CIVIL ENGINEERING

- Building Materials & Construction Practices
- Concrete Technology
- Geotechnical Engineering
- Hydraulics and Water Resources Engineering
- Urban and Transportation Engineering
- Engineering Survey
- Engineering Mechanics & Strength of Materials
- Project Management and Estimation
- Environmental Engineering and Pollution Control
- Structural Analysis
- Design of Reinforced Concrete, Prestressed Concrete and Steel Structures

BUILDING MATERIALS AND CONSTRUCTION PRACTICES

BUILDING MATERIALS

Introduction

The use of the construction materials depends on the nature and purpose of the structure to be built. There are many types of building materials used in construction such as Concrete, Steel, Wood and Masonry. Each material has different properties such as weight, strength, durability and cost which makes it suitable for certain types of applications.

The choice of materials for construction is based on cost and effectiveness to resist the loads and stresses acting on the structure.

Stones

- In many places, stones are more freely available than any building material. They are derived from rocks.
- The stones for construction works are obtained by quarrying rocks. Such stones are very irregular in shape and size. They are therefore dressed for proper bedding, thin joints and speedy construction. When such stones are laid with cement or lime mortar in a systematic manner, they form a structural mass which can resist load without disintegration.

Classification of Rocks

Rocks are classified into three types. They are,

1. Geological classification
2. Physical classification
3. Chemical classification

1. Geological Classification

According to this classification, rocks are of 3 types. They are:

1. Igneous rocks
2. Sedimentary rocks
3. Metamorphic rocks

- **Igneous Rocks :** Stones obtained from these rocks are very strong and durable. It is the result of cooling and consolidation of molten lava released from volcanoes. E.g. Granite, Basalt.
- **Sedimentary Rocks :** They are formed by gradual deposition of broken pieces of rocks which are disintegrated by atmospheric actions. It is transported from one place to another place and deposited at the bottom of rivers or lakes. These deposits harden due to water pressure. E.g. Limestone, Sandstone
- **Metamorphic Rocks :** Metamorphic rocks are a type of rock that have become changed by intense heat or pressure while forming. In the very hot and pressured conditions deep inside the Earth's crust, both sedimentary and igneous rocks can be changed into metamorphic rock. In certain conditions these rocks cool and crystallize into bands of crystals. Later they can become exposed on Earth's surface. The change in colour, structure and texture are due to either pressure or heat or both. Eg. Marbles, Slates.

2. Physical Classification

This classification is based on general structure of rocks. According to this classification, rocks are of three types. They are:

1. Stratified Rocks
2. Unstratified Rocks
3. Foliated Rocks

- **Stratified Rocks :** Sedimentary rocks are distinctly stratified rocks. They are formed by series of parallel layers. E.g. Limestone, Sandstone, Slates.
- **Unstratified Rocks :** Igneous and sedimentary rocks which are affected by movements of earth are of this type of rocks. They cannot be split into thin slabs. E.g. Granite, Marble.
- **Foliated Rocks :** These rocks have a tendency to split up in a definite direction. Such foliated structure is very common in metamorphic rocks. E.g. Gneiss.

3. Chemical Classification

This classification is based on their chief constituents. Chemically, rocks are of three types. They are :

1. Silicious Rocks
2. Calcareous Rocks
3. Argillaceous Rocks

- **Silicious rocks :** These rocks have silica or sand as their main constituent. They are hard and durable. E.g. Sand stone, Granite.
- **Calcareous Rocks :** These rocks have calcium carbonate as their main constituent. E.g. Lime stone, Marble.
- **Argillaceous Rocks :** In these rocks clay predominates. E.g. Slate, Laterite.

Uses of Stones

Stones are widely used in many permanent engineering works on account of their strength and durability. The principal uses of stone in construction are:

- As material for foundation
- As aggregate for concrete making
- As material for road construction
- As thin slabs for Pavings
- In Ornamental Works
- As Wall, Columns, Beams and Lintels in Buildings.
- Limestone for manufacture of cement
- As roofing tiles in the form of slates

Characteristics of Good Building Stones

Following are the characteristics of good building stone:

SURA'S

- **Crushing Strength :** For a good structural stone, the **crushing strength should be greater than 100 N/mm².**
- **Appearance :** The stones which are to be used for face work, should be decent in appearance and they should be capable of preserving their colour uniformly for a long time. The colour of the stones for face work should be chosen by keeping in mind the environmental condition of the surrounding area.
- **Durability :** A good building stone should be durable. The various factors contributing the durability of a stone are its chemical composition, texture, resistance to atmosphere and other influences, location of the structure, etc. The important atmospheric agency which affect the durability of a stone is alternate conditions of heat and cold due to difference in temperature.
- **Dressing of Stones:** Stones should be such that they can be easily carved, moulded out and dressed. Dressing of stones results in economy of construction.
- **Fracture :** For a good building stone, its fracture should be sharp, even, bright and clear with grains, well cemented together. A dull, chalkey and earthly fracture of a stone, reduces the life span of the building.
- **Hardness :** The co-efficient of hardness, as worked out in hardness test should be **greater than 17 for a stone to be used in road work. If it is between 14 and 17, the stone is said to be of medium hardness.**
- **Attrition :** In attrition test, if wear is more than 3%, the stone is not satisfactory. If it is equal to 3%, the stone is just tolerable.
- **Fire Resistance :** The minerals composing stone should be fire resistant in such a way that the shape is preserved when a fire occurs.
- **Seasoning :** The stones should be well seasoned before putting into use. The stones obtained freshly from a quarry, contain some moisture which is known as the quarry sap. The presence of this moisture makes the stone soft.
- **Specific Gravity :** For good building stone, the **specific gravity should be greater than 2.7 or so.**
- **Texture :** A good building stone should have compact, fine, crystalline structure free from cavities, cracks or patches of soft or loose material. These stones with such texture are strong and durable.
- **Water Absorption :** All the stones are more or less porous, but for a good stone, percentage of water absorption by weight s**hould not exceed 0.60 after 24 hours immersion in water.**

Crushing strength of common building stones

Name of Stone	Crushing Strength in N/mm²
Trap	300 to 350
Basalt	153 to 189
Granite	104 to 140
Slate	70 to 210
Marble	72
Sand stone	65
Lime stone	55
Laterite	1.8 to 3.2

Tests on Stones

To acertain the required properties of stones, the following tests can be conducted:

- crushing strength test
- water absorption test
- abrasion test
- impact test
- acid test.

Crushing Strength Test : For conducting this test, specimen of size 40 × 40 × 40 mm are prepared from parent stone. Then the sides are finely dressed and placed in water for 3 days. The saturated specimen is provided with a layer of plaster of paris on its top and bottom surfaces to get even surface so that load applied is distributed uniformly. Uniform load distribution can be obtained satisfactorily by providing a pair of 5 mm thick play wood instead of using plaster of paris layer. The specimen so placed in the compression testing machine is loaded at the rate of 14 N/mm² per minute. The crushing load is noted. Then crushing strength is equal to the crushing load divided by the area over which the load is applied. At least three specimen should be tested and the average should be taken as crushing strength.

Water Absorption Test : For this test cube specimen weighing about 50 grams are prepared and the test is carried out in the steps given below:

- Note the weight of dry specimen as W_1.
- Place the specimen in water for 24 hours.
- Take out the specimen, wipe out the surface with a piece of cloth and weigh the specimen. Let its weight be W_2.
- Suspend the specimen freely in water and weight it. Let its weight be W_3.
- Place the specimen in boiling water for 5 hours. Then take it out, wipe the surface with cloth and weigh it. Let this weight be W_4. Then,

Percentage absorption by weight

$$= \frac{W_2 - W_1}{W_1} \times 100 \qquad \text{..... (1)}$$

Percentage absorption by volume

$$= \frac{W_2 - W_1}{W_2 - W_3} \times 100 \qquad \text{..... (2)}$$

Percentage porosity by volume

$$= \frac{W_4 - W_1}{W_2 - W_3} \times 100 \qquad \text{..... (3)}$$

$$\text{Density} = \frac{W_1}{W_2 - W_1} \quad \ldots\ldots (4)$$

$$\text{Specific gravity} = \frac{W_1}{W_2 - W_3} \quad \ldots\ldots (5)$$

$$\therefore \text{ Saturation coefficient} = \frac{\text{Water absorption}}{\text{Total porosity}}$$

$$= \frac{W_2 - W_1}{W_4 - W_1}$$

Abrasion Test : This test is carried out on stones which are used as aggregates for road construction. The test result indicate the suitability of stones against the grinding action under traffic. Any one of the following test may be conducted to find out the suitability of aggregates:

1. Los Angeles abrasion test
2. Deval abrasion test
3. Dorry's abrasion test.

However Los Angeles abrasion test is preferred since these test results are having good correlation with the performance of the pavements.

Then Los Angeles value can be calculated as :

$$= \frac{\text{Weight of aggregate passing through sieve}}{\text{Original weight}} \times 100$$

The following values are recommended for road works:

For bituminous mixes – 30%

For base course – 50%

Impact Test : The resistance of stones to impact is found by conducting tests in impacting testing machine. It consists of a frame with guides in which a metal hammer weighing 13.5 to 15 kg can freely fall from a height of 380 mm.

Aggregates of size 10 mm to 12.5 mm are filled in cylinder in 3 equal layers; each layer being tamped 25 times. The same is then transferred to the cup and again tamped 25 times. The hammer is then allowed to fall freely on the specimen 15 times. The specimen is then sieved through 2.36 mm sieve. Then,

$$\text{Impact value} = \frac{W_2}{W_1}$$

where W_2 = weight of fines

W_1 = original weight.

