12 Electrical Installation

Learning Outcomes

After reading this chapter, the reader will able to

- Classify the cables along with their specifications
- List the factor effecting the choice of wiring
- Illustrate different types of electric wiring schemes
- Illustrate first-aid for electric shock
- Explain the necessity of earthing/ grounding
- Illustrate various methods of earthing
- Illustrate the components of low voltage switchgear
- Differentiate fuse and circuit breaker
- Outline the batteries along with its types
- Compare primary and secondary cells
- Outline the energy consumption calculations

12.1 Wire and Cable

The use of conductors and their insulation is regulated by Indian Electricity (IE) regulation and Indian Standard (IS) code of practice. Wires and cables are the most common forms of conductors. They carry electric current through all types of circuits and systems. A conductor is a wire or cable or any other form of metal, suitable for carrying current from generating station to the point where it is used.

12.1.1 Difference Between Wire and Cable

According to Bureau of Indian Standards (BIS), wire and cable can be defined as follows:

Bare Conductors: They have no covering. The best example is overhead transmission and distribution lines.

Wire: If a bare conductor is provided with insulation, then it is known as a wire. The insulation separates the conductor electrically from other conductors.

Cable: It consists of two or more conductors covered with suitable insulation and surrounded by a protecting cover. The necessary requirements of a cable are that it should conduct

electricity efficiently, cheaply, and safely. This should neither be so small that it has a large internal voltage drop nor be too large so that it costs too much. Its insulation should be such that it prevents leakage of current in unwanted direction to minimize risk of fire and shock.

The cable essentially consists of three parts:

(i) *conductor or core*- the metal wire, or strand of wires, carrying the current
(ii) *insulation or dielectric*- a covering of insulating material to avoid leakage of current from the conductor and
(iii) *protective covering* for protection of insulation from mechanical damage

Basically, there is no difference between a cable and a wire. It is a relative term. The term cable is used for all heavy section insulated conductors, whereas a wire means a thin (i.e., smaller) section insulated conductor used for carrying current from one point to another point.

12.1.2 Classifications of Wires/Cables

The wires/cables used for domestic or industrial wiring are classified into different groups as follows:

(i) According to the conductor material used
  (a) Copper conductor cables
  (b) Aluminium conductor cables

(ii) According to number of cores
  (a) Single core cables (SCC)
  (b) Double core or twin core cables (DCC)
  (c) Three core cables
  (d) Four core cables
  (e) Two core with earth continuity conductor cables

(iii) According to type of insulation
  (a) Vulcanized Indian rubber (VIR) insulated wires/cables
  (b) Tough rubber sheathed (TRS) or cable tyre sheathed (CTS) cables
  (c) Polyvinyl chloride (PVC) cables
  (d) Lead sheathed cables
  (e) Weather proof cables
  (f) Flexible cords and cables
  (g) XLPE cables

(iv) According to the voltage at which they are manufactured
  (a) Low tension (LT) cables — up to 1000V
  (b) High tension (HT) cables — up to 11kV
  (c) Super tension (ST) cables — from 22–33kV
  (d) Extra high tension (EHT) cables — from 33–66kV
  (e) Extra super voltage cables — beyond 132kV

12.1.3 Specifications of Cables

Cables are specified by providing

(i) Size of the cable in metric system (e.g., 19/2.24, 7/1.70, 7/2.24, 7/2.50 etc.) giving the number of strands used and diameter of each strand, or giving the area of cross-section of conductor used.
(ii) Type of conductor used in cables (copper or aluminium).
(iii) Number of cores that cable consists of e.g. single core, twin core, three core, four core etc.
(iv) Voltage grade (240/415V or 650/1100V grade).
(v) Type of cable with clear description regarding insulation, shielding, armouring, bedding etc.

A few specifications of a cable are given below:

(i) $\frac{7}{20}$, VIR, aluminium conductor, twin core, 650/1100 grade.

In this case, the numerator 7 indicates the number of strands in a cable and denominator 20 represents the gauge number of each strand. The cable has two cores made with aluminium, with VIR insulation and is used for 650/1100 voltage

(ii) $\frac{19}{1.12}$, aluminium conductor, $3\frac{1}{2}$ core, 1100V, PVC cable, PVC sheathed.

