the conventional supports. This type includes soft and stratified rocks, such as sand stone, shales, cemented sand and gravel and hard clays.

2.1.3 Running Ground — This is the ground which requires special treatment before excavation can be done. It may be highly crushed rock, dry sand and gravel, water bearing sand or gravel, silts and muds.

*Rules for rounding off numerical values (*revised*).

†Safety code for blasting and related drilling operations.

‡Code of practice for construction of tunnels: Part III Underground excavation in soft strata.

3. SAFETY PROGRAMME

3.1 Safety Personnel — All operations inside the tunnel or shaft shall be carried out under the immediate charge of a competent foreman. The foreman shall also be responsible for the safety arrangements of the work. In larger jobs these responsibilities and functions in respect of safety arrangements may be delegated to an independent qualified and competent supervisor working under the overall control of the foreman. A safety committee shall also be appointed in jobs where 100 or more persons are employed. It shall have at least three members — one each from workers, supervisors and management. The committee shall be responsible for advising safety arrangements of the work and safety supervisor/foreman shall assist in this committee's work. This committee shall conduct its meeting at least once in 15 days and discuss safety problems on the work.

3.1.1 An effective and workable safety programme shall be planned in advance and adhered to. Workmen shall be thoroughly instructed in safety rules and shall be required to follow them at all times. They shall be required to report immediately any unsafe conditions observed.

3.1.2 The foreman/supervisor appointed to look after the tunneling work may also take the guidance about the bad reaches expected to be met in the tunnel from the geologists so that necessary safety measures could be adopted.

3.1.3 Where the geological data collected so warrants advance probe holes by percussion or core drilling, as required, shall be drilled ahead of the tunnel faces to locate any gas, flowing mass of rock, aquiferous strata, geological disturbances, etc. In case presence of gases like methane is detected, further tunneling work shall be stopped and the advice of Director General Mines Safety (DGMS) shall be sought about the supervising personnel to be entertained and additional safety precautions necessary.

3.1.3.1 Also, if the geological data collected and information from other sources indicate presence or likelihood of gases like methane, advice of DGMS shall be sought as referred to under **3.1.3**.

3.2 Reporting of Accidents — The occurrence of any accident, involving personal injury or of any dangerous incident, such as serious break-down of or damage to any apparatus/equipment shall be reported to the supervisory staff/officers and adequate precautionary measures shall be taken by the engineer-in-charge to prevent recurrence. An accurate record of such accidents shall be properly maintained. Probable reasons of accidents shall be investigated and precautionary measures taken to avoid further recurrence.

3.2.1 Accidents occurring during the fortnight shall be discussed in the safety committee (**3.1**) meetings and adequate publicity shall be given to the causes of these accidents and their preventive measures.

4. MEDICAL AND OTHER FACILITIES

4.1 First-Aid Arrangements

4.1.1 Arrangements for rendering prompt and adequate first-aid to the injured persons shall be maintained at every work site under the guidance of a medical officer-in-charge of the project. Depending upon the magnitude of the work the availability of an ambulance at a very short notice (at telephone call) shall be ensured.

4.1.2 First-aid arrangements commensurate with the degree of hazard and with the number of workers employed shall be maintained in a readily accessible place throughout the whole of the working hours. At least one experienced first-aid attendant with his distinguishing badge shall be available on each shift to take care of injured persons. Arrangements shall be made available for calling the medical officer, when such a need may arise. It is recommended that foreman/assistant foreman/supervisor/permanent workman who is normally present at each working face in each shift is given adequate training on first-aid methods to avoid employment of a separate attendant.

4.1.2.1 Stretchers and other equipment necessary to remove injured persons shall be provided at every shift and portal.

4.1.3 Where there are more than 50 persons working in a shift, effective artificial respiration arrangements shall be provided, with trained men capable of providing artificial respiration.

4.2 Protective Wear

4.2.1 All the persons entering the tunnel shall be provided with protective wear, such as helmets, steel toe safety shoe, gum boots or other suitable type of protective foot wear. In the case of steeply inclined tunnels and in shafts, safety belts shall also be provided.

