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Guidelines for Safety in Tunnels during construction



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PREFACE

This report is prepared on the basis of field visit, literature survey and literature search on Internet. Views expressed in this report are subject to modification from time to time in the light of future developments on the subject and as such do not represent the views of the Ministry of Railways (Railway Board), Government of India.



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SYNOPSIS

Tunneling projects have always remained a challenge for engineers owing to the unpredictable behavior of the ground strata. Present Report is based on field visit, literature survey of codes & reference books and literature search on Internet. . This report covers safety precautions and maintenance practices of tunneling.

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1.0 Safety at the design and planning Stage:

1.1 General:

- 1.1.1 The design and planning stage of any tunnelling project should be adequately resourced in terms of money, staff and time.
- 1.1.2 Resources (time, money and expertise) spent on design and planning as well as on ground investigation and its interpretation should result in a more informed choice of excavation and lining methods and in more effective planning of safe construction methods.
- 1.1.3 It is recommended that preliminary research/investigation works like those mentioned below be done during planning/design stage to have a proper appreciation of ground & site conditions:
- Research of available historical data, existing regional and site specific geological data etc.
 - Consultation with concerned National/State bodies (like GSI, CWC, Irrigation & Water Supply departments etc.)
 - Consultation with utility service providers, particularly in urban areas, including the electricity, gas, water, communications, highway etc.
 - Survey of the condition of adjacent buildings or subsurface structures whose structural integrity may be affected by the proposed tunnelling works.
 - Adequate Ground/site investigation by means of seismic methods, boreholes, trial pits, exploratory shafts and tunnels etc. (in accordance with advice of experts/designers).
 - An assessment of the geology & hydrology of the area.
 - An assessment of the risk of encountering methane or other hazardous gas in the ground or hazardous substances such as asbestos or industrial waste - solid or liquid.
 - An estimate of the levels of atmospheric and other contamination in the tunnel during construction e.g. dust from rock drilling, concrete spraying etc.
- 1.1.4 Thorough review should be made of the preliminary research/investigation results and how they may affect:
- The selection of the most appropriate tunnelling shape.
 - The selection of the most appropriate tunnelling methodology.
 - The selection of suitable tunnelling machinery.
 - The selection of appropriate support & lining methods.
 - The monitoring scheme to be put in place to evaluate the safety of the working environment during the construction phase.

1.2 Risk Assessment:

- 1.2.1 Once the tunnel construction has been awarded but before any construction work takes place, risk assessment should be undertaken after identification of likely hazards and for each risk occurrence an estimate of the possible resulting consequences should be determined.
- 1.2.2 Based on that assessment appropriate risk mitigation and control measures should be taken to control or minimise the risks.
- 1.2.3 On-going risk assessment will be needed during the construction phase, particularly if design changes are made or unforeseen ground conditions encountered.

1.3 Health and Safety Plan (HSP):

- 1.3.1 Before actual commencement of work, occupational health and safety strategy for the work should be drawn up and set out in a Health and Safety Plan. The Health and Safety Plan should form the basis for the identification and management of all health and safety risks arising from the works. The engineer-in-charge for the work should join with the designers and contractors for developing the HSP & monitoring its implementation.
- 1.3.2 Tunnelling involves both the general construction risks and risks specific to the tunnelling environment and therefore HSP should be developed by competent staff.
- 1.3.3 The plan should also contain details of emergency procedures, workers welfare measures and medical facilities. A copy of the plan should be made available to all supervisors/engineers at site. Workers should regularly be briefed/educated about provisions of HSP relevant to their work area.
- 1.3.4 Careful consideration should be given to the design and safety of any temporary works associated with the tunnelling project. These could include: temporary access shafts and adits, pilot tunnels, any temporary ground support etc. along with materials storage areas, working areas and site offices.
- 1.3.5 While many of the main hazards to be addressed in the plan are covered in some detail in the following sections, it is expected that site specific HSP will cover all the identified risks & corresponding avoidance, control & mitigation measures.

2.0 Safety Management & Training:

- 2.1 Safety policies should be established for all the parties involved in the project which will include a clear chain of command and communication. These policies should also specify responsibilities for safety.

2.2 All operations inside the tunnel or shaft shall be carried out under the supervision of a competent engineer. The engineer shall be responsible for ensuring safety stipulations laid down for the work, to enforce the rules, guard against the use of defective safety appliances, tools and materials, to see that no man is permitted to do work for which he is not qualified and to brief all workmen on the plan of work before it is started with special emphasis on all potential hazards and on the ways to eliminate or guard against them.

In larger jobs these responsibilities and function in respect of safety arrangements may be delegated to an independent qualified and competent safety officer working under the overall control of the engineer-in-charge. Periodically meetings preferably once every month shall be conducted to review the effectiveness of safety measures.

2.3 Appropriate training courses should be designed and put in place for people unfamiliar with the nature of the tunnelling work to be undertaken. No workers should be deployed to work underground unless they have undergone a safety and health orientation programme to acquaint them with all the hazards associated with all the operations.

2.4 For a tunneling operation where 25 or more employees have to work underground at any one time, at least one rescue crew of 5 employees per shift must be trained in rescue procedures and resuscitation, the use, care and limitations of oxygen breathing apparatus, and the use and maintenance of fire fighting equipment.

2.5 For a tunnelling operation where less than 25 employees work underground not less than 5 employees must have such training in rescue work.

2.6 Workmen shall be thoroughly instructed in safety rules and shall be required to follow them at all times. All workers should also be trained in use of safety devices and appliances provided to them. Workers who are not aware of hazards, peculiar to the work should not proceed to work without being properly instructed and they should obey the instructions of qualified and authorized person under whom they would work. They shall be required to report immediately if any unsafe conditions observed. In case any worker feels that he cannot perform a work safely he should immediately inform the site in charge of his inability to carry on with the work.

2.7 The engineer in-charge may also seek guidance about the bad reaches expected to be met in the tunnel from the geologists so that necessary safety measures could be adopted.

2.8 Where the geological data collected so warrants, advance probe holes drilling shall be drilled ahead of the tunnel faces to locate any flowing mass of rock, aquiferous strata, geological disturbances, gas etc. In case presence of gases like methane is detected, further tunnelling work shall be stopped and the advice of Director General Mines Safety (DGMS) shall be sought.

2.9 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 in format approved by Engineer-in-charge. Probable reasons of accidents shall be investigated and precautionary measures taken to avoid further recurrence.

- 2.10 There should be procedures for the handing over of critical safety related information from the outgoing to the incoming shift. A written record of this information should be maintained.
- 2.11 Accidents occurring during the fortnight shall be discussed in the safety meetings and adequate publicity shall be given to the causes of these accidents and their preventive measures.
- 2.12 Display of names, contact numbers and addresses of officials/organisations to be contacted in case of emergency should be done at prominent locations of the site.
- 2.13 Mock drills should be conducted periodically (preferably once every six months) to assess the level of safety preparedness/ awareness. Appropriate state Govt./District administration authorities should also be briefed about and involved in conducting of mock drills. Mock drill can include scenarios for evacuation and rescue/ relief in case of “fire accidents” serious injuries to workers etc.