In this case, the cable consists of 19 strands, each strand has a diameter of 1.12mm. The conductor is made with aluminium, insulation is made with PVC, is covered with PVC sheathing, and is used for 1100V supply system.

12.2 Electrical Wiring

State electricity board provides electric supply up to a point outside the consumer premises. From this point the consumer takes the connection to his main board. Insulated electrical wires will be taken out to various places in the premises to supply power to different types of loads. A network of wires/cables connecting various electrical accessories for distribution of electrical energy from the supplier meter board to the numerous electrical energy consuming devices such as lamps, fans, televisions, refrigerators, and other domestic appliances through controlling and safety devices is known as a wiring system.

The supply used in houses for lighting and power purposes is single phase AC supply, where as for industries 3-phase AC supply is employed. The single phase circuit is connected to 220V, across one phase and neutral.

12.2.1 Factors Affecting the Choice of Wiring

(i) **Durability:** Type of wiring selected should confirm to standard specifications, so that it is durable, i.e., without being affected by the weather conditions, fumes etc.

(ii) **Safety:** The wiring must provide safety against leakage, shock, and fire hazards for the operating personnel.

(iii) Appearance: Electrical wiring should give an artistic appeal to the interiors.

(iv) Cost: Electrical wiring should not be expensive and the maintenance cost should be minimum.

(v) Accessibility: The switches and plug points provided should be easily accessible. There must be provision for further extension of the wiring system, if necessary.

(vi) Mechanical Safety: The wiring must be protected against any mechanical damage.

12.2.2. Types of Electrical Wiring

Electrical wiring system can be classified into the following five categories:

(i) Cleat wiring
(ii) CTS wiring or TRS wiring or Batten wiring
(iii) Metal sheathed wiring or lead sheathed wiring
(iv) Casing and capping
(v) Conduit wiring

(i) Cleat Wiring

Material Used: The various materials used in cleat wiring are VIR or PVC insulated wires, weather proof cables, porcelain or plastic cleats (two or three grooves), and screws.

Procedure: In this type of wiring, insulated conductors (usually VIR, Vulcanized Indian Rubber) are supported on porcelain or wooden cleats as shown in figure (12.1). The cleats have two halves- one base and the other cap. The cables are placed in the grooves provided in the base and then the cap is placed. Both are fixed securely on the walls by 40mm long screws. The cleats are easy to erect and are fixed 4.5–15cms apart. This wiring is suitable for temporary installations where cost is the main criteria but not the appearance.