The recommended impact values for various works are:

- for wearing course $\not>$ 30%
- for bituminous mechadam $\not>$ 35%
- for water bound mechadam $\not>$ 40%

Acid Test : This test is normally carried out on sand stones to check the presence of calcium carbonate, which weakens the weather resisting quality. In this test, a sample of stone weighing about 50 to 100 gm is taken and kept in a solution of one per cent hydrochloric acid for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface intact. If edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate. Such stones will have poor weather resistance.

BRICKS

- Clay bricks were used by humans from very early dates. First, it was used without burning as sundried bricks. Burnt brick was a common building material among the Egyptians. Now a days, they are made from specially selected and matured brick earth. It is used to construct the building because of its good bearing capacity, long life and strength. Bricks are made up of blending a good clay, moulded to a rectangular shape of uniform size, dried and burned. As bricks are in uniform size they can be beautifully laid in masonry work.
- Bricks are obtained by moulding clay in rectangular moulds, then by drying and burning them. In places where stones are not easily available, bricks are used in construction. These are preferred because of its durability, strength, reliability, low cost, etc.

- The earliest bricks were sun dried and made from mud.
- It was used in 8000 BC in southern Turkey around the city of Jericho.
- In Mesopotamia (modern Iraq) the first true arch of sun baked brick was made about 4000 BC.
- Ceramic or fried (burned) bricks were used as early as 3000 BC in early Indus valley cities.

Size and Weight of Brick

- The Bricks are prepared in various sizes. The custom in the locality is the governing factor to decide the size of brick. Such bricks which are not standardised are known as traditional bricks.
- BIS has recommended the bricks of uniform size. Such bricks are known as Modular bricks. **The actual size of modular bricks is 190mm × 90mm × 90mm. With mortar thickness (10mm) the nominal size of modular brick is 200mm × 100mm × 100mm.**
- But practically to match with the beam width, a brick or block of width **230mm is used widely in construction industry. 115mm is considered for half brick. The brick of size 230 mm × 110mm × 110 mm or 230mm × 110mm × 76mm is generally used in construction industry.**
- **It is found that the weight of 1m^3 of brick earth is about 1800 kg. Hence the average weight of brick will be about 3.0 to 3.5 kg.**
- The size of Indian brick, we are using is 228mm × 107mm × 69mm.

Brick Earth

Bricks are easily moulded from plastic clays also known as brick clay or brick earth.

which $\sigma_2 = \sigma_3 = 0$. The cell pressure in the triaxial cell is also called the confining pressure. Due to the absence of confining pressure the uniaxial test is called the unconfined compression test.

Advantages and Limitations

- The unconfined compression test is a quick, simple and widely used test.
- This test has a significant cost advantage over a triaxial test.
- This test is quite suitable for studying sensitivity of clays.
- This test is only applicable to soils which can stand unsupported and are fairly impervious so that undrained conditions effectively exist on the test duration.
- The sample must be fully saturated so that apparent angle of cohesion may be assumed zero.
- This test is suitable for intact homogeneous clays.
- This test underestimates in-situ strength because sampling inevitably causes a remoulding disturbance and decrease in strength. The test should not be used for the estimation of undrained modulus.

d) Vane Shear Test

The vane shear test is essentially a quick test used either in the Laboratory or in the field, to determine the undrained shear strength of cohesive soil. A laboratory vane consist of four blades of 12 mm in diameter and 20 mm high mounted on rod.

The maximum moment of the total shear resistance about the axis of torque rod equals torque T at failure. Hence,

$$T = \pi\ D\ H\ \tau_f \times \frac{D}{2} + 2\int_0^{\frac{D}{2}} \left(2\pi\ r\ dr\ \tau_f\right) r$$

$$= \frac{\pi\ D^2\ H\ \tau_f}{2} \times \frac{\pi \tau_f D^3}{6} = \pi\ D^2 \tau_f \left(\frac{H}{2} + \frac{D}{6}\right)$$

If only the bottom end partakes in the shearing the above equation takes the form

$$T = \pi\ D^2 \tau_f \left(\frac{H}{2} + \frac{D}{12}\right)$$

SOIL EXPLORATION

An engineer can design a structure by knowing reasonably well the physical properties and sequence of occurrence of the subsoils. The field and laboratory investigations required to obtain the above information are called soil exploration.

Purpose of Soil Exploration

The main purposes of soil exploration are as follows :

- To determine the properties of soil and ground water which affect the design and safety of structures.
- To determine the extent and properties of the material to be used for various engineering construction.
- To determine the sequence, thickness, the level of bed rock and lateral extent of the soil strata.
- To obtain disturbed and undisturbed samples for identification and laboratory testing.
- To carry out field tests to know about the insitu soil properties.

Depth of Exploration

Exploration is generally carried out upto a depth after which the increase in pressure due to structural loading is not likely to cause perceptible settlement or shear failure. The depth of exploration must penetrate through all the deposits which are not suitable for a sound foundation. In other words, the exploration should be extended upto a strata which is of adequate bearing capacity to resist all the loads coming on it. The depth of exploration depends upon the following factors :

- Type of structure, its size, shape and weight.
- Load coming on foundation.
- Soil profile and its properties.
- Design consideration such as safety against foundation failure, excessive settlement, seepage failure, earth pressure etc.
- Depth of exploration different for various types of foundations and structures.

Methods of Exploration

The various methods of exploration are as follows :

(a) Open Excavations
(b) Borings
(c) Geophysical Methods
(d) Sounding and Penetration Tests

OPEN EXCAVATIONS

Soil can be inspected in their natural condition and samples both disturbed or undisturbed can be conveniently taken from open excavations. The open excavations are considered suitable for shallow depths upto 3 m as their cost increases rapidly with depth.

Test Pits

Test pits are normally either square or circular in section of about 1.2 m to 1.5 m in width or diameter are often used for investigating all types of soils. Both disturbed as well as undisturbed samples can be collected at various locations as the excavation work progresses. The cost of test pits increases rapidly with depth. Test pits are normally excavated manually however power equipment can also be used depending upon soil conditions. Test pits are not suitable if rock strata is encountered during excavation.

Test Trenches

Test trenches are normally square or rectangular in section with minimum width of 1 m to 1.2 m. It is advisable to always use trenching machine during excavation work. Test trenches furnish a continuous two

dimensional profile. Test trenches can be conveniently used for shallow exploration in soils requiring little or no support for the sides of the trenches.

Open Borings

A open boring of about 1.2 m diameter is generally preferred. Open borings are drilled with power machines in soil and very soft rock. A fairly stable soil conditions are needed as open borings are incased and dry.

Advantages of Open Excavation

Open excavation has following advantages :

- It is the most suitable and reliable technique for obtaining detailed information on soil and rock.
- It is possible to examine the samples and perform field tests as per the requirement.
- It furnishes probable cost of proposed structure.
- It furnishes the difficulties that will be encountered during the construction of the proposed structure.
- The samples obtained from open excavations are larger and less disturbed as compared to other methods.

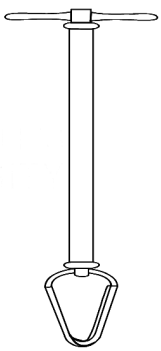
METHODS OF SOIL EXPLORATION BY BORINGS

Boring are generally used for depths greater than 3 m or when difficult ground water conditions are met. The diameter of bore hole generally varies from 50 mm to 250 mm depending on the type of investigation, size of required samples and the type of available equipment. The various methods of boring are as follows :

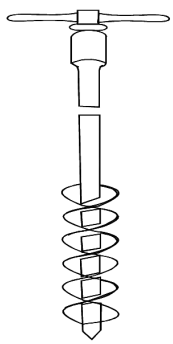
(a) Auger Boring
(b) Wash Boring
(c) Percussion Drilling
(d) Rotary Drilling

Auger Boring

In auger boring the hole is advance by rotations a soil auger while pressing it into the soil. Two types of augers as shown in Figure below are normally used.



Post Hole Auger

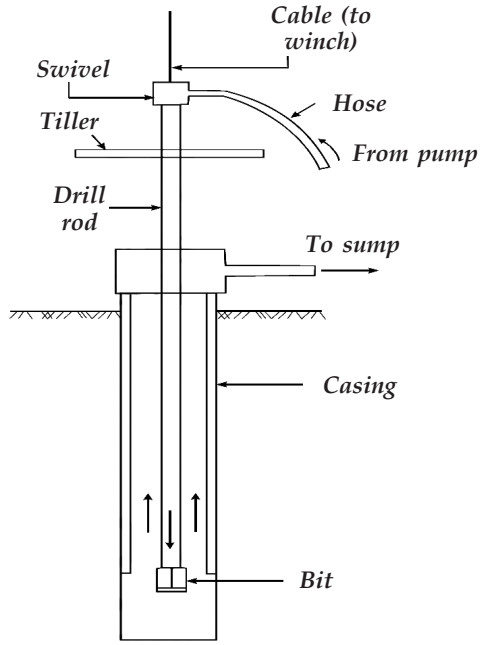


Helical Auger

The normal size of hand operated auger is upto 10 cm. These augers are primarily used in soils in which the bore hole can be kept dry and unsupported by a casing. The auger is withdrawn when its blades have pierced the soil for their full height and the soil is removed from the blades. Hand operated augers are most commonly employed for subsurface exploration for highways, railways and airfields but still they can be used upto depths of about 30 meters. Power operated augers can be used for larger depths. If the sides of a hole cannot stand unsupported, the soil is prevented from falling in by means of a pipe known as casing. Casing pipe is used for drilling in sand below water table. The rate of progress of power driven auger with casing is reduced because the auger has to be withdrawn every time the casing pipe is driven.