4.2.2 Sign boards 1×1.5 m in size with the following wording shall be erected at the access to these areas:

‘ CONSTRUCTION AREA, HELMET REQUIRED BEYOND THIS POINT ’

4.2.3 No loose garments or ragged clothing shall be worn by the personnel engaged in the tunneling operations.

4.3 Sanitation and Drinking Water

4.3.1 Sanitation — Unless the worksite is within 500 m of the portal of the tunnel, sanitation facilities shall be provided closeby. Dry closets or water closets or closet cars shall be provided in the tunnel at the scale of one unit for each fifty men in the shift unless it is impracticable. In any case the entire tunnel shall be treated with disinfectants periodically to eliminate unhygienic conditions. Closets shall be effectively and regularly cleaned and disinfectants provided.

4.3.2 Drinking Water — Drinking water, at least 5 litre per person employed in the shift, shall be provided near the portal and also inside the longer tunnels. It shall be stored in a clean container provided with tight fitting lid. The use of salt tablets shall be encouraged.

4.3.3 Washing and cleaning facilities shall be provided for all workers near the portal.

4.4 Miscellaneous

4.4.1 Only the materials required for work in progress shall be kept inside the tunnel. All other materials shall be removed from inside the tunnel and sufficient space of the formation shall be as even as possible and without any obstacles to enable the workers to get out of the tunnel quickly in case there is any collapse or any other mishap inside the tunnel.

4.4.2 All storage handling and use of flammable liquids shall be under the supervision of qualified persons. Flammable liquids shall not be stored inside the tunnel.

4.4.3 All sources of ignition shall be prohibited in areas where flammable liquids are stored, handled and processed. Suitable warning and 'NO SMOKING' signs shall be posted in all such places. Receptacles containing flammable liquids shall be stacked in such a manner as to permit free passage of air between them.

4.4.4 All combustible materials like rubbish shall be continuously removed from such areas where flammable liquids are stored, handled and processed. All spills of flammable liquids shall be cleared up immediately. Containers of flammable liquid shall be tightly capped.

4.4.5 Fire extinguishers and fire-buckets appropriate to the hazard should be conveniently located and identified.

4.5 Telephone System — A telephone system shall be provided to ensure a positive and quick method of communication between all control locations inside tunnel and portal of the tunnels when longer than 500 m and for shafts when longer than 50 m.

4.6 Warning Signals — Irrespective of length and bends in the tunnel, arrangements shall be made for transmitting of warning signals by any one of the following means:

- a) By electrically operated bells, operated by battery/dry cells with the bell placed outside the tunnel and the position of the switch shifting with the progress of the tunneling work. The position of the operating switch although temporary shall be so chosen as to ensure proper accessibility and easy identification.
- b) By the use of two field (magnet type) telephone.
- c) Any other suitable arrangement like walkie talkie.

4.6.1 Up to 100 m length of the tunnel only one of the systems mentioned above shall be provided whereas in tunnels of length more than 100 m at least two systems shall be installed; the wires running along opposite sides of the tunnel, if practicable.

4.6.2 Red and green lights of adequate size and brightness shall be provided at suitable intervals on straight lengths and curves, cross over points, etc, to regulate the construction traffic.

4.6.3 In all the cases as above the system(s) shall be subject to daily checks regarding proper serviceability. The checks shall be carried out every day immediately prior to the commencement of the tunneling work under the supervision of a responsible person.

5. ELECTRICAL INSTALLATIONS AND LIGHTING

5.1 The entire electrical installation shall be carried out according to the existing Indian Electricity Rules as modified from time to time.

5.2 General Provisions

5.2.1 All parts of the electrical installation shall:

- a) have all conductors and contact areas of adequate current carrying capacity and characteristics for the work they may be called upon to do and all joints in conductors shall be properly soldered or otherwise efficiently made;
- b) be so constructed, installed and maintained as to prevent danger of fire, external exposition and electric shock;
- c) be of adequate mechanical strength to withstand working conditions underground;
- d) be not liable to be damaged by water, dust or electrical, thermal or chemical action, to which they may be subjected;

- e) be efficiently insulated or have all bare live parts enclosed or otherwise protected; and
- f) be installed at such a location that dumpers or wagons do not come in contact with the same.