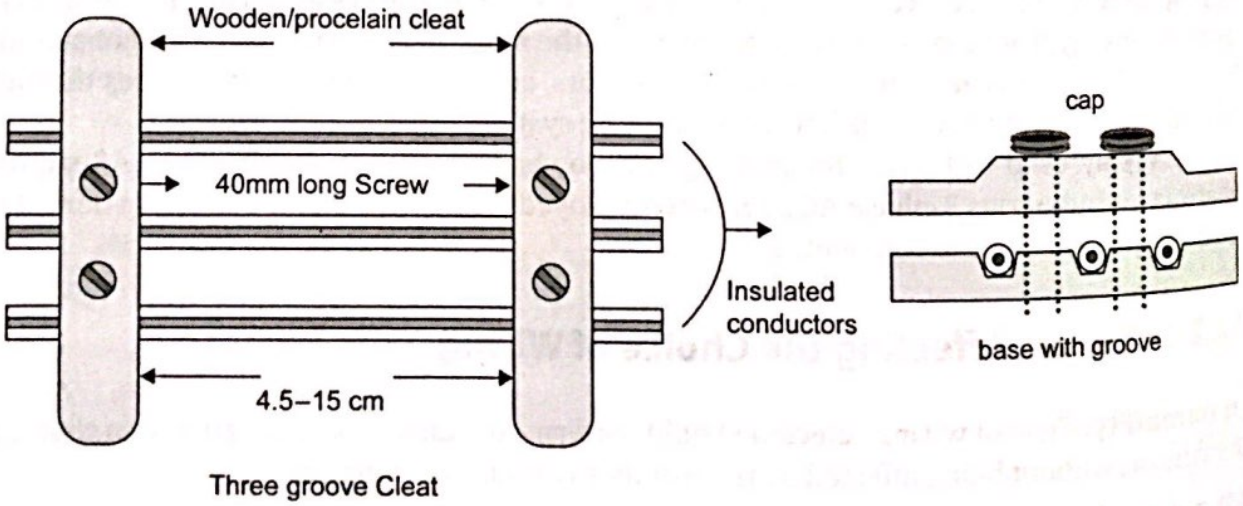


Figure (12.1): *Cleat wiring*

Advantages:
The advantages of this type of wiring are

- Cheap and easy wiring
- Easy to fault detection
- Easy to repair
- Alteration and addition is easy.
- Skilled manpower not required

Disadvantages:
The disadvantages of this type of wiring are

- Appearance is not good.
- Higher risk of mechanical injury i.e., chances of shock or fire
- Open system of wiring requiring regular cleaning

Applications:
This type of wiring is used for purely temporary purposes like army camps, etc.

(ii) Cable Tyre Sheathed or Tough Rubber Sheathed or Batten wiring
Material Used: The various materials used in batten wiring are CTS or TRS cable, straight teak wooden batten (at 10 mm thick), tinned brass link clip (buckle clip), and brass pins

Procedure: In this type of wiring system, wires sheathed in tough rubber are used which are quite flexible. They are clipped on wooden battens with brass clips (link or joint) and fixed on to the walls or ceilings by flat head screws, as shown in figure (12.2). These cables are moisture and chemical proof. They are suitable for damp climate but not suitable for outdoor use in sunlight. TRS wiring is suitable for lighting in low voltage installations. Buckle clips are fixed with brass pin on the wooden batten at an interval 10 cm for horizontal runs and 15 cm for vertical runs.

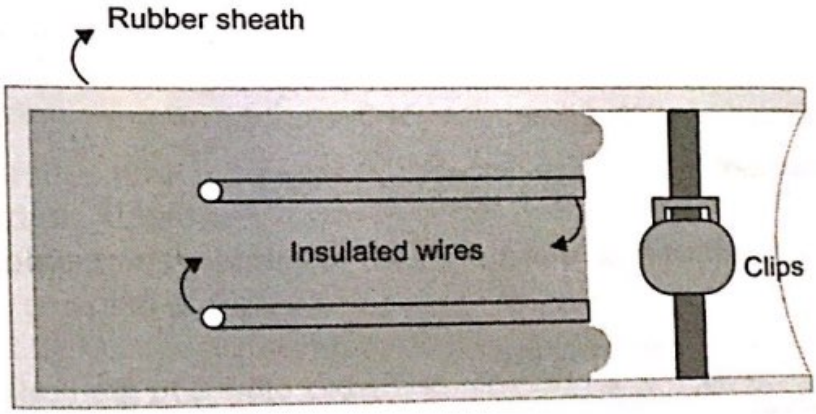


Figure (12.2): *Batten wiring*

Advantages:
The advantages of this type of wiring are

- Easy installation and durability
- Cheap in material cost
- Gives a good appearance if properly erected.
- Customization is easy
- Low risk of short circuit

Disadvantages:
The disadvantages of this type of wiring are

- Not suitable for outdoor wiring
- Humidity, smoke, steam, etc. directly affect wires.
- Heavy wires are not recommended for this wiring scheme.
- Only suitable for below 250 V
- High risk of fire
- Skilled workmen are required.

Applications:
This wiring is suitable for low voltage installations used for lighting purpose in all places, such as domestic, industrial, commercial, etc.

(iii) Metal Sheathed or Lead Sheathed Wiring
Material Used: The various materials used in this type of wiring are CTS or TRS cable, straight teak wooden batten, tinned brass link clip (buckle clip), and brass pins.