3.0 General Safety Measures:

3.1 Medical facilities:

- a) First-Aid Arrangements: 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. Depending upon the magnitude of the work the availability of an ambulance at a very short notice (at telephone call) shall be ensured.
- b) First-aid arrangement 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 for calling the medical officer, when such a need may arise. It is recommended that engineer or foreman who is normally present at each working face in each shift be given adequate training on first-aid methods to avoid employment of a separate attendant.
- c) Stretchers and other equipment necessary to remove injured persons shall be provided at every shift and portal.
- d) 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.

3.2 Stacking of Material:

Only the materials required for work in progress shall be kept inside the tunnel. All other materials shall be kept in a planned & organized manner to avoid mishaps & to enable the workers to get out of the tunnel quickly in case there is any collapse or any other mishap inside the tunnel.

Following special precautions should be followed for storage/handling of flammable material:

- a) All storage, handling and use of flammable liquids shall be under the supervision of qualified persons. Unless totally unavoidable, flammable liquids shall not be stored inside the tunnel.
- b) All flammable liquids shall be kept in a secure fire resistant store protected from electrical sparks, welding sparks, open flames and smoking.
- c) Only such amounts of flammable liquids should be issued as are required for immediate use. Cans for carrying flammable liquids should be leak proof and properly stoppered and clearly marked "FLAMMABLE LIQUID."
- d) 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.
- e) All combustible materials like rubbish shall be continuously removed from such area 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.
- f) Fire extinguishers and fire-buckets appropriate to the hazard should be conveniently located and identified.

3.3 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. Maximum distance between two telephone should preferably not exceed 500 m.

3.4 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:

- 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 tunnelling work. The position of the operating switch although temporary shall be so chosen as to ensure proper accessibility and easy identification.
- By the use of two field (magnet type) telephone.
- Any other suitable arrangement like walkie-talkie.
- For 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.
- Red and green lights of adequate size and brightness shall be provided at suitable intervals on straight lengths and curves etc. to regulate the construction traffic.

In all the cases as above the system(s) shall be subject to daily checks regarding proper serviceability. These checks shall be carried out under the supervision of a responsible person.

3.5 Ventilation & Protection from Noise:

Ventilation: Measures to keep workers safe from harmful effects of dust, gas, smoke and high temperature in tunnel during construction fall under any of the following three categories:

- 1) Management to reduce the generation of dust, gas and smoke.
- 2) Individual protection.
- 3) Adoption of appropriate ventilation system.

The selection of explosives generating less gas/fumes, the adoption of wet type shotcreting having less rebound, the adoption of mechanical excavation system without using explosive, etc, belong to the first category.

The requirement of workers using personal protective equipment like safety goggles, gas masks, falls under second category.

The adoption of ventilation system using a fan or blower, and dust collector falls under the third category.

3.5.1 In general, fresh air must be supplied to all underground work areas in sufficient amounts to prevent any dangerous or harmful accumulation of dusts, fumes, mists, vapors, or gases. A minimum of 200 cubic feet of fresh air per minute is to be supplied for each employee underground. Mechanical ventilation, with reversible airflow, is to be provided in all of these work areas, except where natural ventilation is demonstrably sufficient.



3.5.2 Where blasting or drilling is performed or other types of work operations that may cause harmful amounts of dust, fumes, vapors, etc., the velocity of airflow must be at least 30 feet per minute.

3.5.3 For gassy or potentially gassy operations, ventilation systems must meet additional requirements.

3.5.4 The exposure to airborne contaminants of an employee working in a tunnel or shaft should not exceed the specified exposure limits.

3.5.5 Employees should be removed from any area in which there is an airborne contaminant at a concentration which exceeds the exposure limit for that contaminant.

3.5.6 Portable instruments should be provided to test the atmosphere quantitatively for carbon monoxide, hydrogen sulphide, nitrogen dioxide, flammable or toxic gases, dust or other toxic contaminants that occur in the tunnel or shaft. Tests should frequently be conducted to ensure that the required quality of air is maintained. A record of all tests should be maintained and be kept available for inspection.

Protection from Noise: Deafness caused by noise at the working place is a recognized occupational illness, and tunneling is one of the noisiest occupations. Exposure to a noise level of 85 dB(A) can cause damage to hearing. Steps must therefore be taken to reduce the noise.

As far as possible noise in the environment should be reduced through a number of measures like:

- Reduce noise from a machine at source.
- Fit larger mufflers to exhaust and ventilation fans.
- Erect screens to separate the source of noise from the rest of the working area.
- Improved maintenance of machine.
- Improvements in design of machines.

The risk from, exposure to noise can be reduced by reducing the exposure time however this leads to increased labour costs and may not be commercially viable for tunneling. Consequently the measures outlined above should be taken.

Where this cannot be done for technical reasons, personal hearing protective equipment must be provided. As proper protection is only possible when the protective devices are properly fitted and worn, an effective assessment, fitting and training program should be put in place.

3.6 Lighting:

3.6.1 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.



3.6.2 Emergency lights 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.

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

3.7 Protection against fire:

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

3.7.2 No flammable material shall be stored in rooms, recesses or compartments containing electrical apparatus (other than telephone & lighting apparatus).

3.7.3 **Fire Fighting Equipment:** Clearly visible **Fire Points** shall be established inside the tunnel (near any room, recess or compartment etc.) for use in an emergency.



Each fire point should have available as a minimum the following type of equipment:

- (a) Dry Powder Extinguisher.
- (b) Water Type Extinguisher.
- (c) Bucket of Sand.



Recharging of fire extinguishers and their proper maintenance should be ensured and as a minimum should meet Indian Standards. These equipments shall be tested at least as per manufacturer's specifications.

Water supply for fire fighting purposes should be provided at the construction site. This may be in the form of static water tank of adequate capacity or a hydrant line with adequate water pressure at outlet points.

Sufficient number of fire hoses with branch pipes should be provided at site so that the fire can be controlled until the arrival of the Fire Brigade.

The contractor shall need to give consideration to the provision of adequate fire fighting arrangements within the underground and tunnelling operations including the provision of Fire Service compatible hose connections and emergency lighting.

The Telephone Number of the local fire brigade should be prominently displayed near each telephone on site. Fire Alarms should be provided at appropriate locations inside the tunnel.



Supervisors and workmen at the site should be trained in the use of fire fighting equipment provided at the site.

3.7.4 On the occurrence of a fire caused by any electrical apparatus or a fire liable to affect any electrical, the supply of electricity should be cut off from such apparatus or installation as soon as practicable.

3.7.5 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.