5.2.2 A passageway not less than 60 cm wide shall be maintained in front of switchboards.

5.2.3 Rubber mats shall be provided in front and in back of the switch boards. No one shall be permitted at the back of switchboards when the current is on.

5.2.4 In no case, space in front or back of a switchboard shall be allowed to be used as a change room, locker or storage room.

5.2.5 All electric wires carrying voltage 440 and above installed underground shall be in the form of insulated, lead covered cables, armoured effectively against abrasion and effectively grounded.

5.3 Identification — Each electrical equipment in use shall bear the essential details of voltage, amperage and circuit diagrams, etc.

5.4 Protection Against Fire

5.4.1 As far as practicable, combustible material shall not be used in the construction of any room or recess containing electrical apparatus.

5.4.2 No flammable material shall be stored in rooms, recesses or compartments containing electrical apparatus other than telephone, lighting apparatus and damp-proof apparatus.

5.4.3 Adequate fire extinguishing equipment suitable for use on live parts shall be kept ready for immediate use in or near any room, recess or compartment containing such parts as will be readily accessible safely for use in case of emergency. These equipment shall be tested at least once in a month.

5.4.4 On the occurrence of a fire caused by any electrical apparatus or a fire liable to affect any electrical installation:

- a) the supply of electricity should be cut off from such apparatus or installation as soon as practicable, and
- b) the fire shall be attacked as soon as possible and reported to the nearest available supervisor.

5.4.5 All waste and combustible rubbish shall be removed at least daily from the tunnel.

5.5 Ventilation — All places where electrical apparatus is installed shall be adequately ventilated in order to ensure proper cooling of the apparatus and dilution of flammable gases (*see also* 1.2).

5.6 Lighting

5.6.1 Adequate lighting shall be provided at the face and at any other point where work is in progress, at equipment installations, such as pumps, fans and transformers. A minimum of 50 lux shall be provided at tunnel and shaft headings during drilling, mucking and scaling. When mucking is done by tipping wagons running on trolley tracks a minimum of 30 lux shall be provided for efficient and safe working. The lighting in general in any area inside the tunnel or outside an approach road, etc, shall not be less than 10 lux.

5.6.1.1 Emergency lights (battery operated) shall be installed at the working faces and at intervals along the tunnel to help escape of workmen in case of accidents. All supervisors and gang-mates shall be provided with cap lamps or hand torches. It shall be ensured that at least one cap lamp or hand torch is provided for every batch of 10 people.

5.6.2 Any obstruction, such as drill carriages, other jumbos and drilling and mucking zones in the tunnel shall be well lighted.

5.6.3 Temporary Lighting — Most tunnels are wet or damp providing a perfect ground for short circuits. Electrocutions in tunnels are all too frequent. Steel forms and drill carriages shall, therefore, be properly grounded. The switches shall be located on a high ground and these shall be properly grounded.

5.6.4 Use of Hand Lamps Underground — Hand lamps shall be:

- a) equipped with strong cover of glass or other transparent material,
- b) dust and waterproof, and
- c) equipped with a strong and guard over the cover.

5.6.5 The exterior of all lamp sockets shall be non-metallic.

5.6.6 All electrical apparatus including portable tools shall be connected only to an electrical supply system which shall have proper earthing and grounding.

5.7 Notices and Signs

5.7.1 The following notices shall be kept exhibited at suitable places:

- a) A notice on the board of 45 × 30 cm prohibiting unauthorized persons from entering electrical equipment rooms;
- b) A notice on the board of 45 × 30 cm prohibiting unauthorized persons from handling or interfering with electrical apparatus;

- c) A notice on the board of 60 × 90 cm containing directions as to the procedure in case of fire;
- d) A notice on the board of 60 × 90 cm containing directions as to the rescue of persons in contact with live conductors and the restoration of persons suffering from electric shock; and
- e) A notice specifying the person to be notified in case of electrical accident or dangerous occurrence, and indicating how to communicate with him.

5.7.2 Suitable warnings shall be placed at all places where contact with or proximity to electric equipment can cause danger.