Procedure: The wiring is similar to that of CTS but the conductors (two or three) are individually insulated and covered with a common outer lead-aluminum alloy sheath. The sheath protects the cable against dampness, atmospheric extremities and mechanical damages. The sheath is earthed at every junction to provide a path to ground for the leakage current. They are fixed by means of metal clips on wooden battens. The wiring system is very expensive. It is suitable for low voltage installations.

Precautions to be Taken During Installation:

- The clips used to fix the cables on battens should not react with the sheath.
- Lead sheath should be properly earthed to prevent shocks due to leakage currents.
- Cables should not be run in damp places and in areas where chemicals (may react with the lead) are used.

Advantages:
The advantages of this type of wiring are

- Easy installation and aesthetic in appearance
- Highly durable
- Suitable in adverse climatic conditions provided the joints are not exposed

Disadvantages:
The disadvantages of this type of wiring are

- Requires skilled labour
- Very expensive
- Unsuitable for chemical industries

Applications:
This wiring is suitable for low voltage installations used for lighting purpose in all places such as domestic, industrial, commercial, etc.

(iv) Casing and Capping Wiring
Material Used: The various materials used in casing wiring are VIR or PVC insulated wires, casing enclosure (made of wood or plastic), capping (made of wood or plastic) and casing and capping joints.

Procedure: It consists of insulated conductors laid inside rectangular, teakwood or PVC boxes having grooves inside it. A rectangular strip of wood called capping, having same width as that of the casing, is fixed over it. Both the casing and the capping are screwed together at every 15cms. Casing is attached to the wall. Two or more wires of same polarity are drawn through different grooves.

Advantages:
The advantages of this type of wiring are

- Cheap and easy to install
- Strong and durable wiring
- Customization can be done easily
- Safe from smoke, dust, rain, and steam, etc.
- Due to casing and capping no risk of shock.

Disadvantages:
The disadvantages of this type of wiring are

- Very costly
- Not suitable for weather with high humidity and acidic conditions.
- Insects, like termites or ants, can damage wooden casing and capping.
- High risk of fire.

Applications:
This type of wiring is suitable for indoor and low voltage domestic installations.

(v) Conduit Wiring
Material Used:
Metallic Conduit: The various materials used in metallic conduit wiring are thin layer steel sheet low gauge conduit in Class A and thick sheet of steel high gauge conduit in Class B.

Non-metallic Conduit: The various materials used in non-metallic conduit wiring are 13, 16.2, 18.75, 20, 25, 37, 50 and 63 mm (diameter) PVC conduit, VIR or PVC insulated cables, GI wire of 18SWG , Screw, Coupling, Elbow, Rigid off set, 2-hole strap, and lock nut.

Procedure: In general, conduit means tube or channel. Tubular conduits are most commonly used in electrical installations. When wire/cables are drawn through the conduit and terminated at the outlets (switches, holders, ceiling rose etc.), such a system of wiring is known as conduit wiring.

Conduit wiring consists of PVC wires taken through either steel or PVC conduit pipes as shown in figure (12.3). On the surface of the wall or ceiling, conduit pipes (with GI wire inside) are attached with the help of 2-hole strap and base clip at a regular distance. When conduits are run over the surface of the wall, the wiring is called surface conduit wiring. When conduits are run inside wall, the wiring is called concealed conduit wiring. Conduit wiring is water proof and replacement of defective wire is very easy.

Advantages:
The main advantages of this type of wiring are

- No risk of fire and good protection against mechanical injury
- Appearance is better
- No risk of damage of cable insulation
- Safe from humidity, smoke, steam, etc.
- No risk of shock