3.8 Electrical installations:

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

3.8.2 General Provisions: All parts of the electrical installations shall:

- 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.
- be so constructed, installed and maintained as to prevent danger of fire, external exposition and electric shock.
- be of adequate mechanical strength to withstand working conditions underground.
- be not liable to be damaged by water, dust or electrical, thermal or chemical action, to which they may be subjected.
- be efficiently insulated or have all bare live parts enclosed or otherwise protected.
- be installed at such a location that dumpers do not come in contact with the same.
- Usage of Earth leakage circuit breakers shall be encouraged for distribution of power supply from the panels.
- A passageway not less than 60 cm wide shall be maintained in front of switchboards.
- 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.
- 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.
- 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.
- Identification – Electrical equipments in use shall bear the essential details of voltage, amperage and circuit diagrams, etc.
- 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.
- All electrical apparatus including portable tools shall be connected only to an electrical supply system, which shall have proper earthing and grounding.
- The following notice shall be kept exhibited at suitable places:
 - ❖ A notice on the board of 45 x 30 cm prohibiting unauthorized persons from entering electrical equipment rooms.
 - ❖ A notice on the board of 45 x 30 cm prohibiting unauthorized persons from handling or interfering with electrical apparatus.

- ❖ A notice on the board of 60 x 90 cm containing directions as to the rescue of persons in contact with live conductors and the restoration of persons suffering from electrical shocks.
- ❖ A notice specify the person to be notified in case of electrical accident or dangerous occurrence, and indicating how to communicate with him.
- ❖ Suitable warnings shall be placed at all places where contact with or proximity to electric equipment can cause danger.
- Telephone lines shall be laid on the opposite of the electric side in the tunnel. 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.
- 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.
- 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.

3.9 Personal Safety Equipment:

Personal safety equipment serves as an additional measure to ensure safety where it is not possible to improve the environment by engineering means. Following Personal Safety Equipment should be provided to workers working in the tunnel:

- 3.9.1 Hard hats for head protection should be issued to every person entering the works and the wearing of hard hats should be made compulsory.
- 3.9.2 Eye protection for activities such as welding, Shotcreting etc.
- 3.9.3 If noise levels are excessive and cannot be reduced, hearing protection should be used e.g. ear muffs or ear plugs.
- 3.9.4 Under all conditions where dust levels are high, appropriate respiratory protective equipment should be used, e.g. during shotcreting operations.
- 3.9.5 All underground workers should be provided with safety boots of acceptable quality. Such boots should be suitable for both dry and wet conditions.
- 3.9.6 Hand protection in the form of gloves should be provided where the type of work requires some form of protection. A general purpose type of glove may be adequate for most types of work but special conditions would require special gloves, e.g. special gloves required for welding operations.
- 3.9.7 High visibility clothing including waterproof clothing should be provided and used by all workers underground. No loose clothing shall be worn by the personnel engaged in the tunnelling operation.

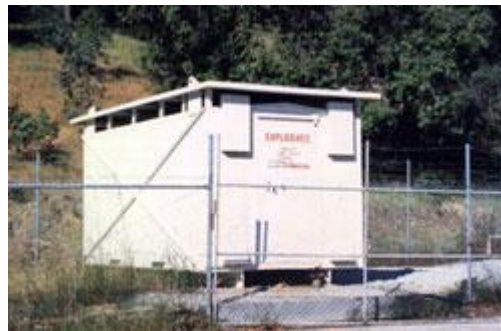
3.9.8 Cap lamps should be issued to all persons entering the underground works except where adequate lighting and emergency lighting systems are installed.

3.9.9 Where necessary, safety harnesses should be provided and used for persons working unprotected at height.

3.10 Use of explosives:

3.10.1 General: The use of explosives is very essential in hard ground open excavation, tunneling construction. Selection and judicious use of proper kind and quality of explosives is essential for success, safety and efficient progress of every job. Proper storage, transportation, handling and use of explosives is important not only to ensure that these materials are kept out of reach of the unauthorised persons and to reduce the hazards of accidental explosion but also to maintain them in good condition for use. The storage, transportation, handling & use of explosives shall be strictly in accordance with the provisions of Indian Explosives Act, 1884, and Rules made there under.

3.10.2 Explosive Magazines:



The following precautions shall be taken for operation & maintenance of explosive magazines.

- a) The magazines shall be clean and the floor be cleaned with a brush on each occasion the magazine is opened for delivery or receipt of explosives.
- b) All magazine keepers shall always ensure that smoking material and matches are not taken into the magazine.
- c) Adequate quantity of water and fire fighting equipment shall be provided in the magazine.
- d) All the tools used in the magazines for opening of explosive boxes shall be of wood or soft non-ferrous metal such as brass, copper or bronze. Iron and steel tools are prohibited as they may cause sparking.

- e) The area surrounding the explosive magazines shall be kept free from bushes and other vegetation.
- f) Empty boxes, loose packing material or cotton waste shall not be kept in magazine premises.
- g) The magazines shall be well ventilated and it is advisable to keep magazines open every day for a period of one hour.
- h) Detailed records of all outgoing and incoming stocks shall be kept. Explosives shall be used according to their dates of manufacture.
- i) All magazines shall be securely locked, when not attended.
- j) Sign boards reading “DANGER, HIGH EXPLOSIVES,” “PROTECTED AREA”, “NO SMOKING” etc. shall be conspicuously displayed in the front of the magazine.
- k) Proper Guard shall be posted to guard the magazine.
- l) Packing cases of explosives shall be stacked on trestles clear of floor and a 15 cm air space shall be left between the cases and walls to allow circulation of air.
- m) Care shall be taken that repairs to the magazines are attended to on priority basis by skilled persons.
- n) Every explosive magazine shall also prominently display:
 - A copy of Explosives Rules.
 - A statement showing the stock in the magazine.
 - Certificate showing the last date of testing of the lightning conductor.
 - A copy of the Licence and lightning conductor test certificate shall also be preserved in the magazine.
- o) The magazine, on no account shall be opened during or on the approach of a thunderstorm and no person shall remain in the vicinity of the magazine during such a storm.
- p) Magazines shall be guarded at all times. Guards shall also be properly trained in handling fire fighting equipment.
- q) Magazine shoes, without nails, shall be kept at all times in the magazine. Persons entering the magazine shall put on the magazine shoes provided for the purpose.
- r) Wooden tub or cement trough, approximately 300 mm high and 450 mm in diameter filled with water shall be fixed near door of the magazine.

3.10.3 Transportation of Explosives:

- a) Explosives shall be transported in specially fabricated explosive van confirming to the provisions of Explosives Rules. 1983.
- b) The van shall bear the inscription "EXPLOSIVES VAN" so as to warn the workers and the public. 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.



- c) Metal tools, oil matches, electrical storage batteries, acids or other corrosive compounds, etc, shall not be carried in the vehicle.
- d) At the back of the van, there shall be two chains hanging from the body in such a way that all the time they touch the ground to provide necessary Earthing for safety against lightning or short-circuiting of the vehicle.
- e) The driver should have valid license, physically fit and familiar with the precautions to be taken while carrying the explosives in the vehicle.
- f) Two Carbon dioxide fire extinguishers, each of not less than 3 kg. Capacity, conforming to relevant IS, shall be carried on each vehicle. The driver shall know how to operate the fire extinguishers.
- g) A motor vehicle carrying explosives shall not be re-fuelled except in emergencies and even then only when the motor has been stopped other precautions have been taken to prevent accidents.
- h) Loading, unloading and handling of explosives shall be supervised by qualified personnel. At the time of loading or unloading of explosives, no electrical switch should be operated.