5.7.3 Telephone lines shall be laid on the opposite of the electric side in the tunnels. No blasting line shall preferably be laid within 3 m of the light and power line; its distance from a telephone line being immaterial so long as insulation can be ensured.

5.7.4 Voltage for lighting in a tunnel should be 125 V between phases as specified for underground lighting in terms of Rule 118(c) of Indian Electricity Rules, 1956.

5.7.5 Adequate number of persons, including all supervisors and electricians shall be adequately trained in the manual application of artificial respiration to persons suffering from electric shock and in particular should be aware of the necessity for immediate and continued application. A board of instructions for artificial respiration shall be hung at a conspicuous place.

6. UNDERGROUND EXCAVATION

6.1 Drilling Equipment

6.1.1 All drilling equipment shall be kept in good working order. Safe handling and proper lifting methods shall be used.

6.1.2 Only wet drilling shall be permitted.

6.1.3 Jumbos or other drill platforms shall be carefully designed, built and maintained to provide safe working conditions. The jumbo should be provided with a suitable railing around the top deck.

6.2 Drilling Operations — The drilling operations are given below:

- a) Drilling shall not be resumed after blasts have been fired until a thorough examination has been made by blasting foreman (head blaster) to make sure that there are no misfired charges which the drill may strike.

- b) All holes shall be of slightly greater diameter than the diameter of cartridges of explosives used.
- c) A drill, pick or bore shall not be inserted in butts of old holes even if examination fails to disclose explosives; separate holes shall be so drilled as to be nowhere less than 30 cm clear distance away from the previous hole.
- d) Charging of drilled holes and drilling shall not be carried out simultaneously in the same area.
- e) The air supply manifolds and the lines of supply to each drill shall be examined according to the numbers of drilling equipment.

6.2.1 All explosives are dangerous and shall be handled and used with care either by or under the direction of competent persons. It is obviously impossible to include warnings or approved methods for every conceivable situation. It is the responsibility of competent man-in-charge to know and to follow the Indian Explosive Act, 1884 and Explosive Rules, 1940.

6.2.1.1 Care shall be taken in storing, handling, transporting and use of explosive, etc, as specified in IS : 4081-1967*.

6.3 Underground Transportation and Storage

6.3.1 Explosives and detonators shall be placed in separate insulated carriers, whether carried by persons or conveyed mechanically and an attendant shall ride with the explosives being conveyed mechanically on slopes in shafts or in underground work areas. For carrying explosives mechanically, prior permission of Chief Inspector of Explosives shall be obtained.

6.3.2 Insulated containers, used for carrying explosives or detonators shall be constructed of finished wood not less than 5 cm thick or plastic not less than 6 mm thick or pressed fibre not less than 10 mm thick. There shall be no metal parts not even nails, screws, bolts, etc, and it shall be waterproof and provided with lid. The container shall be provided with suitable non-conductive carrying device, such as rubber, leather or canvas handle or a strap. For use of plastics in the containers for carrying explosives, prior permission of Chief Inspector of Explosives shall be obtained.

6.3.3 Explosives and detonators shall be transported in separate insulated containers, and in separate compartment where rope or locomotive haulage is used. Cars shall not have metal parts exposed on the inside. They shall have an open space of 45 cm between explosive and detonator compartments and nothing shall ever be carried in that space. The car

*Safety code for blasting and related drilling operations.

body and compartments shall be made of plank not less than 5 cm thick. Doors for the explosive and detonator shall open on opposite sides of the car and kept locked except when loading or unloading. Explosives or detonators may be transported in ordinary cars, if they are placed in separate insulated carriers or compartments or containers.

6.3.4 Cars used for transportation of explosives shall not be loaded beyond their rated capacity and explosives shall be so secured to prevent shifting of load or dislodgement from car in transit.

All cars transporting explosives shall be marked or placarded on both sides and ends with word 'Explosives' and provided with two red flags and during night by two red lights. Cars transporting explosives shall be equipped with at least two fire extinguishers.

6.3.5 Cars shall be pulled and not pushed when being moved by the locomotive and there shall be at least one empty car between locomotive and the car containing explosives.