Wash Boring

Wash boring is a cheap and rapid method of boring specially in uniform sands or clays. The disturbance of the soil below the bottom of the borehole is generally not much. The washings obtained from wash borings are so disturbed and mixed up as to be value less even for identification.



Wash boring

The water is pumped through a string of hollow drill rods called the wash pipe and it issues under pressure through narrow holes in a chisel attached to the lower end of the wash pipe. The wash pipe is worked up and down or rotated by hand. The water jets and the up and down movements and rotation of the chisel loosen and broke up the soil. The water carries the soil up the annual space between the wash pipe and the side of the bore hole. The washings are allowed to settle in a tank or pond at the ground level and the fluid is recirculated or discharged to waste as desired. The bore hole is generally cased. The need for casing may be eliminated by using drilling mud in place of water.

Percussion Drilling

It is employed in situations when the hole is to be made in very hard or soft rock because in both of these cases auger or wash borings cannot be employed. In percussion drilling a heavy drilling bit is alternatively

raised and dropped inside a casing pipe. The water is poured into the casing pipe above the water table. The fall of the bit onto the subsoil grinds it and a slurry is formed with water near the bottom of the drill hole. The bore hole may be kept dry except for some distance hear its bottom. When sufficient slurry has been formed, it is removed by means of bailers or samp pumps. A casing pipe may not be necessary if sides of the hole do not cave in except close to the ground surface.

Rotary Drilling

It is the fast method of boring in highly resistant strata and the disturbance of the soil below the borehole is slight. Depending on ground conditions and the equipment, 35-60 mm diameter or larger holes can be drilled to great depths. This method is not suitable in soil containing high percentage of gravel or larger particles as they tend to rotate under the bit and are not broken up. In rotary drilling method a rapidly rotating drilling bit cuts and ginds the subsoil or rock at the bottom of the drill hole into small fragments. These fragments of chopped subsoil are removed either by circulating water or drilling mud. Casing pipe is usually unnecessary especially if drilling mud is used. Drilling mud is a slurry of bentonite in water. The drilling fluid becomes a gel and holds the rock cuttings in suspension when drilling stops at the end of days work. Thus the rock cuttings do not accumulate near the cutting bit and Jam it.

GEOPHYSICAL METHODS

These methods consists of identifying changes in the character of surface materials by measuring changes in certain physical characteristics of sub-surface deposits. These methods may also be used to explore large areas much more rapidly and economically than is possible by borings. Sub surface exploration methods are useful to determine stratification of soils are rocks, define the limits of granular borrow areas and large organic deposits and yield general information on sub surface conditions including depth to ground water. The various methods of sub surface exploration are :

(a) Seismic refraction method, and

(b) Electrical resistively method.

Seismic Refraction Method

This method is based on the fact that shock waves have different velocities in different types of materials. The velocity is faster in denser and more consolidated materials. The shockwaves are created into the soil at their ground level or certain depth below it by exploding small changes in the soil or by striking a plate an the soil with a hammer. The radiating shock waves are picked up by the geophone where the time of travel gets recorded. A number of geophones are arranged along a line to produce shock waves at given intervals. Three kinds of waves are produced.

Primary waves, secondary waves and surface waves. In general only primary waves are observed. Primary waves travel directly from the shock point along the ground surface and picked up first by the geophones. Primary waves are of three kinds :

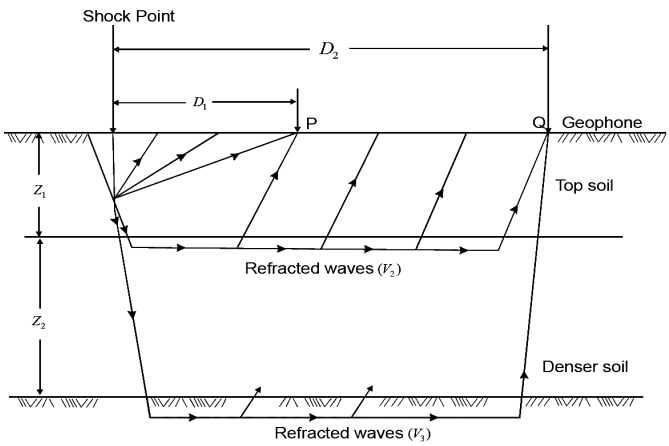
(a) direct waves

(b) reflected waves

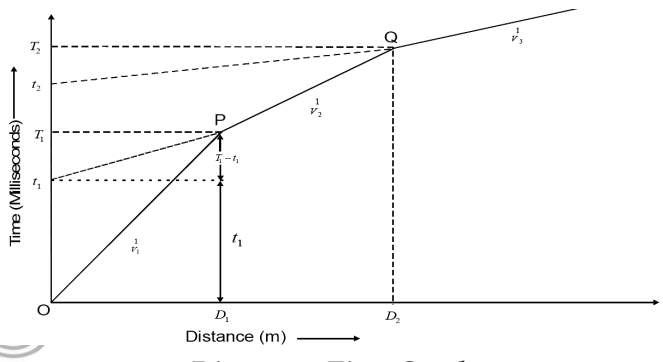
(c) refracted waves

The direct waves travels in approximately straight lines from the source of impulse to the surface. The waves which are turned back when they meet a boundary separating media of different seismic velocities are called reflected waves. The waves which undergo a change or a bending in their direction on meeting a boundary separating media of different seismic velocities are called the refracted waves.

As the distance between the shock point and the geophone increases, the refracted waves are able to reach the geophone earlier than the direct waves.



Seismic Refraction



Distance - Time Graph

Figure above shows the travel of primary and refracted waves. The results are plotted as a graph between distance as abscissa and time of travel as ordinate as shown in Figure above.

The point P and Q in distance time graph represents the point of simultaneous arrival of primary and refracted waves. The corresponding distance is knows as the critical distance which is a function of the thickness and velocity ratio of the deposit.

This method can be used for identification of deposits having more than two strata or inclined strata boundaries.

Electrical Resistivity Method

This method is based on the fact that different types of soil offer different resistance to the flow of an electrical current. The resistance to flow of current is determined by measurement of resistivity (ρ). Resistivity (ρ) is defined as the resistance in ohms between opposite faces of a unit cube of the material. It can be expressed as

$$\rho = \frac{RA}{L}$$

where R is the resistance in ohms of a block of conducting material of length L and cross-sectional area A.

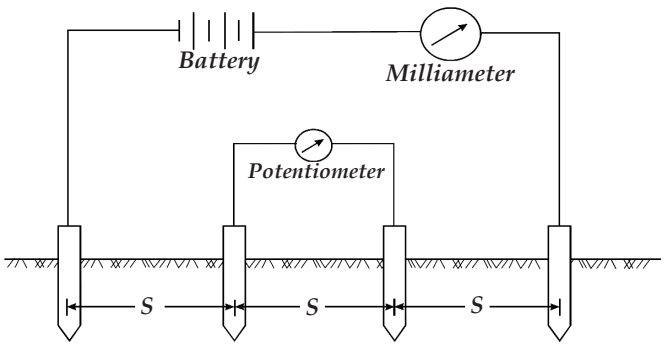
The resistivity of a soil depends primarily upon the moisture content and the concentration of dissolved salts. The resistivity will decrease as both the moisture content and salt content increase.

The test is conducted by driving four equally spaced electrodes into the ground at a straight line. A direct voltage is imposed between the two outer potentiometer electrodes and the potential drop is measured between the inner electrodes.

The apparent resistivity is given by

$$\rho = 2\pi\ s\frac{E}{1} = 2\pi\ s\ R$$

where, s = electrode spacing.



Electrical Resistivity Method

The apparent resistivity is the weighted average of the true resistivities of the materials to a depth equal to the electrodes spacing(s).

Two methods are adopted for exploration

(a) Resistivity Profiling, and (b) Resistivity Sounding

Resistivity Profiling

This method is used for investigation of lateral variation of soil types. It is used particularly for delineating boundaries of pervious deposits and for locating faults and steeply dipping contacts between different materials. The four electrodes with a constant spacing are moved as a unit either along a single line or along several parallel lines and a series of reading is taken. The apparent resistivity is plotted against the centre position of the four electrodes to natural scales. Contour of equal resistivity is plotted for the area traversed.

Resistivity Sounding

- This method is used to get information on the variation of sub surface materials with depth. The centre of the electrodes is maintained at a fixed level and the equal spacing of the electrodes in increased for each successive reading to get the requisite information. The depth of material affecting the apparent resistivity increases with increase of spacing of electrodes and the changes in material are reflected in the measured values of resistivity. This method can be used to know the sequence of high and low sensitivity zones, to estimate the depth to sand and gravel, bedrock or water bearing strata, and to estimate the thickness of strata.
- The sounding data are plotted preferably on a log-log graph which can be interpreted by comparing with a set of standard curves.

BEARING CAPACITY

ULTIMATE BEARING CAPACITY FOR SHALLOW FOUNDATIONS

The supporting power of a soil or rock is referred as bearing capacity.

Definition of Terms

Total Overburden Pressure

The total overburden pressure on any horizontal plane is the intensity of total pressure, due to the weight of both soil and water. It is represented by σ.

Surcharge Pressure

The total overburden pressure at the base level of the foundation before commencement of construction operation is called the surcharge pressure. It is represented by σ_o.