- i) The containers shall be of standard make as designed in accordance with Explosive Rules and relevant Indian Standards.
- j) Containers used for storing explosives or detonators shall be used for that item only.
- k) Smoking shall be prohibited in the vehicle carrying explosives and in its vicinity.
- l) No unauthorised person shall be allowed in the vehicle carrying explosives.
- m) Explosives and detonators of blasting caps shall not be permitted to be transported in the same vehicle.
- o) Detonators and other explosives for blasting shall be transported to the site of work in the original containers or in securely locked separate non-metallic container and shall not be carried loose or mixed with other materials.
- p) Care shall be taken in loading and unloading of explosives. The filled containers shall not be handled roughly or dropped.
- q) Drivers shall not leave the vehicles unattended while transporting explosives.
- r) The speed of the vehicle shall not exceed 25 km/h on rough roads and 40 km/h elsewhere.
- s) Vehicles transporting explosives shall not be taken into a garage, repair shop or parked in congested areas, public parking or similar places.
- t) Explosives shall not be transported on public highways during darkness, except in emergencies and even then only when the written approval of the project authorities has been obtained. Such vehicles shall be fitted with adequate warning lights on both ends, while operating in darkness.
- u) Explosives shall not be transferred from one vehicle to another on public highways, except in cases of emergency.
- v) For transportation by road, the quantity of explosives carried in single vehicle shall not exceed 75 % of the rated load carrying capacity of that vehicle or 3,600 kg, whichever is less.
- w) Place of Loading and unloading - Loading and unloading of explosive shall be done at safe distance from dwelling housed, powerhouse buildings, transmission tower, stores of petroleum, stores of timber or any other flammable materials.
- x) The explosive van used for transportation of explosives shall be inspected before every use with following checklist:
 - Fire extinguishers - for their healthy condition.

- Electrical wirings - for complete protection to prevent short-circuiting.
 - Chassis, motor, pan and underside of the body of the vehicle - for reasonably clean and free of excess oil or grease.
 - Fuel tank and feed line - for no leaks.
 - Brakes, lights, horn, windshield, wipers and steering apparatus - for their good functioning.
 - Tyres - for proper inflation and defects.
- y) Supervision: Explosive shall be transported by or under the supervision of competent persons who are fully experienced in the work and who have received adequate instructions as to the dangers connected therewith and the precautions to be observed.
- z) Explosives shall not be transported to the site of operation except in suitable cases or containers which are so made as to prevent any spillage of explosives and any danger of sparks or other sources of ignition during conveyance. No explosive shall be removed from such cases or containers except when it is to be used forthwith for the purpose of the work.
- aa) No explosives shall be transported in a mechanically propelled vehicle unless such vehicle is locked and is of a type approved in writing by the Chief Inspector of explosives.
- bb) Vehicles must have springs under the body. Unsprung country carts should not be used. Tyre pressures shall be as per India Explosives Regulations.
- cc) Besides the driver, only one helper shall be accommodated in the vehicle. The vehicle carrying the explosives must not be used to transport workmen or other materials to work spots although there may be enough space for men or materials.
- dd) 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.
- ee) 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 6mm 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 canvas handle or a strap. For use of plastics in the container for carrying explosives, prior permission of Chief Inspector of explosives shall be obtained.



- ff) 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 dislodgment from car in transit.
- gg) 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.

3.10.4 Handling and use of explosives:

- a) Handling of explosives shall be avoided during thunderstorm or when thunderstorm is expected. All persons shall retire to place of safety.
- b) Any package containing explosives shall not be dragged, dropped or handled roughly.
- c) Sparking metal tools shall not be used to open kegs of explosives.
- d) Smoking shall not be permitted nor matches, open lights, fire, flame, or any other device capable of producing sparks or flame shall be carried while handling or using explosives.
- e) Explosives shall not be placed where these may be exposed to flame, excessive heat, sparks or impact.
- f) The covers of the explosive cases or packages shall be replaced every time after taking out part of the contents as long as any explosives are left in them.
- g) Explosives shall not be carried in the pockets or folds of clothing by any person.
- h) Nothing shall be inserted in the open end of a, blasting cap except fuses.
- i) No person shall strike, tamper with, or attempt to remove or investigate the contents of a blasting cap or an electric blasting cap or attempt to pull out the crimped safety fuse out of a blasting cap.

- j) Children and unauthorised or unnecessary persons shall not be present where explosives are being handled or used.
- k) No attempt shall be made to soften hard-set explosives by heating over a fire or by rolling the explosive on the ground.
- l) The blasting powder, explosives, detonators, fuses, etc, shall be in good condition and not damaged due to damp moisture or any other cause. They shall be inspected before use and damaged articles shall be discarded totally and removed immediately.
- m) No attempt shall be made to reclaim or use fuses, blasting caps, electric blasting caps or any other explosives, which have been water soaked, even if these have been dried out. The manufacturers shall be consulted.

3.10.5 Explosives Disposal:

- a) No explosive shall be abandoned. These shall be disposed off or destroyed strictly in accordance with the approved methods and in doing so the manufacturers or the appropriate authority shall be consulted. The expired deliveries shall be sent back to the manufacturer.
- b) Explosives, caps, boxes, or material used in packing of explosives shall not be left lying around in places to which children or unauthorised persons or livestock can have access.
- c) Paper or fibrous material employed in packing explosives shall not be put to any subsequent use. Such material shall be destroyed by burning in the presence of a responsible person.

3.10.6 Explosive Accountal:

- a) A careful day-to-day account of the explosives shall be maintained in a register in an approved manner, which shall be open to inspection at all times by the concerned authorities.
- b) Explosives shall be issued only to competent persons upon written requisition signed by the blaster or by an official authorized for the purpose and only against the signature or thumb impression. Such requisitions shall be preserved by the person-in-charge of the magazine.

3.11 Safety while working with Construction Machinery& equipment:

Appropriate precautions for safety while working with construction machinery & equipment shall be followed as per Manufacturer's guidelines & applicable codes. Special care should be taken while working with compressed air in accordance with Manufacturer's recommendations and applicable Indian Standards.

3.12 Access Control:

An access control system should be operated to account for all personnel underground and to restrict access to the underground workings to authorized persons only. Visitor groups should only enter the tunnel when they are not endangered by operation and traffic. Visits shall be organized accordingly.

3.13 Insects-leeches-Vermins-Snakes:

Protection against hazards involving insects, vermins, leeches or snakes shall include the following:-

- Instruction regarding potential hazards.
- Boots, hoods, netting, gloves, masks or other necessary.
- Drainage or spraying of breeding areas.
- Elimination of unsanitary conditions which propagate insects or vermins.
- Approved first-aid remedies for the affected.

3.14 Tunnel Instrumentation:

Use of appropriate kind of tunnel instrumentation is advisable to ensure adequate design of support system & monitoring of tunnel deformations.