6.3.6 Explosives and detonators shall be brought to the working places in separate, tight, well insulated containers, and kept in the containers until removed for placement in drill holes. If drill holes are not ready, they shall be stored in locked box type magazines located at a safe distance of at least 170 m from the working space.

6.3.7 Wooden explosive cases shall be opened only with wooden mallets and wedges. Metal tools shall not be used. Scooping out or breakage of cartridges and spilling of their contents shall be avoided.

6.3.7.1 No person other than a shot firer shall carry any priming cartridges into a shaft, in which the sinking is in progress. No such cartridge shall be so carried except in a thick felt bag or other container sufficient to protect it from shock.

6.4 Loading and Blasting

6.4.1 Electric firing shall be done by an approved method. A departure from this may be permitted only with the specific approval of the engineer-in-charge.

6.4.2 All drilling equipment and personnel not engaged on loading shall be removed from the site before loading of holes start. Loading of a round shall be completed by the crew starting the work of loading. Firing of round shall be the responsibility of the blasting foremen (head blaster).

6.4.2.1 Just before loading is started each hole shall be blown out with a high pressure air jet to remove loose cuttings and water.

6.4.2.2 In the process of charging or stemming a hole, iron or steel tool, scrapper or tamping rod shall not be used, nor shall undue force be employed in pressing the explosive into the hole. Only wooden tamping sticks shall be used for tamping the charge. Stemming and tamping of the charge may also be accomplished by the use of air jet.

6.4.2.3 No material other than clay sticks 25 mm dia and 10 cm long shall be used for blinding and sealing the holes after charging the same.

6.4.2.4 Before use each and every electric detonator shall be tested for a positive test with the help of an ohm-meter. Before shot firing, the circuit shall be tested for insulation and for continuity.

6.4.2.5 Before a shot is fired in an underground working place due warning shall be given to persons within 330 m in all directions and every entrance to the place where a shot is about to be fired shall be guarded so as to prevent any person, not having received warning from placing himself in dangerous proximity to the shot.

6.4.3 For loading purposes the employees shall be equipped with permissible battery lamps.

6.4.4 Only such explosives as produce less than 4 530 ml of poisonous gas (carbon monoxide and hydrogen sulphide) per 3×20 cm cartridge shall be used for underground blasting work.

6.4.5 Approved electrical detonators of known characteristics shall be used for blasting.

6.4.6 As far as possible, blasting shall be carried out using suitable exploder with 25 percent excess capacity. Electric power from the main shall be used only when it is absolutely necessary.

6.4.7 In case electric power is used for blasting, a separate safety switch shall be used and the safety switch shall be kept in closed locked box, the key of which shall be kept with the blaster. A fuse shall be provided to be replaced every time a blasting is done.

6.4.8 In case the exploder is used the revolving handle of the exploder shall be in the custody of the blasting foreman to prevent anybody else firing the shot when the blasting foreman and other persons are inside.

6.4.9 Stray currents may cause fatalities while loading and utmost care shall be taken in removing all faults from electrical circuits.

6.4.10 Electric power, light and other circuits in the vicinity within 70 m of the loading points shall be switched off after charging the explosive and before the blasting operation starts. Power supply is to be switched

on only after the blasted area has been properly inspected by the blasting foreman for misfires.

6.4.11 All tracks, air lines and vent pipes shall be kept properly grounded.

6.4.12 The heading shall be properly lighted with the electric flood lights before and after blasting.

6.4.13 Only one cartridge shall be inserted at a time and gently pressed with tampering rod.

6.5 Inspection and Blasting

6.5.1 Immediately after a blast has been fired, the firing line shall be disconnected from the blasting machine or other source of power.

6.5.2 When at least 5 minutes have passed after the blast was fired, a careful inspection of the face shall be made by the blaster to determine if all charges have been exploded. Electric blasting misfires shall not be examined for at least 15 minutes after failure to explode. Other persons shall not be allowed to return to the area of blast until an 'ALL CLEAR' signal is given by the blasting foreman.

6.5.3 All wires shall be carefully traced and search made for any exploded cartridge by the man-in-charge of the blasting operation.

6.5.4 Sufficient time shall be given for the fumes to clear before permitting the labour to work for mucking operations.

6.5.5 Loose pieces of rock and other debris shall be scaled down from the sides of the face of excavation and the area made safe before proceeding with the work.