Effective Overburden Pressure

It is the total overburden pressure minus the pore water pressure at the foundation level. It is represented by σ′.

Total Foundation Pressure or Total Bearing Pressure

It is defined as the total pressure at the foundation level after the structure has been fully constructed and fully loaded. It is represented by q.

Net Foundation Pressure or Net Bearing Pressure

It is defined as the net increase in pressure at the foundation level due to the dead and live loads applied by the structure. It is represented by q_n. It can be calculated from the following equation :

$$q_n = q - \sigma_o = q - \gamma D$$

where D is the depth of foundation and γ is the average unit weight of soil above foundation base.

Ultimate Bearing Capacity

The ultimate bearing capacity of a soil is defined as the gross load intensity at which the supporting soil immediately below and adjacent to a foundation fails in shear. It is represent by q_{ult}.

Solution:

Given A = 16, F = 10, h = 20, d = 6

$$\text{System capacity, } Q = 2780 \times \frac{16 \times 6}{10 \times 20 \times 70}$$

$$= 19 \text{ liters/sec.}$$

Drip Irrigation

Drip irrigation, also known as trickle irrigation or micro irrigation is an irrigation method which minimizes the use of water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. It is becoming popular for row crop irrigation. This system is used in place of water scarcity as it minimizes conventional losses such as deep percolation, evaporation and run-off or recycled water is used for irrigation. Small diameter plastic pipes fitted with emitters or drippers at selected spacing to deliver the required quantity of water are used. Drip irrigation may also use devices called micro-spray heads, which spray water in a small area, instead of dripping emitters. These are generally used on tree and vine crops with wider root zones. Subsurface drip irrigation (SDI) uses permanently or temporarily buried dripper line or drip tape located at or below the plant roots. Pump and valves may be manually or automatically operated by a controller. The modern technology of drip irrigation was invented in Israel.

Drip irrigation is the slow, frequent application of water to the soil though emitters placed along a water delivery line. The term drip irrigation is general, and includes several more specific methods. Drip irrigation applies the water through small emitters to the soil surface, usually at or near the plant to be irrigated. Subsurface irrigation is the application of water below the soil surface. Emitter discharge rates for drip and subsurface irrigation are generally less than 12 liters per hour. Bubbler irrigation is the application of a small stream of water to the soil surface. The applicator discharge rate (up to 250 liters per hour) exceeds the soil's infiltration rate, sb the water ponds on the soil surface. A small basin is used to control the distribution of water. Micro-spray irrigation applies water to the soil surface by a small spray or mist. Discharge rates are usually less than 120 liters per hour.

Components of Drip Irrigation System (Listed in Order from Water Source)

(a) Pump or pressurised water source.
(b) Water Filter(s) - Filtration Systems : Sand Separator, Cyclone, Screen Filter, Media Filters.
(c) Fertigation Systems (Venturi injector).
(d) Backwash Controller.
(e) Main Line (larger diameter Pipe and Pipe Fittings).
(f) Hand-operated, electronic, or hydraulic Control Valves and Safety Valves.
(g) Smaller diameter polytube (often referred to as "laterals").
(h) Poly fittings and Accessories (to make connections).
(i) Emitting Devices at plants (Example : Emitter or Drippers, micro spray heads, inline drippers, trickle rings).

Suitability and Limitation

- From stand point of crops, soil, and topography, drip irrigation is best suited for tree, vine, and row crops. A lot of research work has been conducted to establish the suitability of drip irrigation for different vegetable crops. Drip irrigation has been found suitable both for field vegetable crops and also under covered cultivation practices. The main limitation of drip irrigation system is the cost of the system, which can be quite high for closely-spaced crops. That is why, it is highly suitable for vegetable crops. Drip irrigation is suitable for most soils, with only the extremes causing any special concern. On very fine textured soils, drip application rates may cause ponding, with potential runoff, erosion and aeration problems. On very coarse textured soils, lateral movement of water under the applicators will be limited, so more emission outlets per plant may be required to wet the desired root area. With proper design, using pressure compensating emitters and pressure regulators if required, drip irrigation can be adapted to virtually any topography. In some areas, drip irrigation is successfully practiced on such steep slopes that cultivation becomes the limiting factor.
- With respect to water quantity and quality, drip irrigation uses a slower rate of water application over a longer period of time than other irrigation methods. The most economical design would have water flowing into the farm area throughout most of the day, every day, during peak use periods. If water is not available on a continuous basis, on-farm water storage may be necessary. Drip irrigation can be used successfully with waters of some salinity, although some special cautions are needed. Salts will tend to concentrate at the perimeter of the wetted soil volume. If too much time passes between irrigations, the movement of soil water may reverse itself, bringing salts back into the root zone. Salts concentrating on the surface around the edge of the surface wetted area can be a hazard should a light rain occur. Such a rain can move the salts down into the root zone, without applying enough water to leach the salts through and below the root zone. When rain falls after a period of salt accumulation, irrigation should continue as normal until about 50 mm of rain have fallen to prevent salt damage. In arid regions where annual rainfall is insufficient (less than 300 to 400 mm) to leach the salts, artificial leaching may be necessary from time to time, requiring the use of a supplemental sprinkler or surface irrigation system.
- Though a form of pressurized irrigation, drip is a low pressure, low flow rate method. These conditions require small flow channel openings in the emission

devices, which are prone to plugging. The sensitivity of emitters to plugging varies with design, but virtually all emitters will require some degree of water treatment in agricultural situations. Cyclonic-separators and screen filters are used to remove inorganic particles from the irrigation water, and media filters are used to remove organic contaminants. Chemical treatment of the water may also be required to control biological activity in the water to adjust pH, or to prevent chemical precipitation which could plug emitters. Proper design and care of the water treatment system is vital to the successful use of drip irrigation.

- High efficiencies are the advantages of drip irrigation system. Properly designed and maintained drip systems are capable of high efficiencies. Design efficiencies should be on the order of 90 to 95%. With reasonable care and maintenance field efficiencies in the range of 80 to 90% may be expected. Where plugging is a problem, or emitter performance is highly variable field efficiencies may be as low as 60%.
- Labour and energy considerations are very important consideration in drip irrigation system. Due to their low flow characteristics, drip irrigation systems usually have few sub-units, and are designed for long irrigation times. The systems are easily operated manually. But can also be fully automated. Thus, the major labor requirement is for system maintenance and inspection. The amount of maintenance labor required is related to the sensitivity of the emitters to plugging and the quality of the irrigation water. In a vineyard situation, one irrigator can inspect and maintain about 50 acres per day.
- Drip irrigation systems generally use less energy than other forms of pressurized irrigation systems. The emission devices usually operate at pressures ranging from 5 to 25 PSI. Additional pressure is required to compensate for pressure losses through the control head (filters and control valves) and the pipe network. System pressures range from about 30 PSI (small systems on flat terrain) to 60 PSI (larger systems on undulating terrain).
- Economic factors need special attention in case drip irrigation system as initial cost and operational cost is reasonably high. Drip systems costs can vary greatly. Depending on crop (plant. and therefore, emitter and hose spacings) and type of hose employed (permanent or "disposable" thin-walled tubing). Drip costs will be the lowest for widely-spaced orchard crops. Government of India has taken a number of initiatives including subsidy to popularise this method of irrigation methods. It is being used on large commercial scale now in different parts of the country particularly Western and Southern part and pockets of Northern India.

Advantages

The advantages of drip irrigation are :

- Minimised fertilizer/nutrient loss due to localized application and reduced leaching, allows safe use of recycled water.
- High water distribution efficiency. Moisture within the root zone can be maintained at field capacity.
- Leveling of the field not necessary. Soil type plays less important role in frequency of irrigation, minimised soil erosion.
- Highly uniform distribution of water, i.e. controlled by output of each nozzle.
- Lower labour cost.
- Early maturity and good harvest.
- Foliage remains dry thus reducing the risk of disease.

Comparison between Conventional and Drip Irrigation

Performance Indicator	Conventional Irrigation Methods	Drip Irrigation
Water saving	Waste lot of water. Losses occur due to percolation, runoff and evaporation	40-70% of water can be saved over conventional irrigation methods. Runoff and deep percolation losses are nil or negligible.
Water use efficiency	30-50%, because losses are very high	80-95%
Saving in labour	Labour engaged per irrigation is higher than drip	Labour required only for operation and periodic maintenance of the system
Weed infestation	Weed infestation is very high	Less wetting of soil, weed infestation is very less or almost nil.
Use of saline water	Concentration of salts increases and adversely affects the plant growth. Saline water cannot be used for irrigation	Frequent irrigation keeps the salt concentration within root zone below harmful level
Diseases and pest problems	High	Relatively less because of less atmospheric humidity
Suitability in different soil Type	Deep percolation is more in light soil and with limited soil depths. Runoff loss is more in heavy soils	Suitable for all soil types as flow rate can be controlled