4.0 Safety Requirements for various activities during construction:

The works involved in tunnelling is very specialized and hazardous in nature. Cramped working space (particularly in the heading), wet and slippery flooring, artificial lighting – too often inadequate, difficult ventilation, obnoxious gases, unseen weakness in the rock, handling of explosives, leading and hauling muck, haphazardly lying/stored construction material etc. might contribute to accidents.

Safety Precautions/Measures as detailed below should be taken to ensure safety during the construction period. It is recommended that site specific detailed method statements be developed; also listing various safety precautions to be taken during different construction activities.

4.1 Underground Excavation

4.1.1 Drilling Equipment:

- All drilling equipment shall be kept in good working order. Safe handling and proper lifting methods shall be used.
- Only wet drilling shall be permitted
- 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.

4.1.2 Drilling operations: The drilling operations shall be carried out with due safety precautions:

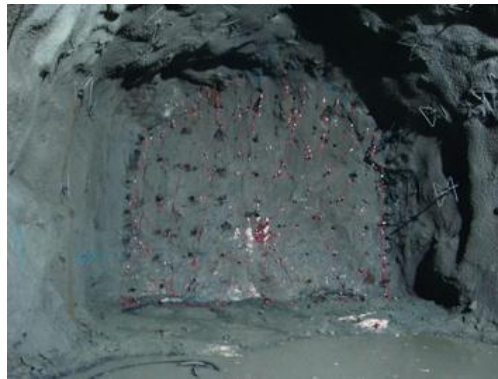
- While planning drilling operations for blasting purpose, consideration must be given to the nature of stratum and the overburden with a view to avoiding the possibilities of heavy loose fall, chimney formation, excessive loosening etc. after blasting.
- The position of all holes to be drilled shall be marked out.
- The face of rock shall be carefully examined before drilling, to determine the possible presence of unfired explosive. No attempt shall be made to drill at a site if undetonated explosives are suspected.
- No drilling shall be started until previous holes in the blasted area are flushed with air and water.
- A drill hole near another hole loaded with explosives shall not be sprung.
- All holes shall be of slightly greater diameter than the diameter of cartridges of explosives used.
- 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.
- No person shall be allowed to deepen drill holes, when have contained explosives, or blasting agents, or insert a drill, pick or bore in butts of old holes even if examination fails to disclose explosives.
- Charging of drilled holes and drilling shall not be carried out simultaneously in the same area by using non-electric detonation.
- The air supply manifolds and the lines of supply to each drill shall be examined according to the numbers of drilling equipment.
- Rock drillers shall be equipped with approved respirators for use in siliceous dusty atmosphere arising out of drilling operations.

Use of mechanised drilling with machinery like drilling jumbo would help in improving safety during drilling operation.



4.1.3 Loading & Blasting: Loading and Blasting is a specialized job involving a numerous hazards, which often lead to accidents. It is necessary that safety precautions shall be

scrupulously followed these operations with a view to minimize the risk of accidents and injuries.



- The drill hole shall be carefully checked for length, presence of water, dust, etc., with a wooden tamping pole before loading. It shall be cleared of all debris before explosives are inserted.
- Surplus explosives shall not be stacked near working areas during loading.
- Loading and drilling shall not be carried out at the same time in the same area.
- Cartridges or explosives shall not be forced down a drill hole or on obstruction in a drill hole.
- No holes shall be loaded except those to be fired on the next round of blasting and after blasting, all remaining explosives and detonators shall be immediately returned to an authorized magazine.
- No cartridge shall be cut or explosive removed from it for any purpose whatsoever.
- Metallic devices of any kind shall not be used in tamping. Wooden tamping tools with no exposed metal parts except non-sparking metal connectors for jointed poles shall be used. Violent tamping shall be avoided.
- Care shall be taken to confine the explosives in the borehole with sand, earth, clay or other suitable non-combustible stemming material.
- Welding / cutting of metal shall not be done, inside the tunnel at the time of loading at the face, until the blast has been fired.
- Blasting shall be carried out only by competent, experienced supervisor and workmen who are thoroughly acquainted with the details of handling explosives and blasting operations. All the materials, tools and equipment used for blasting operations shall be of approved type.
- The blaster shall be licensed, competent and qualified and should have working knowledge of Rules & Regulations pertaining to explosives. The blaster shall be in good physical condition and not be under influence of drugs, alcohol, intoxicants, etc.

Inspection after blasting:



- a) Immediately after a blast has been fired, the firing line shall be disconnected from the blasting machine or other source of power.
- b) 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.
- c) All wires shall be carefully traced and search made for any unexploded cartridge by the man-in-charge of the blasting operation.
- d) Sufficient time shall be given for the fumes to clear before permitting the labour to work for mucking operations.
- e) 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.
- f) Misfired holes shall be dealt with by the blaster preferably by the same person who had done the charging operations.
- g) 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.

4.1.4 Defuming: Appropriate defuming time should be allowed to lapse before allowing workers to resume the work.

4.1.5 Scaling and Mucking:

Scaling:

- a) Scaling shall not commence unless the roof and walls of the tunnel and sides of the shaft are carefully inspected after the blast by a tunnel foreman.

- b) Scaling shall be performed only by the experienced crews under the direct supervision of a competent supervisor. Use of mechanical scalers would go a long way in ensuring safety during this highly safety-critical activity.



- c) If the structure of the rock is weak, poor or structurally defective it shall be adequately supported by providing appropriate support system depending on soil/rock classification or type.
- d) For tunneling in soft strata, the provision of IS: 5778-Part III (Code of practice for construction of tunnels) shall be followed in respect of quick supporting of such strata.
- e) Periodical Inspections: More accidents in tunneling result from rock falls than from any other cause. Except for premature explosions, rock falls are also perhaps the most serious of all tunnel accidents.

Careful and frequent inspection of walls and roofs as well as of tunnel supports shall be carried out. Through scaling of loose rocks at all weak spots are the best preventives against the rock falls.

Periodic inspection of un-supported 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 ensure 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 sat ladders.

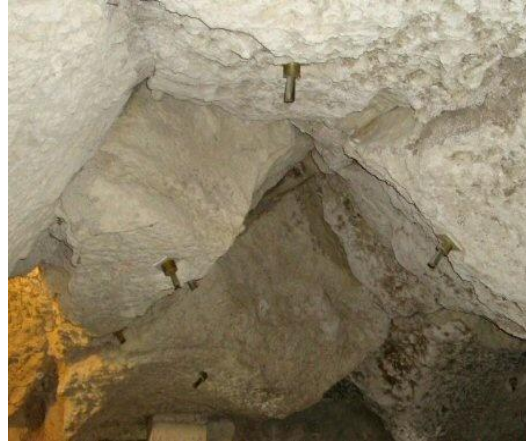
Mucking:



- a) The loading zones shall be well lighted and workmen shall be kept away from the vicinity of the tippers/trucks/dumpers being loaded to prevent injury due to rock falling off the car. The road should be maintained properly with adequate drainage system.
- b) Loading of muck into tippers/trucks/dumpers shall be done evenly; the muck shall not be piled dangerously high above the sides.
- c) Appropriate safety precautions should be followed depending on kind of machinery employed for mucking.
- d) Warning lights & alarms should be fitted in machinery/equipment used for mucking operation.