- Long lasting

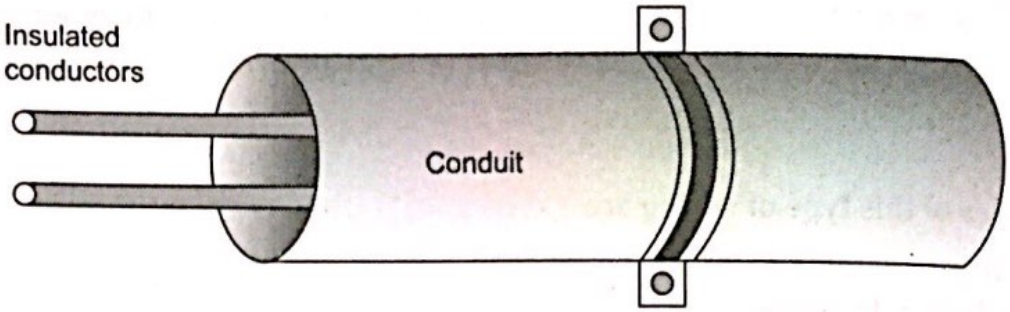


Figure (12.3): *Conduit wiring*

Disadvantages:
The disadvantages of this type of wiring are

- Very expensive
- Installation is not easy
- Not easy to customize for future
- Hard to detect the faults

Applications:
Due to its good protection against mechanical damage, most commonly used in places like textile mills, flour mills, saw mills, workshops, factories, etc.

12.2.3 Comparison between different Wiring Systems

The following table shows the comparison between all the above mentioned wiring systems.

S. No.	Particulars	Cleat Wiring	Casing and Capping Wiring	Batten Wiring	Conduit Wiring
01	Life	Short	Fairly long	Long	Very long
02	Cost	Low	Medium	Medium	Highest
03	Possibility of fire	Nil	Good	Good	Nil
04	Mechanical protection	None	Fair	None	Very good
05	Protection from dampness	None	Little	None	Good
06	Type of labour required	Semi skilled	Highly skilled	Semi skilled	Highly skilled
07	Installation	Very easy	Difficult	Easy	Difficult
08	Inspection	Easy	Easy	Easy	Difficult

S. No.	Particulars	Cleat Wiring	Casing and Capping Wiring	Batten Wiring	Conduit Wiring
09	Repair	Easy	Little bit difficult	Easy	Difficult
10	Popularity	Nil	Fair	Nil	Very high
11	Applications	For temporary installations e.g., functions, marriages, etc.	For residential, commercial and office buildings	For residential, commercial and office buildings	Workshops, factories, godowns, etc

12.3 Electric Shock

The human body has an electrical conducting property. Without sweating, the resistance of the human body is approximately 80000Ω and during sweating resistance of the human body is approximately 1000 Ω. If we touch the current carrying conductor, the current is conducted through our body to the earth. So the electric circuit is closed and we get electric shock, due to which nervous structure, heart, lungs and brain are affected. If the current is large, death may occur. Therefore, we must know that even though current is essential, if it is used in a wrong manner, it will cause heavy loss. i.e., death and economical loss.

To prevent this electrical shock, we know about the methods of preventive care and protective methods for safety precautions.

12.3.1 Preventive Method to Avoid Electric Shock

The points should be kept in mind to avoid electric chock are

(i) The operation of electrical equipment must be known.
(ii) Damaged wire not to be used for wiring works or electrical connection.
(iii) The electrical instruments used for connections (i.e., switch, plug, pushings, etc.) do not have any scratch or break; otherwise they should be replaced by a new one.
(iv) The hand tools are insulated essentially.
(v) Proper earthing is provided.
(vi) If the supply is taken from the socket, only the plug top is used. To avoid, the supply is taken by inserting the wire with stick in the socket.
(vii) Depending upon the load, rated ampere fuse wire is used.
(viii) The electrical equipment is repaired after the main source is switched off.
(ix) For any reason do not operate, overlooking the safety rules.

12.3.2 First-Aid for Electric Shock

If anyone suffers an electric shock, the electricity source should be cut off immediately. Conduct the first-aid only after the victim is in a safe place. Check the victim's breath and pulse. If the person is unconscious but is breathing normally, he or she should be placed in a recovery position. If the victim is not breathing and has no pulse, cardiopulmonary resuscitation should be conducted.

Note: Cardiopulmonary resuscitation should be carried out only by competent first-aid personnel.

Cardiopulmonary Resuscitation:

(i) Open the Airway

Lift the jaw and tilt the head back to open the airway. Clear any obstacles.