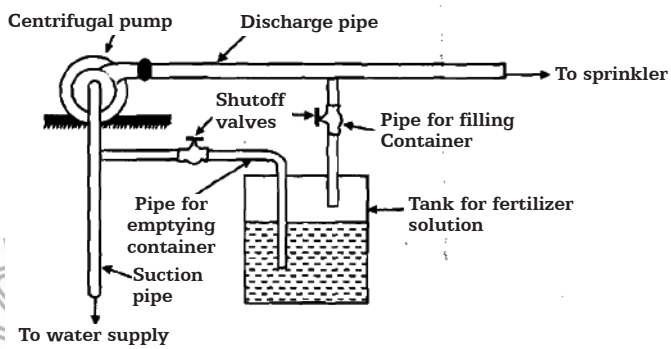
Performance Indicator	Conventional Irrigation Methods	Drip Irrigation
Water control	Inadequate	Very precise and easy
Efficiency of fertilizer use	Efficiency is low because of heavy losses due to leaching and runoff	Very high due to reduced loss of nutrients through leaching and runoff water
Soil erosion	Soil erosion is high because of large stream sizes used for irrigation.	Partial wetting of soil surface and slow application rates eliminate any possibility of soil erosion
Increase in crop yield	Non-uniformity in available moisture reducing the crop yield	Frequent watering eliminates moisture stress and yield can be increased up to 15 - 150% as compared to conventional methods of irrigation

Extent of Water Saving and Increase in Yield with Drip Irrigation Systems

Crops	Water Saving (%)	Increase in Yield (%)
Sugarcane	50	99
Tomato	42	60
Watermelon	66	19
Cucumber	56	45
Chili	68	28
Cauliflower	68	70
Okra	37	33
Ground nut	40	152
Mulberry	22	23
Banana	45	52
Grapes	48	23
Sweet lime	61	50
Pomegranate	45	45

Fertigation

Fertigation is the process of application of water soluble solid fertilizer or liquid fertilizers through drip irrigation system. Through fertigation nutrients are applied directly into the wetted volume of soil immediately below the emitter where root activity is concentrated. Fertigation is practiced only in drip irrigation system. However, fertilizer solution can be added with sprinkler irrigation system also. The method of adding fertilizer solution through the suction side of a centrifugal pump is shown in Figure below.



Adding Fertilizer in Solution through the Suction Side of a Centrifugal Pump

Components of Fertigation

The main component of a fertigation is drip irrigation system. The main components are :

(a) Venturi pump (injector)
(b) Fertilizer tank with flow bypass
(c) Pressure bypass tank
(d) Injection pump

The operation principle of venture is to create a pressure difference due to presence of constriction in the pipeline. The constriction creates high velocity of the solution, as an effect of continuity principle, due to that head loss is created in the constriction. This creates suction effect, which is used by the pump to suck the fertilizer solution into the main line. The injector operates over a wide range of pressure.

Computing Fertilizer Quantities

Fertilizer recommendations are given in many different ways, such as :

(a) Tables of fertilizers.
(b) Results of laboratory tests by extension service.
(c) Direct advice in the field by crop specialists.

The data may be expressed as: weight or volume of fertilizer; amount of fertilizer element; concentration in the irrigation water; fertilizer water ratio and others.

By Weight per Unit Area

The recommendation is expressed as kg/ha/day.

Fertilizer required, kg/ha/day

$$= \frac{\text{Fertilizer element, kg / ha}}{\text{\% of element in the fertilizer}} \times 100$$

By Volume per Unit Area

When liquid fertilizer is used, it is easier, in preparation and control, to use the volume measured.

Volume of fertilizer required, 1/ha

$$= \frac{\text{Weight of fertilizer, kg / ha}}{\text{Density of fertilizer, kg / l}} \times 100$$

Quantity per Irrigation Shift

It is used when the fertilizer is applied during a specific irrigation without reference to duration or diluation.

Amount of fertilizer (kg or l)

= Per hectare application × Area

Calibration of Fertilizer Tank in Bypass Flow

Rate of delivery, l/min

$$= \frac{\text{Volume of water, l}}{\text{Duration of fertilizer ion, min}} \times 100$$

By Weight per Unit Area

$$\text{Weight, g/m}^3 = \frac{\text{Concentration of element, ppm}}{\text{\% of element in the fertilizer}} \times 100$$

Advantages of Fertigation

- The fertilizer solution is distributed evenly in the irrigation network with the same uniformity as the irrigation water.
- The availability of nutrients including micro-nutrients is high, therefore the efficiency is very good.
- The fertilizer system can also be used for other activities such as incorporating acid to flush the drip system.
- It eliminates the work of spreading fertilizer. Manual spreading of fertilizer causes soil compaction and may damage the growing crop.
- Fertilizer placement is exactly to the root zone of plant and can be uniformly applied through drip irrigation system.
- All types of nutrients can be given simultaneously.
- Lower doses of fertilizer could be applied daily or weekly (i.e. a large number of split application) to avoid leaching and fixation in soil.
- Some liquid fertilizers are free of sodium and chloride salts, so these are not harmful to soil.
- Optimum production in light soil is possible.
- Spraying with liquid fertilizer is possible.
- Liquid fertilizers are immediately available to plants.
- Fertilizer use efficiency can be increased by 25 to 30% over the tradition method of fertilizer application.
- It decreases labour and energy cost.
- The quality and quantity of crop production can be improved.

Limitations

The fertigation system also has some limitations. The main one is the danger of poisoning people who drink the irrigation water particularly laborers those work on the farm. It is therefore necessary to warn the people in the field about drinking water separately and put up warning signs. The reverse flow of water mixed with fertilizer must be prevented.

Toxicity and Contamination

Care must be taken whenever fertilizer solution is introduced into a water supply system.

Fertilizer Suitability

Slowly water-soluble fertilizer such as super phosphate or calcium ammonium phosphate is not suitable. This method is suitable for liquid fertilizers or those that are readily soluble in water.

Corrosion

The metallic parts of the equipment are highly prone to corrosion. Sensitive parts of the equipment must be made out of corrosion resistant materials and extra care should be taken when filling the tanks.

Chemical Reaction in the Network

Certain fertilizer, e.g. phosphates may be subjected to precipitation within the pipeline depending on pH reaction. Criteria for applying fertilizers through drip system.

All the chemical fertilizers applied through drip irrigation systems must meet the following criteria :

(a) They must avoid corrosion, softening of plastic pipe and tubing or clogging of any component of the system.

(b) Fertilizers must be safe for field use.

(c) They must increase or at least not decrease crop yield.

(d) Fertilizers should be 100 per cent water soluble so as to leave no residue in the system.

(e) They should not react adversely with salts or other chemicals in the irrigation water.

In addition, the fertilizers must be distributed uniformly throughout the field. Distribution of fertilizers to a field depends on flow characteristics of water in the system and the uniformity of water application by emitters. A drip irrigation system should be designed with no more that 5% discharge variation and close to or above 94% emission uniformity. As the system clogs, discharge variation will increase, causing more variation in the fertilizer application.

WATER LOGGING AND DRAINAGE

Water is a scarce commodity; quality water is rare. Just as any water is not fit for human consumption similarly any water is not suitable for plant growth. Water comprising impurities to the extent which are injurious to plant growth, is not suitable for irrigation, and is called the unsatisfactory. Whatever may be the source of water, surface water sources like river, canal, tank or ground water sources like open well or tube well, some soluble salts are always dissolved in it. The main soluble constituent in water is calcium, magnesium sodium and potassium as cation and sulphides, bicarbonates and sometimes carbonates as anion. The above soluble constituents along with boron are of prime importance in determining the quality of irrigation water and its suitability for irrigation purpose. However, the quality of irrigation water is much influenced by the constituents of soil, its texture, structure, drainage characteristics, nature of crop grown and climatical conditions. A particular water may be harmful for irrigation on a particular soil, but the same water may be tolerable or even useful for irrigation in some other soil conditions. Thus, the suitability of water for irrigation will be determined by the amount and kind of salt present. Keeping in

Location or Construction Surveys

For locating and laying out of engineering works on ground.

Engineering Surveys

For determination of quantities useful in designing of engineering works, e.g. earth work, foundation bed level etc.

Hydrographic Surveys

To obtain information and data about under water features of ground, e.g. showing shorelines, water depths, shape of river bed, and other marine features.

Topographic Surveys

For preparation of plans and maps delineating natural and man-made surface features and ground undulations.

Route Surveys

For collecting data over a narrow belt of land for projects like highways, railways, canals, and transmission lines etc. to plot the longitudinal sections and cross-sections along the route at suitable intervals.

Geological Surveys

To ascertain the composition of earth's crust.

Mine Surveys

For exploring the mineral wealth below the earth's surface.

Archaeological Surveys

Executed to obtain details of the remains of ancient civilisations at site.

Military or Defence Surveys

Carried out to locate information about strategic features on ground for the preparation of maps of defence/ military use and significance.

Cadastral Surveys

These involve determination and plotting boundary locations of individual land holding and/or laying out new property boundaries.

Classification Based on the Instruments Used

An alternate classification may be based upon the instruments or method used. The main types are as follows :

- Chain surveying,
- Compass surveying,
- Levelling,
- Plane Table surveying,
- Theodolite surveying,
- Tacheometric surveying,
- Aerial surveying,
- Photographic surveying,
- Electronic Distance Meter (EDM) and Digital Theodolite,
- Electronic total station, and
- Global Positioning System (GPS) surveys.

Classification Based on the Methods and Phases

In order to ensure preparation of up-to-date and accurate maps of data pertaining to terrain surface, associated features and other collateral data is required for planning and designing of various civil engineering projects, e.g. highways, pipelines, bridges, reservoirs, dams, buildings etc. It is necessary to adopt a systematic approach. Various stages of conducting field surveys for any engineering project requires different methods such as

(a) Reconnaissance survey,
(b) Preliminary survey,
(c) Control survey, and
(d) Construction survey.

Reconnaissance Survey

First of all reconnaissance of the area is conducted for getting the first hand information of the area under investigation. A visit is made to the site to collect all the relevant information pertaining to the project. The existing maps, if any, of the area are referred and the desired portion under investigation is traced to obtain the base map for reconnaissance.