6.6 Misfires

6.6.1 Misfired holes shall be dealt with by the blaster preferably by the same person who had done the charging operations.

6.6.2 If broken wires, faulty connections, or short-circuits are determined as the cause of a misfire, the proper repairs shall be made, the firing line reconnected and the charge fired. This shall be done, however, only after a careful inspection has been made of burdens remaining in such holes and no hole shall be fired when the burden has been dangerously weakened by other shots.

6.6.3 The charge of explosives from a misfired hole shall not be drilled, bored or picked out.

6.6.4 Misfired charges, tamped with solid material, shall be detonated by the method given in **6.6.4.1**, where practicable.

6.6.4.1 The stemming shall be floated out by the use of water or air jet from hose until the hole has been opened to within 60 cm of the charge, and the water shall be pumped out or syphoned off and the new charge placed and detonated. Whenever this method is not practicable, a new hole shall be drilled not nearer than 60 cm and 30 cm shallower which shall then be loaded and detonated. A careful search shall be made of the unexploded material in the debris of the second charge. In different situations, for example, in congested locations, holes may be drilled nearer provided it is ensured that nowhere the clear distance of the new hole from the misfired hole is less than 50 cm.

6.7 Shaft Excavation

6.7.1 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.

6.7.2 Hoisting 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 and a non-failing automatic brake shall be provided on the hoist to control speed.

6.7.2.1 There shall be a fencing round the shaft opening at least 90 cm high and it shall comprise two rail guards and also a toe 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.

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

6.7.3.1 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 workmen shall be made in the shaft for access to the shaft and the tunnel.

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

6.7.4.1 Any code of signals used shall be kept conspicuously exhibited near workplace or entrance.

6.8 Water Handling — The methods given below shall be followed:

- a) A study of boring data and geological formations shall be made to have an indication of locations, where water can be expected.

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

- b) Water inflow may be reduced or even entirely stopped by grouting off the wet seams. A wet area covering more than a single seam shall be scaled off by installing a suitable section of concrete lining.
- c) In case of a steady flow of water from the roof or side of the tunnel the flow shall be deflected down the sides to sumps by metal shields.
- d) The number of pumps provided at site shall be 50 percent more than the requirements calculated on the basis of the estimated pumping needs or at least one whichever is more.
- e) In case of steeply inclined tunnels steps shall be provided for quick exit in case of failure of haulage.
- f) Gutters and sumps shall be kept clean. Suitable arrangement shall be made to indicate the position of sumps in case tunnel invert is flooded.

6.9 Machinery and Mechanical Equipment

6.9.1 The signalman shall be instructed in his duties and positioned so as to have a clear view of the rear of the truck, the operator and the operation.

6.9.2 All equipment having a drop type skip pan shall be provided with guards on both sides and open end of the skip pan area, to prevent persons from walking under the skip while it is in an elevated position.

6.9.3 Platforms, footwalks, steps, guardrails, handholds and toe-boards shall be provided on machinery and equipment as necessary, to ensure safe footing and access ways.

7. VENTILATION

7.1 Necessity — The purpose of ventilation in tunnels is to make the working space safe for workers by keeping the air fresh and respirable and by eliminating harmful and obnoxious dust, dynamite fumes and other gases (*see 1.2*).

7.1.1 Mechanical ventilation shall be adopted where necessary to force the air in or exhaust the air out from the working face to the portal through a pipe to achieve the safety as laid down in **7.2** and **7.3**.

7.2 Purity Requirements

7.2.1 The ventilation is required to remove polluted air, gases and smoke produced by explosives, dust formed by the disintegration of rock, exhaust gases from the diesel operated equipment like locomotives,

dumpers, trucks, shovels, etc, and also to ensure temperatures of not more than 40°C dry and 29°C wet at the working place (*see* 1.2).