4.1.6 Installation of Temporary Supports:

- a) Where workers are liable to be injured by falling or sliding material from the roof, face or wall of the tunnel, suitable measures (as per design) such as shotcreting, rock bolting or other appropriate measures should be taken to ensure the safety of the workers.
- b) All supports including steel supports, lagging, backfill concrete, shotcreting, rock bolts etc. should be designed and installed appropriately to ensure the stability of the excavated areas.



- c) The roof, face and walls of the work area in a tunnel should be examined and tested (if required) at the start of each shift and at regular intervals thereafter to ensure that they are safe for the workers.
- d) The stability of temporary supports should be checked regularly.
- e) The bolts should be tested at regular intervals determined by rock conditions and the distance from vibration sources.

4.2 Structural Steel Erection:



- a) All employees working in places where they are exposed to falling hazards should use safety belts.
- b) Hardhats should be worn by employees working on or around erection operation and should be worn with chin straps fastened.



- c) All employees when handling steel cables or other rough or sharp edged materials should wear Gloves of suitable type.
- d) Goggles should be worn when grinding, chipping, scrapping, caulking, cutting and heating rivets.
- e) Good footwear should be worn by all employees and the soles should be kept free from mud and grease.
- f) Workmen should stand in clear when derrick is in operation. The signalman and the operator should check to see that all men have cleared out before lifts are made.
- g) Workmen should not stand, walk or work beneath suspended loads.
- h) When guiding a beam, it should be so held that the hands do not get jammed against other objects.
- i) When lifting and object in a group, one person should be designated to give the signal for all to lift or set the object down in unison.
- j) When lifting, legs should be bent, body kept straight and leg muscles used for the lift.
- k) There shall be no riding on steel that is being hoisted, no riding on the overhauling weights, hooks, cables or slings, nor sliding down on ropes or cables.
- l) Public or workers in other trades operating close to steel erectors should be safeguarded at all times.
 - They should be cautioned and instructed on any exposure condition existing or that may arise and result in accident.
 - They should be advised to wear hard hats when required to work close by.
 - They should be instructed not to operate directly underneath scaffolds that are being used.
 - Red flags or warning signs should be strategically posted to assist in cautioning and instructing others.

- When receiving or unloading steel on job site adequate protection such as barricades, sign flags and watch-man should be provided to protect the public.

4.3 Fall Protection:

Adequate safety precautions including those listed below should be taken to eliminate fall hazards, to prevent falls, and to ensure that workers who may fall are not injured.

- Making fall protection part of detailed Work Plans by identifying and evaluating fall hazards.
- Eliminating fall hazards by engineering solutions, if possible.
- Train workers to recognize fall hazards.
- Use appropriate equipment to prevent falls and to protect workers if they fall.
- Inspect and maintain fall-protection equipment before and after using.

Following measures should be taken to control and eliminate these causes:

- Ensuring that walkways are free from debris, air hoses and electric cords, and projecting materials to eliminate tripping hazards.
- Cleaning up foreign substances such as grease, oil, and mud to alleviate slipping hazards.
- Making sure that work areas and walkways are well lit.
- Keeping floor elevations clearly marked or ramped.
- Ladders should be made of adequate strength material & should be secured properly

4.4 Scaffolds:

4.4.1 Scaffolds of proper type shall be provided for all work that cannot be done from the ground or from part of a permanent structure or from ladder or other available means of support and safe means of access shall be provided to every place at which workers are required to work.

Use of mobile gantry type of scaffolding would help in ensuring safety during related operations:



- 4.4.2 Every scaffold and every part thereof including supports shall be of good construction, of suitable and sound material and of adequate strength for the intended purpose and it shall be properly maintained. Construction and dismantling of every scaffold shall be under the supervision of a competent person. Boards and planks used for the floors shall be of uniform thickness, well jointed, closely laid, and securely fastened in place.
- 4.4.3 Every scaffold shall be securely supported or suspended and shall, where necessary be sufficiently and properly strutted or braced to ensure stability. The use of cross braces or framework as means of access to the working surface shall not be permitted.
- 4.4.4 All scaffolds or working platforms of any nature shall be braced or guyed or adequately secured by other means to prevent sway.
- 4.4.5 During dismantling of scaffolds, necessary precautions shall be taken to prevent injury to persons due to fall of loose materials, bracing and other members of the scaffold shall not be removed pre-maturely. While dismantling, the entire scaffold shall be maintained stable and rigid so as to avoid the danger of collapse. Nails from the planking and various members of the scaffold shall be carefully removed and all material carefully piled.

4.5 Working Platforms:

- 4.5.1 All working platforms from which workers are liable to fall more than 2 m shall be:
- Adequately designed & of adequate width depending upon the type of work done and closely boarded, planked or plated. For platforms, the width shall not be less than 60 cms.
 - Provided with suitable guardrails of adequate strength to height of 1 meter above the working surface to prevent fall of persons, materials or tools.
- 4.5.2 Every platform shall be kept free from any unnecessary obstruction, material or rubbish and from any projecting nails, and when they become slippery appropriate steps shall be taken by way of sanding, cleaning or otherwise to remedy the defect.
- 4.5.3 Each supporting member used in the construction of platforms shall be securely fastened and braced.

4.6 Concreting:

- 4.6.1 Cement Handling:** Workmen should be instructed to ensure personal cleanliness to guard against cement dermatitis and should be advised to report any susceptibility to cement burns. Hand cream or petroleum jelly shall be provided for the use and protection of men handling cement.
- 4.6.2 Formwork:** Safety hazards in form-work construction such as those due to poor housekeeping, leaving materials and tools where they may fall and cause injuries; the tops of forms used as walkways not equipped with standard guardrails on the open side etc. can be reduced, if not eliminated, by careful planning. Formwork shall be adequately designed, handled & maintained properly. All form stripping shall be conducted in a safe and orderly manner and in accordance with the rule for good

housekeeping. All stripped material shall be placed in piles or removed immediately from the work area.

4.6.3 Mixing Plant: Mixing plants shall be adequately designed and precautions taken to protect workmen from falling objects. Walkways, platforms, stairways and ramps shall be well built and protected. The operations of the plant shall be coordinated by signals etc. as may be necessary to ensure the safety of all workmen. An air exhaust system shall be installed to remove cement and other dusts from the inside of the plant. Respirators should be worn when necessary.

4.6.4 Pumped Concrete:

- a) The scaffolding supporting the pipe shall be adequately designed to carry the pipe, overload, workmen etc. with appropriate factor of safety.
- b) The pipeline shall be anchored at all curves and near the end. Air release valves shall be installed at high points to release entrapped air. The use of these valves will assist in preventing line plugging which in turn reduce accident possibilities.
- c) The work of cleaning a pipeline must be carefully done by experienced workmen. If and when necessary to open a pipe to clear it of an obstruction, the work must be carefully done in order that workmen are not injured by concrete blown out by air pressure in the pipe.