(ii) Check the Breaths

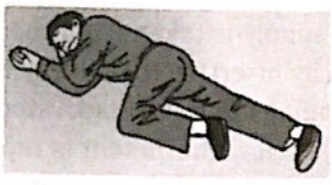
See : See if the chest rises and falls.
Listen : Listen for breathing.
Feel : Feel breathing on your cheek.

(iii) Check the Pulse (Circulation)

Use your fingers to feel the pulse.

(iv) Recovery Position

If the casualty is unconscious but is breathing normally, place them in the recovery position (as shown in figure along side).



(v) Mouth to Mouth Expired Air Resuscitation

If the person is not breathing, mouth-to-mouth resuscitation should be used to help the resumption of breathing.

vi) External Chest Compression

f the casualty has no pulse, cardiopulmonary esuscitation should be carried out (combining he expired air resuscitation and external chest ompression).

12.4 Earthing or Grounding

The process of connecting the metallic frame (i.e., non-current carrying part) of electrical equipment or some electrical part of the system (e.g., neutral point in a star-connected system, one conductor of the secondary of a transformer, etc.) to the earth (i.e., soil) is called grounding or earthing. The potential of the earth is to be considered zero for all practical purposes. Earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential. This ensures safe discharge of electric energy due to failure of the insulation line coming in contact with the casing, etc. Earthing brings the potential of the body of the equipment to zero i.e., to the earth's potential, thus protecting the operating personnel against electrical shock.

The earth resistance is affected by the following factors:

(a) Material properties of the earth, wire and the electrode
(b) Temperature and moisture content of the soil
(c) Depth of the pit
(d) Quantity of the charcoal used

12.4.1 Necessity of Earthing

The requirement for provision of earthing can be listed as follows:

- To protect the operating personnel from the danger of shock.
- To maintain the line voltage constant, under unbalanced load condition.
- To avoid risk of fire due to earth leakage current through unwanted path.
- Protection of the equipments.
- Protection of large buildings and all machines fed from overhead lines against lightning.

12.4.2 Methods of Earthing

The various methods of earthing in common use are

(i) Plate earthing
(ii) Pipe earthing
(iii) Rod earthing
(iv) Strip or wire earthing

(i) Plate Earthing

In this method either a copper plate of 60cm × 60cm × 3.18 or GI plate of 60cm × 60cm × 6.35 is used for earthing. The plate is buried into the ground not less than 3m from the ground level. The earth plate is embedded in alternate layers of coal and salt for a thickness of 15 cm as shown in figure (12.4). In addition, water is poured for keeping the earth's electrode resistance value below a maximum of 5Ω. The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.