The base map is taken to the site and rough surveys are carried out using minor instruments, e.g. compass, sextant etc. This helps in deciding about the possible location of survey stations which are thereby determined and transferred on this map.

Preliminary Survey

After the reconnaissance surveys, pre engineering surveys also called preliminary surveys, location surveys or data gathering surveys are conducted. These involve collection of vital information and data for the design and construction. The map scale and contour intervals are decided upon. The various steps for conducting the preliminary survey are :

- provision of horizontal and vertical control,
- construction of gratecule and plotting of control points, and
- detailed plotting and contouring.

Control Survey

- The establishment of a base for horizontal and vertical measurements is known as control survey. The first essential step of control is to produce an accurate map and cover the whole area with a number of carefully selected points forming a framework on which to base the subsequent detail construction surveys. This leads to establishment of control points both horizontal control points and vertical control points. The main objective of providing the control points is to prevent accumulation of errors in the subsequent detail surveys and to connect the project survey to the state and national survey systems.
- The horizontal control is generally established by either triangulation/trilateration or traversing. Triangulation is the process of measuring the angles

of a chain or a network of triangles formed by stations marked permanently on the ground earth surface. The basic principle of triangulation is that if the angles of a triangle and length of one side are known precisely, the length of all other sides can be computed. Trilateration is similar to triangulation except that instead of measuring angles to the desired precision, the distances of the sides of the triangles are measured precisely. Due to the advent of electronic distance measurements equipment, the distances can be measured with very high accuracy and precision. Hence trilateration is gaining preference over triangulation.

- For project covering areas of smaller extent, traversing is ideal and fast. Traversing is also preferred when the terrain is flat. Traversing may not provide as accurate control as triangulation or trilateration but is good enough for control fixation for an engineering project survey. A traverse is a chain of finite straight lines fixed in a direction between pair of consecutive inter visible stations. The length and bearing of these lines are measured from which the coordinates of the points can be computed. Traverses are generally of two types :

  (a) Open traverse for route surveys, and

  (b) Close traverse for buildings, reservoirs and dams etc.

- The triangulation, trilateration or traversing are essentially for establishing the horizontal position of control stations (e.g. x and y coordinates). In addition to this, vertical control is also required to be determined with accuracy. This may be achieved by levelling.

Construction Survey

Construction surveys are detailed surveys conducted during construction of the project, to fill up the details of ground features both horizontal and vertical by simple and less accurate methods, in between the accurately established control points by more precise equipment. These methods are discussed in detail in subsequent units and consist of measuring distances, angles and heights of specified natural or man-made features on ground.

Importance Of Surveying

For the successful execution of any engineering project, it is essential that the necessary ground data regarding location, distances and levels of all the critical features either natural or man-made be known accurately. This is necessary for designing, planning and subsequently in execution of these projects. Engineering projects generally require maps with different scales. Large scale maps are used for control points and gradually smaller scale maps for planning and construction purposes. Field surveys are conducted to prepare these maps on desired scales and accuracies. These are of great importance for variety of engineering functions, e.g. location of bridges and dams, fixing the road or railway alignment, computation of earthwork in highway and canal construction, hydraulic design of reservoirs and dams, setting out bridges and buildings and variety of such similar applications. It can be concluded that planning, designing, execution and operation of any civil engineering project cannot even be visualised in the absence of data pertaining to topography of the site. All this data is generated only by various methods and processes of field surveying. The data to be supplied by survey for some of the civil projects could be as below.

Data for Alignment Survey

- General topography of terrain.
- Geological characteristics.
- Width of waterway and maximum flood levels for each river and other drainages.
- Total length of the route.

Roads and Highways

- Establishing centre line and offset lines.
- Determination of cuts and fills.
- Layout of line and grade and grade transfers/grade separation.

Tunnels

- Surface surveys for alignment of the tunnel.
- Underground surveys and their connection with surface surveys.
- Levelling.

Bridges

- Topographical map for staking out of abutments and length of the bridge and to decide approaches to the bridge.
- Contour plan of bridge site.
- Other data such as river width, hydraulic and soil/ subsoil details for location of abutments centre of piers, distance between piers, types of foundations and their depths etc.

CHAIN SURVEYING

In plane surveying, we usually measure horizontal linear distances between two points and angles between two lines. The linear measurement of distance between two points on the earth's surface can be carried out by several methods depending upon the degree of accuracy and precision required.

Chain surveying is the simplest method of surveying in which only linear measurements are made in the field. It is suitable for survey of smaller areas on open ground to obtain measurements for plotting exact description of boundaries of a piece of land or for taking simple details. The principle of chain surveying is to provide a framework consisting of a number of connected triangles, as the triangle is the only simple figure that can be plotted from the lengths of its side measured in the field. The area to be surveyed is divided into a number of triangles and the sides of the triangle are measured in the field. To get good results in plotting, the framework should consist of triangles which are as nearly equilateral as

possible. Preferably all the sides of a triangle should be nearly equal having each angle nearly 60° to ensure minimum distortion due to errors in measurements of sides and plotting.

Instruments

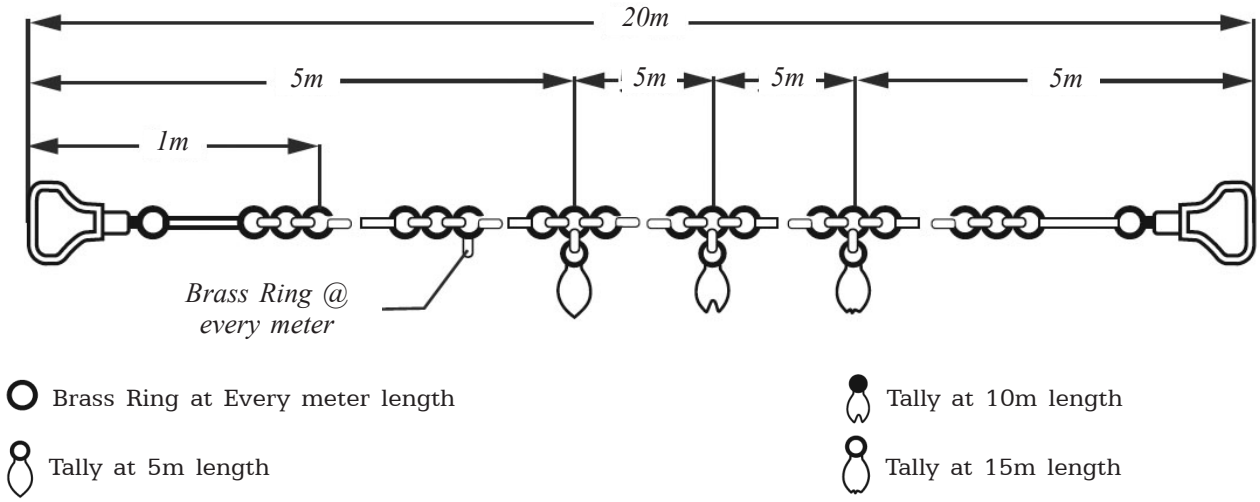
Various methods used for linear measurements of distances between two points on the earth's surface can be broadly classified (based on instruments used) as :

- direct measurements by chain or tape,
- measurements by optical instruments and/or with calculation, e.g. tachometry or triangulation, telemeter, substance bar etc. and
- electronic devices, e.g. Geodimeter, Distomat, EDM etc. based on propagation, reflection and reception of radio/light waves.

The most commonly used method of measuring linear distances particularly in field and engineering surveys is by chain or tape. This process of measuring distances by chain is termed chain surveying.

Chains

- The basic instrument or equipment used in chain surveying is a chain or a tape. **A survey chain is generally composed of 100 or 150 links formed by pieces of galvanised mild steel wire of 4 mm diameter.** The ends of each link are looped and connected together by means of three circular or oval shaped wire rings to provide flexibility to chain. The length of each link is measured as the distance between the centres of two consecutive middle rings. The joints of links are welded to avoid length changes due to stretching.
- The ends of chain are provided with brass handles with swivel joints. This helps in turning the chain without twisting. The end link length includes the length of handle and is measured from the outside of the handle, which is considered as zero point or the chain end. Tallies, which are metallic tags of different patterns, are provided at suitably specified points in the chain to facilitate quick and easy reading. A semi-circular grove is provided in the centre on the outer periphery of handle of chain for fixing the mild steel arrow at the end of one chain length.
- **The number of links in a chain could be 100 in a 20 m chain and 150 in a 30 m chain.** The details of a metric chain are as shown in Figure below :



Metric Chain

The chain can be used conveniently in a rugged terrain and can be subjected to rough use under adverse site conditions. It can be read easily by even semi-literate persons. However, the length is liable to be changed due to continued usage. Its comparatively heavy weight may cause sagging in the chain thereby affecting the measurement accuracy.

Non-metric chains : In this type of chains units other than metric unit are used. Nowadays metric chains are used everywhere, non metric type of chains became obsolete. Generally these chains are of 2 types: Engineer's chain and Gunter's chain.

- **Engineer's chain : The Engineer's chain is 100 ft. long and consists of 100 links,** each link being 1 ft long. It is used in all engineering surveys such as roads, rail route & moderately plain areas.
- **Gunter's chain : The Gunter's chain is 66 ft. long and is divided into 100 links** each 0.66 ft long. It is very convenient for measuring distances in miles and furlongs and to know the area in acre

  10 Gunter's chain = 1 furlong

  50 Gunter's chain = 1 mile

  10 square Gunter's chain = 1 acre

Tapes

Tapes can be used for more accurate measurements of lengths. They are lighter and easier to handle and comparatively less liable to change in length than chain.