7.2.2 The concentration of various gases in atmosphere inside the tunnel by volume shall be as follows:

- a) Oxygen — not less than 19.5 percent.
- b) Carbon monoxide — not more than 0.005 percent.
- c) Carbon dioxide — not more than 0.5 percent.
- d) Nitrogen fumes — not more than 0.000 5 percent.
- e) Methane — not more than 0.5 percent at any place inside the tunnel, for example, in a cavity in the roof, etc (*see also* 3.1.3).
- f) Hydrogen sulphide — not more than 0.001 percent.
- g) Aldehyde — as formaldehyde not more than 0.000 2 percent.

7.2.3 Testing — The tests shall be carried out once every 24 hours but in any case after every blast or a major rock-fall. In case any of the gases mentioned in 7.2.2 are detected to have crossed the threshold value indicated therein, the workmen shall be withdrawn immediately till the percentage is brought down well below the threshold value by improving the ventilation or by other effective measures.

7.2.3.1 Records for the tests of gases as also for temperature measurements and ventilation measurements shall be properly maintained.

7.3 Dust Control — Adequate steps shall be taken to prevent the liberation, accumulation and the propagation of air-borne dust. Only wet drilling shall be permitted inside the tunnel and other underground works. Besides wet drilling, there shall be adequate ventilation for dust control and periodical medical check up of the workers, working in the tunnel shall be done to check up their physical fitness. Such check shall be at least once in three months and the results recorded in the registers provided for the purpose.

7.3.1 The air-borne dust concentration at the working face shall be tested once a month and if the air-borne concentration of total dust exceeds 10 mg/m³ ventilation shall be adequately improved. If required water spraying of the air-borne dust will be resorted to.

NOTE — It is assumed that the air-borne dust is mainly nuisance dust containing not more than 1 percent free silica and also does not contain other toxic impurities.

7.4 Volume of Air Required

7.4.1 Ventilation and exhaust system for tunnel and shaft excavation shall be of sufficient capacity to maintain an adequate supply of uncontaminated pure air at all points in the tunnel or shaft. The design of ventilation system shall provide for size and design of diesel engines to

be used as well as for safe hygienic limits for exposure of employees to the multiple toxic and objectionable gases in the tunnel or shaft.

7.4.2 The volume of air required shall depend on the following:

- a) Length of heading,
- b) Size of tunnel.
- c) Type and amount of explosives used,
- d) Frequency of blasting, and
- e) Temperature and humidity.

On tunnel work 4.25 m³ of air/min/man is usually considered the minimum requirement. In addition to this 2.00 m³ of air/min shall be supplied for such brake horse power of diesel locomotive or other diesel engine used in the tunnel. Where the temperature is high or heavy blasting is resorted to suitably augmented volume of air shall be provided.

8. SCALING AND MUCKING

8.1 Scaling

8.1.1 After blasting inside a tunnel or a shaft scaling shall not commence unless the roof and walls of the tunnel and sides of the shaft are carefully inspected by a tunnel foreman.

8.1.2 Scaling shall be performed only by the experienced crews under the direct supervision of a competent supervisor.

8.1.3 If the structure of the rock is weak, poor or structurally defective it shall be adequately supported by providing either rock bolts or timber or steel supports with proper lagging and back filling and or by shot creting. Also, if the tunnel excavation is in clay, silt, sand or weak layers, the strata shall be supported by well designed members either of wood or steel immediately before further excavation is undertaken. The construction of concrete lining wherever provided for these purposes should follow closely the excavation operations. There should not be a prolonged time interval between the two operations as the risk of accidents increases with such delays.

8.1.3.1 For tunneling in soft strata, the provisions of IS:5778 (Part III)-1972* shall be followed in respect of quick supporting of such strata (*see also 2*).

8.2 Periodical Inspections

8.2.1 More accidents in tunneling result from rock falls than from any other cause. Except for prematured explosions, rock falls are also perhaps the most serious of all tunnel accidents.

*Code of practice for construction of tunnels: Part III Underground excavation in soft strata.

8.2.2 Careful and frequent inspection of walls and roofs as well as of tunnel supports shall be carried out. Thorough scaling of loose rocks at all weak spots are the best preventives against the rock falls. Periodic inspection of untimbered sections of the tunnel from a travelling scaling platform shall be carried out for locating weak spots. Supported sections shall also be inspected regularly to make sure that the weakness of the formation has not spread beyond the supports. Loosened rock shall be supported/removed forthwith. All supports shall be checked occasionally to make sure that there is no member under distress. All scaling platforms shall be equipped with safe ladders.