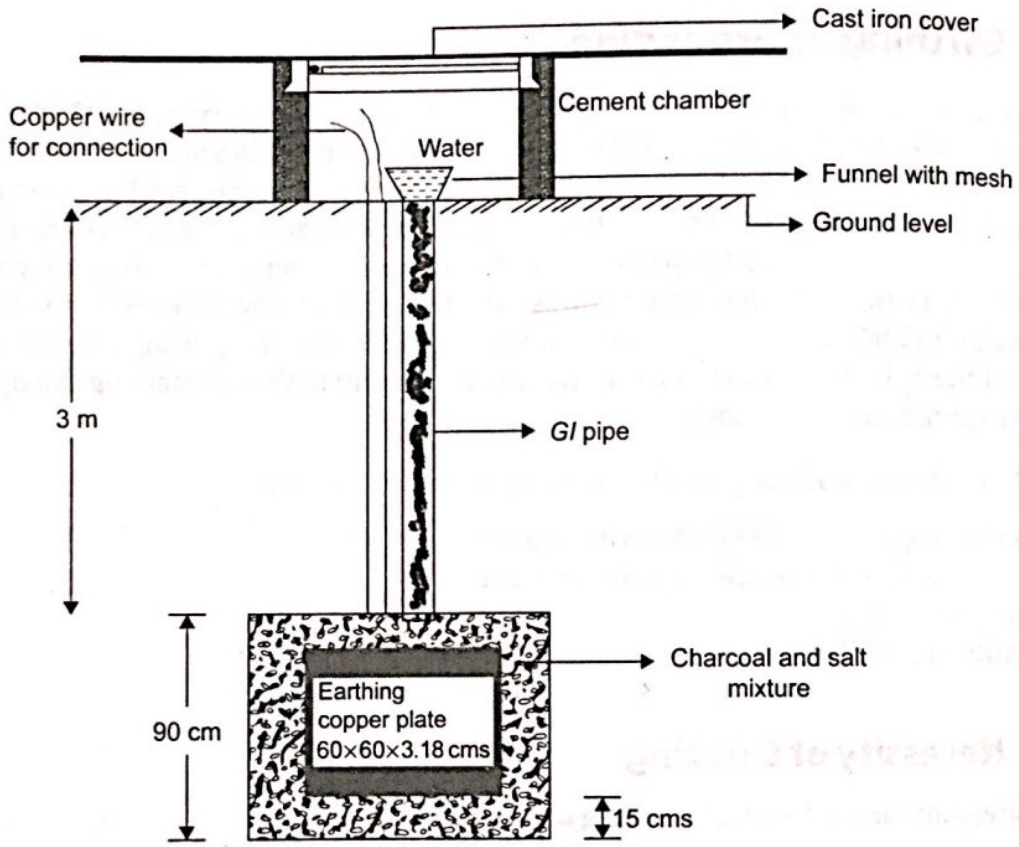


Figure (12.4): *Plate earthing*

(ii) Pipe Earthing

Earth electrode made of a GI (galvanized iron) pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cm) surrounding the GI pipe is filled with a mixture of salt and coal. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross-sectional area are run through a 12.7mm diameter pipe (at 60cm below) from the 19mm diameter pipe and secured tightly at the top as shown in figure (12.5).

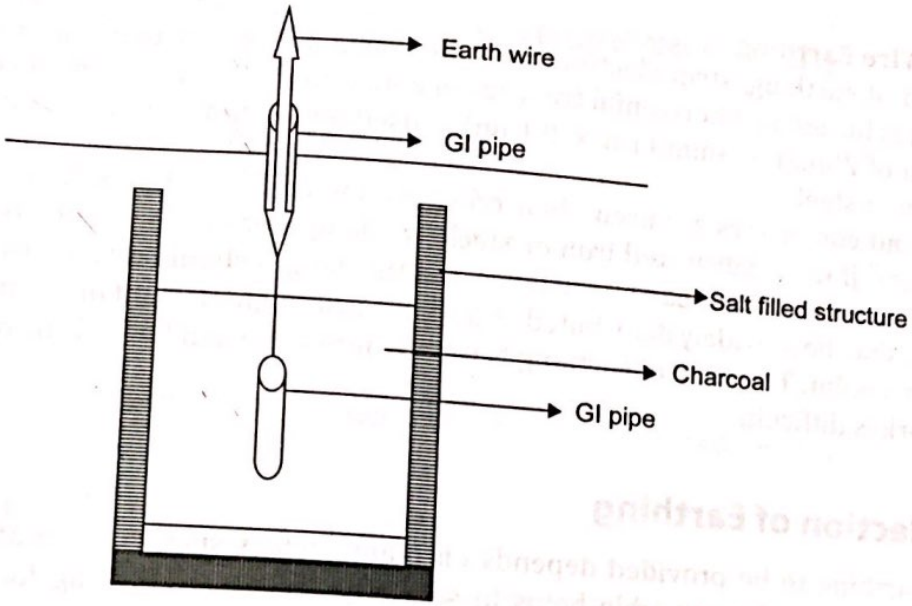


Figure (12.5): *Pipe earthing*

When compared to the plate earth system the pipe earth system can carry larger leakage currents due to larger surface area is in contact with the soil for a given electrode size. This system also enables easy maintenance as the earth wire connection is housed at the ground level.