4.6.5 Reinforcement:

- a) Reinforcing steel shall be well stacked and segregated as to sizes and lengths.
- b) The main accident hazards in bending reinforcing steel are due to sharp burrs in cutting and the whipping of long flexible rods. Tripping hazards will be present if the rules of good housekeeping are not observed. Employees on this work should wear heavy gloves. A leather or heavy denim apron is desirable.
- c) All persons placing reinforcement steel where a falling hazard is present shall use safety belts.

4.6.6 Concrete Placement

- a) All employees placing concrete should wear hard hats. Shirtsleeves should be rolled down, gloves should be worn, and every reasonable precaution taken to keep cement and concrete off the skin.
- b) The water in freshly mixed concrete contains lime and alkalis and may cause severe and painful damage to skin and eyes. Such contacts should be avoided by using proper protective clothing, boots, gloves, goggles etc. If they should occur, the workman should immediately remove liquids or substances by washing in water.
- c) Men in good physical condition should be employed to operate vibrators.

- d) When concrete is transported by means of chutes, the towers shall be of substantial construction, sound material and ample strength to carry the greatest load that could possibly occur. They shall be properly guyed and provided with safe access. At each level of the chute where men work, landing platforms shall be provided and the chute shall be properly guyed and the area below the spout shall be barricaded when practicable to keep people out of the areas where they might be injured by falling concrete.

4.7 Grouting, Guniting & Shotcreting:

4.7.1 Many of the hazards of grouting, guniting and shotcreting operations are common to other construction operations, and are therefore, covered by the above provisions. However, some of the hazards particularly relevant to Grouting, Guniting & Shotcreting are as given below:

- a) Pipe Hoses: All pipes or hoses used for the purpose shall be of sufficient strength conforming to standard specification to withstand the maximum pressures that may be reached during the operation. Pumps shall not be operated at pressure in excess of their rated capacities, or the safe working strength of the conveying system. All hose couplings shall be of standard types, and makeshift wire connections shall not be used. Pipe or hose laid along ladder ways or ramps shall be located at one side of the travel way in order to prevent tripping hazards.
- b) Only experienced man should be employed for guniting and shotcreting which is a special type of concrete work. The nozzle man and helper shall be provided with safety goggles, and shall use them as protection against rebound material. The nozzle man should operate the nozzle so as to keep the rebounds at a minimum.
- c) All scaffolds or platforms used shall be substantially built. No makeshift type of construction shall be permitted.
- d) All hoses and mixers shall be inspected daily and maintained in a safe working condition.
- e) All other workmen shall be excluded from the immediate working area.
- f) Safety Belts: Men working in elevated position shall use suitable safety belts to guard against falling.

4.8 Welding and Cutting:

4.8.1 General Safety Precautions:

- a) All welding and cutting shall be done by workmen who are thoroughly trained in the work. Shields shall be placed around the work to protect person from glare.
- b) Welding and cutting shall not be done in the immediate proximity of flammable materials.

- c) Welders and helpers shall wear non-combustible helmets and gloves during welding operations. They should be careful to keep out of the line of sparks and hot metal and they should wear clothing free from grease, gasoline, oil and other flammable materials.
- d) A helper shall always be at hand to shut off the gas in case of an accident when the welder is working in a space from where escape is difficult.
- e) All welding operations should be carried out in a well-ventilated space. Where any considerable amount of welding is to be done, an exhaust system for carrying away the fumes should be installed.
- f) All torches, regulators, cylinders and other such equipment shall be of an approved design, regularly inspected and kept in good condition. Defective apparatus and equipment shall be removed from service, replaced or repaired and re-inspected before, again being placed in service. Only persons who are thoroughly familiar with such apparatus shall make repairs.
- g) Welder and helpers shall wear suitable eye-protective devices during welding and cutting operation. Eye exposed to welding or flashes should be washed with rose water for better relief.

4.8.2 Fire Protection for oxy-acetylene cutting and welding: To avoid fire hazards, the following additional precautions should be observed on all oxy-acetylene cutting and welding:

- a) Keep hose and cylinder valves free from grease, oil, dust and dirt.
- b) Keep cylinders away from stoves, furnaces and other sources of heat.
- c) Only 'Gas Lighter' shall be used to light the torch.
- d) Avoid use of oxy-acetylene flame in confined spaces.
- e) Clean thoroughly with steam all containers that have been used for storage of flammable liquids, or wash with hot water and soda, and ventilate thoroughly before welding and cutting.
- f) When testing for leaks use only soap water and watch for bubbles.
- g) Valve protection caps shall be in place when cylinders are not in use.
- h) All employees shall be made familiar with the location and proper use of fire extinguishers in their area of work.

4.8.3 Gas Cylinders: Due care shall be taken while loading and unloading oxygen/acetylene gas cylinders.

- a) Gas cylinders shall be kept up right in approved safe places where they cannot be knocked over and well separated from combustible materials. These safe places shall be painted with appropriate warning signs. Empty cylinders should be

marked 'EMPTY' and the valves closed. Loaded and empty cylinders should be kept in separate places.

- b) Tempering with or attempting to repair safety devices or valves of gas cylinders shall be prohibited and if trouble is experienced in any cylinder, a report shall be sent to the supplier forthwith describing the character of the trouble and particulars of the cylinder.
- c) Cylinders found to have leaky valves or fittings, which the closing of the valve will not stop, shall be taken into the open away from any source of ignition, and slowly drained of gas.
- d) Adequate precautions should be taken in handling cylinders.

4.8.4 Hoses and Torches:

- a) The hose shall be specially designed for use on cutting and welding operations.
- b) Special care shall be taken to avoid interchange of oxygen and acetylene hoses, as the mixture of these gases is highly explosive. Some coloured code should always be used on each gas-red for fuel gas and black for oxygen. Glycerin shall be used for lubricating valves.
- c) Some manufactures dust the inside of the hoses with fine talc. New hoses shall, therefore, be thoroughly cleaned on the interior before attaching to the torch.
- d) Compressed air shall never be used to clean hoses as it may contain oil from the compressor. Oxygen shall be used to clean oxygen hoses and acetylene shall be used to clean acetylene hoses.
- e) Torches that leak at any connection, or get hot, shall not be used.
- f) Cooper or brass wire shall be used to clean the tips. Hardwood sticks may also be used.

4.8.5 Gas Welding and Cutting Operations:

- a) The gas cylinders shall not be used unless fitted with required gauges, regulators & relief devices.
- b) Cylinder valves shall be opened only with hand wheel or tools, specially designed for that purpose, and left in place while cylinders are in use. Cylinder valves shall be closed when not in use.
- c) Since explosion may occur, oxygen / acetylene gas cylinders and fittings shall be kept away from oily or greasy substance and shall not be handled with oily hands or gloves.
- d) Tape shall never be used to make repair to hoses.

- e) Oxygen or acetylene cylinder shall never be placed where they can be contacted by electric wires or with ground wires of electrical equipment. If electric arc welding is being done in the same vicinity, such precautions as necessary must be observed to make sure that the oxygen-acetylene gas equipment does not come in contact with electric arc welding equipment.
- f) No smoking shall be permitted by workmen or welders while handling gas cylinders.
- g) Safety precautions & operating procedure prescribed by manufacturer of the equipment shall be followed.