8.3 Mucking

8.3.1 The loading zones shall be well lighted and workmen shall be kept away from the vicinity of the cars being loaded to prevent injury due to rock falling off the car.

8.3.2 Loading of muck into either cars or dumpers shall be done evenly, and the muck shall not be piled dangerously high above the sides.

8.4 Rolling Stock Track

8.4.1 As far as possible, electric power shall preferably be used. Whenever diesel engines are used, they shall be provided with suitable filters, scrubbers, etc, to remove all carbon monoxide and oxides of nitrogen, etc. Petrol engines shall not be used.

8.4.2 Use of rolling equipment with link couplers shall not be permitted. Rocker or cradle type dump cars shall be provided with a positive type lock to prevent accidental dumping in mucking yards.

8.4.3 The trolley tracks shall be properly laid with points, crossings and junctions and adequately maintained.

8.4.4 At each end of the track suitable blocks or buffers shall be provided.

8.4.5 Deadman switches or other installation necessary shall be provided to check accidents occurring due to runaway muck cars.

8.4.6 Trains shall be operated with care and at a speed under control of the operator at all times. If the locomotive is pushing a string of cars, a man shall ride in the front equipped with a whistle and a flash light for warning men along the track and for signalling the locomotive operator.

8.4.7 Every locomotive shall have a head light on each end. It shall be equipped with a whistle or horn with a tone of sufficient volume to be heard by men along the track when the air drills are working.

8.4.8 The crew, working tip wagons on trolley tracks shall be given whistles so that they can announce the movement of tip wagons by blowing the whistles.

8.4.9 A shovel shall never be left unattended with engine running and brakes not set. When it is necessary to park it on a sloping ground, it shall be securely blocked. The operator while leaving the machine shall remove ignition key and keep with him or hand it over to some responsible person so that the machine cannot be operated by unauthorized persons.

8.5 Transport of Material — Cars carrying pipe, rail and timber shall be properly loaded for safe passage through the tunnel. The load shall be kept within the side limits for the car. Loads projecting over the sides are dangerous to men working in the tunnel. If wide loads are transported, a special care shall be ensured in the operation of the train with ample warning to the workmen along the track to ensure a safe journey.

8.6 Transport of Employees — No one shall be allowed to ride on front steps of a loco or on a coupling. None other than trainmen shall ride the dump cars in going to and from work at change of shift or at any other time. A safe and smooth walkway system shall be provided for pedestrians.

8.7 Concreting, Grouting and Guniting

8.7.1 Usual safety precautions that are taken for concreting in open shall be applicable for the concreting of tunnels, shafts and other underground works also.

8.7.2 In addition, the following precautions shall be taken where the pumpcrete or pneumatic placer is used:

- a) The scaffolding supporting the pipe shall be designed to carry the pipe when filled with concrete plus 100 percent overload plus the estimated weight of the maximum number of workmen that may work on the pipes while the pump is operating. A factor of safety of 4 shall then be used.
- b) The pipe line shall be anchored at all curves and near the end. The toggle and flange connections shall be inspected before each placement to ensure tight joints. Air-release valves shall be installed at high points to release entrapped air. The use of these valves will assist in preventing line plugging and in turn reduce accident possibilities.
- c) Pipes and hose used to convey grout shall be of proper size and strength to safely withstand the maximum operating pressures. Pumps shall not be operated at pressures above their rated capacity.

- d) Cleaning of pipe line shall be carefully done.
- c) All workmen in the vicinity of sand blasting or guniting operations shall wear goggles and respirators.
- f) Adequate lighting and ventilation shall be provided for all galleries and shafts where grouting is in progress.

3.8 Pathways

3.8.1 In large tunnels the walk ways shall be placed to the side of track.

3.8.2 In long tunnels, shelter places for workmen shall be provided at suitable intervals during hauling operations.

3.9 Public Safety — Shaft sinking and tunneling fascinate the public. Authorized visitors shall be equipped with safety hats and shall be accompanied by a guide competent to keep the visitors out of dangerous situations.

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