(iii) Rod Earthing

It is the same method as pipe earthing. A copper rod of 12.5mm (1/2 inch) diameter or 16mm (0.6in) diameter of galvanized steel or hollow section 25mm (1 inch) of GI pipe of length above 2.5m (8.2 ft) are buried upright in the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

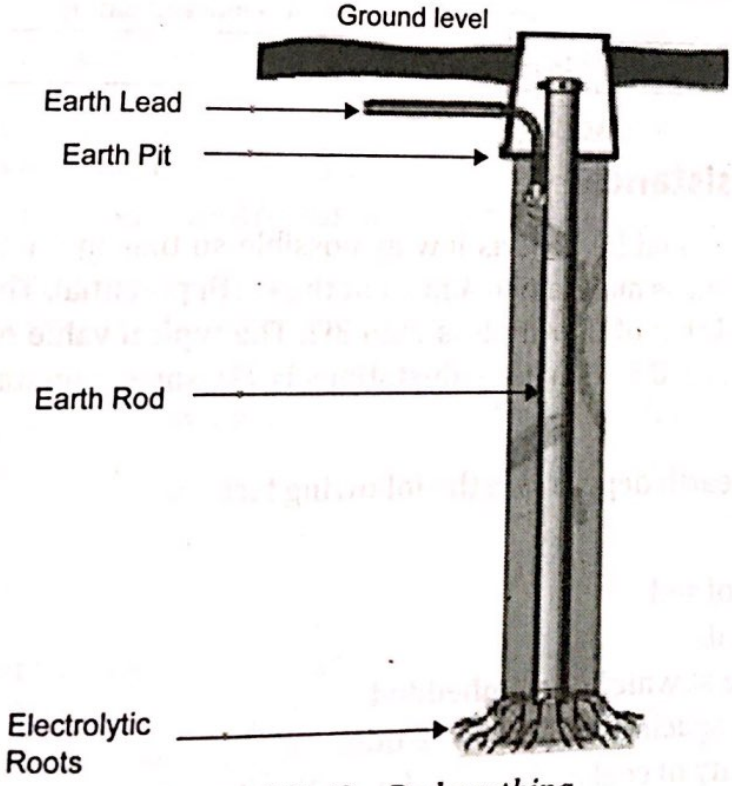


Figure (12.6): *Rod earthing*

(iv) Strip or Wire Earthing

In this method of earthing, strip electrodes of cross-section not less than 25mm × 1.6mm (1in × 0.06in) is buried in a horizontal trenches of a minimum depth of 0.5m. If copper with a cross-section of 25mm × 4mm (1in × 0.15in) is used and a dimension of 3.0mm^2 if it's a galvanized iron or steel.

If at all round conductors are used, their cross-section area should not be too small, say less than 6.0mm^2 if it's a galvanized iron or steel. The length of the conductor buried in the ground would give a sufficient earth resistance and this length should not be less than 15m. The electrodes shall be as widely distributed as possible in a single straight or circular trenches radiating from a point. This type of earthing is used where the earth bed has a rocky soil and excavation work is difficult.

12.4.3 Selection of Earthing

The type of earthing to be provided depends on many factors such as type of soil, type of installation, etc.. The following table helps in selecting a type of earthing for a particular application

S. No.	Type of Earthing	Application
01	Plate earthing	Large installations such as transmission towers, all sub-stations, generating stations
02	Pipe earthing	• For domestic installations such as heaters, coolers, refrigerators, geysers, electric iron, etc. • For 11kV/400V distribution transformers • For induction motors rating upto 100HP • For conduit pipe in a wall, all wall brackets
03	Rod earthing	In areas where the soil is loose or sandy
04	Strip or wire earthing	In rocky ares

12.4.4 Earth Resistance

The earth resistance should be kept as low as possible so that the neutral of any electrical system, which is earthed, is maintained almost at the earth potential. The earth resistance for copper wire is 1Ω and that of GI wire less than 3Ω. The typical value of the earth resistance at large power stations is 0.5 Ω, major sub-stations is 1Ω, small sub-stations is 2 Ω and in all other cases 5 Ω.

The resistance of the earth depends on the following factors

- Condition of soil.
- Moisture content of soil.
- Temperature of soil.
- Depth of electrode at which it is embedded.
- Size, material and spacing of earth electrode.
- Quality and quantity of coal and salt in the earth pit.