4.8.6 Electric Arc welding and Cutting:

- a) The flash from electric arc welding is much more severe than that from oxy-acetylene welding, therefore, the welder shall have adequate eye protection and all persons working in the immediate vicinity should wear suitable goggles unless the work is completely shielded.
- b) Welding shall not be done in the presence of any person not amply protected from the flash. Person should never look at an electric arc with the naked eye; to do so may cause serious eye injury.
- c) Only heavy duty electric cable with unbroken insulation shall be used, and all connections shall be water-proof. All connections shall be checked before welding is started, and frequent inspections shall be made during welding operations.
- d) When it is necessary to couple several lengths of cable for use as a welding circuit and occasional coupling or uncoupling is necessary, insulated cable connectors shall be used.
- e) Frames of all electric welding machines operated from power circuits shall be effectively grounded.
- f) When the operator has occasion to leave his work or stop work for any appreciable time, the power supply switch in the equipment should be opened and the unit shut down.

4.9 Paints:

4.9.1 Fire Hazard from paints: Most paint materials are highly combustible, and every precaution should be taken to eliminate danger from fire.

- a) No attempt should be made to heat paint materials except by placing containers in air, or water at moderate temperature. Dirty wiping rags, paint scraping and paint saturated debris, which always involve the hazard of spontaneous combustion or ignition from other sources, should not be allowed to accumulate, but should be collected and disposed of at frequent intervals.

- b) Smoking, open flame exposed heating elements, and other source of ignition of any kind should not be permitted in paint stores or areas where spray painting is done.
- c) Fire extinguishers of appropriate capacity shall always be at hand where flammable paint materials are being mixed used or stored. Sand buckets or extinguishers of the carbon dioxide and carbon tetrachloride type are generally affective.

5.0 Presence of water:

5.1 General:

- 5.1.1 Care should be taken to avoid the works being flooded from outside sources.
- 5.1.2 Fissures in rock often contain water under pressure. If water is anticipated, exploratory probing or drilling ahead of the face should be carried out, to confirm the quantity, the quality and the pressure.
- 5.1.3 Water containing suspended particles in particular fine sand, and entering a tunnel can over a period of time, creates a void behind the tunnel lining.
- 5.1.4 The presence of water adversely affects the working environment and can affect the stability of exposed ground.
- 5.1.5 The presence of water increases the risk associated with the use of electricity.
- 5.1.6 Adequate protective clothing should be provided for those working in wet conditions.

5.2 Dealing with Water:

- 5.2.1 If water is anticipated, exploratory probing or drilling ahead of the face should be carried out to confirm the quantity, the quality and the pressure.
- 5.2.2 If ground water is encountered, and the ground requires sealing, this should be done ahead of the excavated face.
- 5.2.3 Measures shall be put in place for the evacuation of workers in case of sudden flooding.
- 5.2.4 Water should be removed from the working area either by open drains or by pumps and pipes. Intermediate holding tanks and pumping stations should be set up where water has to be pumped over large distances.
- 5.2.5 Sumps are hazards for persons walking in the tunnel and should be guarded and readily visible to avoid injuries to workers falling into them.
- 5.2.6 To avoid flooding, especially in downward sloping tunnels, pumps with adequate reserve capacity should be provided and so arranged that if flooding occurs they will not be put out of action.

5.2.7 Where the stability of the tunnel face or the tunnel itself is endangered by the presence of water, the tunneling method shall be chosen accordingly. In case water is found to be not fit for drinking, Notice regarding “water fit for drinking” should be clearly displayed at the portals.

5.2.8 If water from the tunnel is to be used for drinking or spraying purposes it should be regularly tested for contaminants and treated as appropriate.

5.2.9 Where water from the tunnel is discharged it may require treatment (settling ponds, etc) to avoid pollution of surface water.

5.2.10 Groundwater lowering may have a detrimental effect on surface structures and gas and water pipelines.

5.2.11 Where groundwater is lowered during construction adequate standby capacity should be available to prevent interruption of this process.

6.0 Planning for emergencies

6.1 Emergency Plans:

6.1.1 Emergency Plans should be prepared for foreseeable emergencies which could arise during the tunneling operations. Such emergencies could include:

- Serious and multiple accidents including personal injury.
- Plant or other power failures.
- Ground collapse at the tunnel face.
- Failure of temporary or permanent ground support some distance behind the excavated face.
- Substantial water or mud inflow leading to flooding.
- An explosion e.g. that caused by a concentration of a naturally occurring gas such as methane.
- Oxygen deficiency.
- Fire in the shaft or tunnel.
- Transport accident.

6.1.2 In emergency planning, particular attention should be given to:



- Means of escape in an emergency situation.
- The maintenance of essential power, firefighting, inundation pumping, lighting and communications systems during an emergency.

- Clear labeling of power supplies and switches — including emergency lighting, pumping and ventilation.
- Ensuring a reliable and clear means of communication from, to and within the tunnel even in the event of power failure.

6.1.3 On every site there should be a clearly defined chain of authority for emergency action. Contingency and emergency plans should be made known to all the work force.

6.1.4 The first priority in any emergency action is to minimize the risk to persons working underground. To achieve this objective it is necessary to know the number of persons working within the tunnel at any one time.

6.1.5 The site management should discuss the handling of possible emergencies with the public rescue services. Such discussions should be commenced before the construction stage of the project begins. There is a need for on-site familiarization of the emergency fire and rescue services.

6.1.6 It shall be the duty of every person on site to report any circumstances that could lead to an emergency, thereby enabling effective action to be taken at the earliest moment.

6.1.7 Contingency planning should ensure that essential equipment and personnel for major emergencies (for example rescue equipment, firefighting equipment, suitable breathing apparatus, stretchers, temporary lighting etc.) can be obtained at short notice if they are not already on site.

6.1.8 If the underground works are complex, a clear, durable and up-to-date diagram of the layout of the underground workings should be posted at each of the access points into the underground works.

7.0 Shafts & Hoists:

Special site specific plan for shafts & hoists should be developed in consultation with designers/contractor & approved by engineer-in-charge.

8.0 Working with specialized machinery like Tunnel Boring Machine:

Special site specific plan should be developed in consultation with designers/contractor & approved by engineer-in-charge.

9.0 Safety Signage:

Appropriate Safety Signages should be provided as per applicable standards like IS 9457 Standard for colours of Safety Signs, IS12349: 1988 Fire Protection - Safety Signs etc.

All safety signages displayed in and around the sites shall be in both local language and English. Examples of signs that shall be required include:

- Wear Safety Helmets.
- Permit to Work areas
- Wear Safety Footwear.

- Wear Hearing Protection.
- Wear Eye Protection.
- Danger Electricity.
- Danger Crane Overhead.
- Stop Look and Listen
- No Smoking.
- First Aid.
- No Entry signs
- Fire precautions.
- Emergency Exit from underground works.

All safety signs shall comply with the internationally recognized Safety Colours as indicated below:

- Blue Mandatory.
- Yellow Danger.
- Red Prohibition.
- Green Safe Condition.