Depending on the material, these can be of following types :

(a) Cloth or linen tape
(b) Metallic tape
(c) Steel tape or Steel band
(d) Invar tape
(e) Fiber glass tape

Cloth or linen tapes are 12 to 15 mm wide closely woven linen varnished for moisture proofing. Commonly used lengths are 10 m, 20 m, and 30 m. Since these are liable to shrink when wet and alter in length due to twisting or stretching, these are rarely used for accurate measurements. The better ones are interwoven with small brass, copper or bronze wires to provide strength and resistance to shrinkage and stretching. **These are available in range varying from 2 m to 50 m in length.**

For accurate measurements, steel tapes are used. **These consist of light strip of steel with width ranging from 6 to 10 mm, in lengths of 2 to 50 m.** Alternatively, steel bands consisting of ribbon of steel with brass swivel handle at each end are used. **The width is usually 16 mm and length of 20 or 30 m.**

Steel tapes and bands can be more accurately graduated. The graduations are etched as meters, decimeters and centimeters on one side and 0.2 m links on other side. Band is normally divided by brass studs at every 20 cm and numbered at every one metre. The tapes and bands are very delicate and hence not suitable for rough usage. These also require frequent cleaning and drying to avoid rusting. It is also difficult to read as compared to chain.

Invar tapes of alloy of Nickel (36%) and steel can be used for higher accuracy as their coefficient of thermal expansion is very low. However, it is costly and more delicate in use. In recent times, fibreglass tapes are extensively used in the field survey because of its low thermal expansion, cheapness, strength, ruggedness and durability. These are available in ranges varying from 5 m to 30 m in length.

Other Auxiliary Equipment

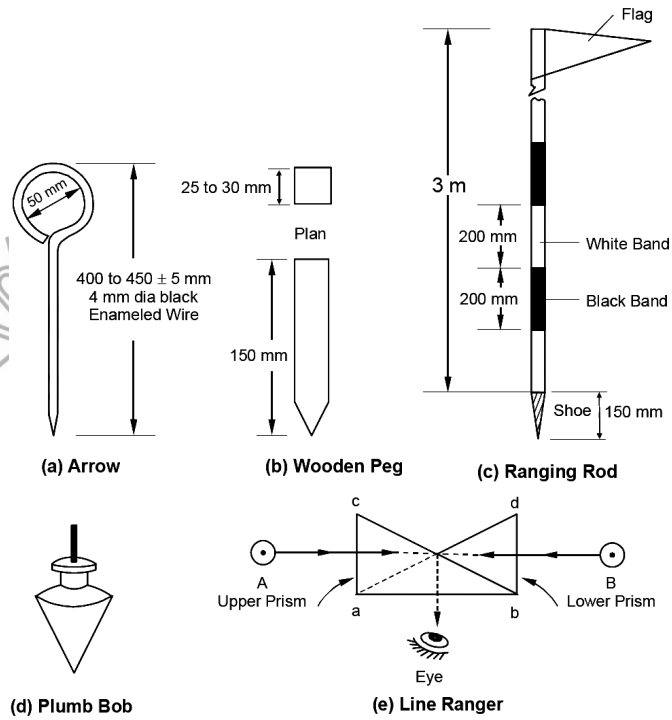
In addition to chain or tape, several other auxiliary equipment are required in a chain surveying exercise.

Arrows

Arrows or chain pins, as these are called sometime, are made of stout steel wire 4 mm in diameter, 400 to 450 mm long and black enameled. These are used to mark the end of each chain length as shown in Figure below.

Wooden Pegs

These are made of stout timber generally 25 to 30 mm square or circular size and 150 mm long as shown in Figure below. Wooden pegs are normally used to mark station position on ground on a quasi-permanent state. These are tapered at one end so that they can be driven in the ground with a hammer. These are kept at about 40 mm (minimum) projecting above the ground.



Auxiliary Equipment

Ranging Rods

These are octagonal or circular in plan normally 25 to 30 mm diameter straight timber or tubular steel rods, 3 m in length and provided with an iron shoe at lower end as shown in Figure. These are painted in black and white alternate bands and normally have a flag at the top for easy recognition and identification from a distance. If the ranging roads are graduated in meters and one tenth of a meter, they are called offset rods and are used for measurement of short offsets.

Plumb Bob

It is usually heavy spherical or conical ball, as shown in Figure and made up of metal and is used to transfer points on ground by suspending it with the help of a strong thread. It is used in measuring distances on sloping ground by stepping. Compass, Dumpy levels and Theodolites are also positioned over the station point accurately with the help of plumb bobs.

Line Ranger

A line ranger consists of either two plane mirrors or two right angled isosceles prisms placed one above the other as depicted in Figure. The diagonals of both the prisms are silvered so as to reflect the incident rays. Line rangers are provided with a handle to hold the instrument. A line ranger can also be used to draw offset on a chain line.

Procedures of Chain Surveying

Principle

The principle of chain surveying is derived from principle of triangulation. The whole area to be surveyed is divided into framework of triangles of suitable sizes.

Hydrographic Surveying

A hydrographic survey, also known as a bathymetric survey, is used to produce a bathymetric contour map, which is a plan of the depth of the sea bed for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection.

It is the branch of surveying which deals with measurement of any water body of still or running water such as a lake, harbor, stream or river. Hydrographic surveys are used to define shore line and under water features.

Uses:

The most common uses of the hydrographic survey can be listed as

- Measurement of tides sea coast work E.g. construction of sea defense works, harbors etc.,
- Determination of bed depth by soundings for location of rocks, sand bars, navigation light.
- Determination of scour and irregularities of the bed
- Determination of shore lines
- Establishment of the mean-sea level
- Preparation of navigation charts
- Measurement of discharge of rivers and streams
- Determination of direction of current to locate sewer fall
- Providing help in the planning of projects like bridges, dam and reservoirs etc.,
- Measurement of quantity of water and flow of water in connection of water schemes, Power scheme and flood controls.

Soundings :

The measurement of depth below the water surface is called sounding. Sounding is the main operation in hydrographic surveying.

Soundings are analogous to levelling on land, and therefore, the reduced level of any point on the bottom of water is obtained by subtracting the sounding from the mean sea-level. To take the sounding a vertical control is necessary. A horizontal is necessary to locate the sounding.

Purpose

Sounding are essential for the following purpose;

- Preparation of accurate chart for navigation
- Deamination of the quantity of the material to be dredged
- Location of the areas from where material to be dredged, and where to be dumped
- Obtaining information for the design of breakwater, wharves, etc.,

Instruments needed

- The essential equipment and instrument employed for taking the sounding are

1. Sounding boat
2. Sounding pole or rod
3. Lead line
4. Sounding machine

1. Sounding boat:

It is a flat –bottom boat of low draft. These are generally provided with opening, called wells through which soundings are taken. The sounding platform is provided and it extended far enough over the side so that the sounding line or sounding poles to do not strike the boat.

2. Sounding pole or rod:

These are made of strong well-seasoned timber usually 5 to 10cm in diameter and 5 to 8m on length. The sounding rods consist of two or three length screwed together so that unnecessary length may be removed when not in required for sounding in shallow water. A lead shoe of sufficient weight is fitted at the bottom, to keep the rod vertical in flowing water and avoid sinking in mud or sand. The graduation on the rod a marked from bottom upward. Hence the reading on the rod corresponding to the water surface , is directly the depth of water.

A lead line

A lead line is graduated rope of hemp or brass chain attached to the lead or sinker. The mass of the lead generally between 5 to 10kg, depending upon the strength of the current and depth of water. Lead lines are used for depth over 6 meters. A correction is required to be applied to the measured length to get true depth when using the lead line in the deep and swift-flowing water. Due to the drag, the measured length will be greater than the true length.

Sounding machine / Fathometer (Echo-sounding)

A fathometer is an echo-sounding instrument used to determine the depth indirectly. It works the principles of recording time travel by sound waves. Knowing the time of travel from a point of the surface of water to the bottom of ocean and back and the velocity of sound waves, the depth can be calculated.

Working principle

Advantages of fathometer

- It gives truly vertical accurate depth
- It is more sensitivity than lead line
- It gives a continuous profile by recording the measurement on a drum
- The sounding can be made with greater speed
- The rocks underlying soft oils are also recorded
- The velocity of sound waves varies with the density of water, adjustments can be made to read the depth of water of any type.

Steps in hydrographic surveying:

Before locating the details in hydrographic survey, the following preliminary steps are required to be carried out

1. Reconnaissance
2. Establishing horizontal control
3. Establishing vertical control
4. Shore-line survey

1. Reconnaissance :

It is the first step in hydrographic survey by careful reconnaissance of the area to be surveyed in order to select the most-expeditious manner of performing the survey, and to plan all operation so that the survey is satisfactorily completed in accordance with the requirements and specifications governing such work. The use of aerial photographs can be considerable help in this preliminary study.

2. The horizontal control :

It is a framework by which land and marine features are in their true relative positions. It usually consists of series of connected lines whose lengths and azimuths are determines accurately. Triangulation and, traverse are most commonly executed to provide horizontal control,. For rough works, a tacheometric traverse or plane–table traverse may be run. However, for more precise control , a theodolite and tape traverse is usually run. For extended survey, where greater precision is required, horizontal control is provided by triangulation.

3. Establishing vertical control :

A number of bench marks are established near the shore line at close spacing to serve as vertical control.

4. Shore-line survey

Shore-line surveys are conducted for delineation of shore lines, determination of high and low-water lines, and the location of prominent points on the shore to which the horizontal position of soundings may be referred. Normal methods of chain survey and plane-table survey are adopted to survey irregularities in the shoreline. Points which are clearly visible from the water surface, are selected as reference points such as churches, temple. Light houses, wind mills, transmission pylons, etc., and their locations plotted easily. Determination of high-water line may be easily judged roughly from the marks on permanent rocks. For accurate, method of contouring may be adopted which a number of points are established at the time of high tide. The line connecting these points so obtained is the required high-water line.

ELECTRONIC DISTANCE MEASUREMENT (EDM)

For providing precise horizontal control using trilateration, it is necessary that the distances be measured as accurately as possible. The advent of EDM has made this possible. The EDM was first introduced in the late 1950. Since then, many refinements to these equipment have been made. The earlier EDMs were very big, heavy and expensive. With the advancements in electronic and computer technologies, these have become smaller, simpler and less expensive. The EDMs come in two parts : the instrument and the reflector.

The Instrument

The EDMs are generally of two types : electro-optical systems and electronic systems. The electro-optical systems use either light and laser waves or infrared waves whereas electronic systems use microwaves. The microwave systems require transmitter/receiver at both ends of the line to be measured. The infrared system requires a transmitter at one end and a reflector at the other end. The microwave systems are capable of measuring distances up to a limit of 100 kms whereas the infrared EDMs come in three different ranges, long range (10-20 km), medium range (3-10 km) and short range (0.5-3 km) equipment.

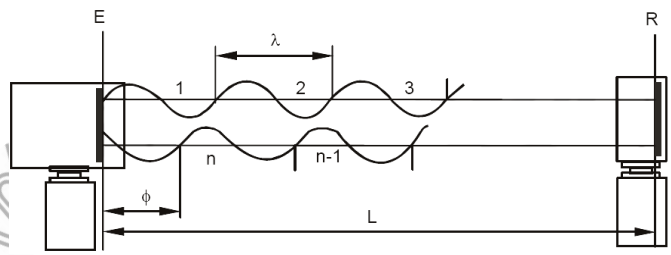
The Reflector

The reflector is usually a prism or a set of prisms. Generally, a cube corner prism is used that has the characteristic of reflecting light rays precisely back in the same direction as they are received. This means that even if the prism is somewhat misaligned with respect to the EDM, it can still be effective. These prisms can be mounted on a tripod or a pole held vertical on the point. For higher accuracy, the prisms should be mounted on a tripod. The height of the prism is normally set equal to the height of the instrument.

Recently, some EDMs have been introduced that can measure the distances without reflectors. In these situations, the surface itself behaves as a reflector. However, the EDMs without reflectors can only be used for the measurement of shorter distances within 1 km and also with reduced accuracy.

The EDM when mounted on a precise theodolite can be used to determine both slope and vertical distances. This arrangement has given rise to another category of surveying instrument known as Total Station or Field Station.

Principle of EDM



Principle of EDM Measurement

S – Station

E – Reference plane within the distance meter for phase comparison between transmitted and received wave

Z – Target

λ – Modulation wave length

R – Reference plane for the reflection of the wave transmitted by the distance meter

φ – Fraction to be measured of a whole wave length of modulation ($\Delta\lambda$).

The EDM systems are based on the principle of

distance travelled between the transmitted wave from one end and its reception at the other end. Thus, the basic relationship between time, speed and distance is applied. The instrument transmitting the infrared or microwaves is kept at one end whereas the reflector is kept at the other end. The instrument sends the waves, which are reflected by the reflector to be received by the instrument. Figure below shows a wave of wavelength λ travelling along the *x*-axis with a velocity v. The relationship between wavelength (λ), frequency (*f*) and velocity (v) can be given as,

$$\lambda = \frac{v}{f}$$

In above Figure, a modulated wave transmitted by the instrument and its reflection back to it is shown. It can be seen that the double distance 2L can be determined by knowing the total number of wavelengths plus the fraction of wavelength reaching the EDM. Thus,

$$L = \frac{(n\lambda + \phi)}{2}$$

The fraction wavelength φ can be determined in the instrument by noting the phase delay required to precisely match the transmitted and reflected waves. The instruments are designed to determine the number of wavelengths (n) within seconds and compute the distance in no time.

Corrections

Since the wave travels through the atmosphere, the velocity of the wave may be affected by temperature, pressure and water vapour content. Therefore, the appropriate corrections for these must be applied. Normally, the provision for these corrections is made in the instruments themselves by supplying the required values of the prevailing atmospheric quantities on the day of measurement.

Alternatively, these corrections can be applied manually by looking at the charts and graphs (showing the relationships between the quantities and the corrections) provided by the manufacturers of the instrument. It may, however, be mentioned that the effect of atmosphere is more pronounced in long distances of the order of kilometers. For short distances, less than a kilometer, the atmospheric corrections are less significant and may not be required.

Working of EDM

Before using EDM in the field, these are normally checked for their accuracy and proper adjustment. EDM instruments are calibrated against the known distances. The zero error (distances between electronic and physical centre), if any, is determined. This activity requires several measurements on different known lengths.

Once zero error is found out, the measurements can be taken. The typical operation of any EDM involves four basic steps of setting up, bisection, observing and recording.

Setting Up

The EDM instrument is first inserted into the tribrach on the tripod, which is centered exactly over the station mark through optical plummet. Reflector is set over the other point of the line whose distance is to be measured. The power of the instrument is turned on and certain initial checks are made. For example, to examine proper working of the battery and the display.

Bisection

The instrument is unclamped to bisect the reflector through the built-in sighting device. There are horizontal and vertical tangent motion screws for exact bisection of the reflector.

Observing

The distances are measured by simply pressing the measurement key and waiting for a few seconds. The result appears on the LCD panels. If there is no display, the user should check the previous steps. Repeated measurements are often made to observe the distances with more precision by pressing the repeat mode key. Some of the corrections normally applied on the distances measured by EDM instruments are atmospheric and zero error correction, slope to horizontal distance conversion etc. Since the measurements obtained are slope distances, some EDM have built-in calculators to compute horizontal and vertical distances if the vertical angles are fed manually through the keypad.

Recording

These days, all the EDMs are supplied with an electronic field book wherein the measurements can be recorded directly or by manual entry. The observations must be accompanied with all relevant atmospheric and instrumental correction data.

Accuracy Considerations

In general, the accuracy of an EDM is expressed in terms of a constant instrumental error and a measuring error proportional to the distance being measured. Thus, an accuracy value of ± (5 mm + 5 parts per million (ppm)) signifies that 5 mm is the constant instrument error (independent of the length of the measurement), whereas the 5 ppm (5 mm/km) represents the distance related error. For example, if the distance to be measured is 10 km then the total error in the measurement shall be 5mm + (5 × 10) mm which works out to be 55 mm or 5.5 cm. This is equivalent to an accuracy of 55 in 1,00,00,000 (or 1 in 181818).

Now-a-days, EDM equipment are being manufactured by various companies throughout the world. The specifications of these vary in terms of the distance range and accuracy.

TOTAL STATION

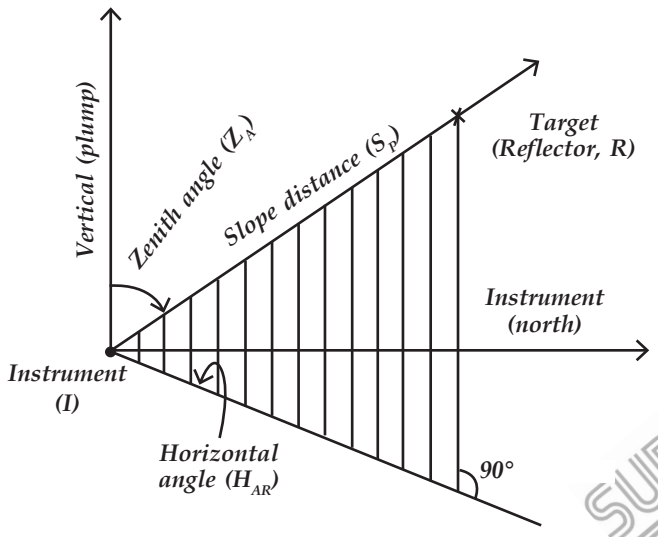
- **A total station is a combination of an electronic theodolite and an electronic distance meter (EDM).** This combination makes it possible to determine the coordinates of a reflector by aligning the instruments

cross-hairs on the reflector and simultaneously measuring the vertical & horizontal angles and slope distances.

- A micro-processor in the instrument takes care of recording, readings and the necessary computations. The data is easily transferred to a computer where it can be used to generate a map.
- As a teaching tool, a total station fulfills several purposes. Learning how to properly use a total station involves the physics of making measurements, the geometry of calculations, and statistics for analysing the results of a traverse. In the field, it requires team work, planning, and careful observations. If the total station is equipped with data-logger it also involves interfacing the data-logger with a computer, transferring the data, and working with the data on a computer. The more the user understands how a total station works, the better they will be able to use it.

Fundamental measurements : When aimed at an appropriate target, a total station measures three parameters :

- The rotation of the instrument's optical axis from the instrument north in a horizontal plane : i.e. horizontal angle
- The inclination of the optical axis from the local vertical i.e. vertical angle.
- The distance between the instrument and the target i.e. slope distance



Fundamental measurements made by a total station

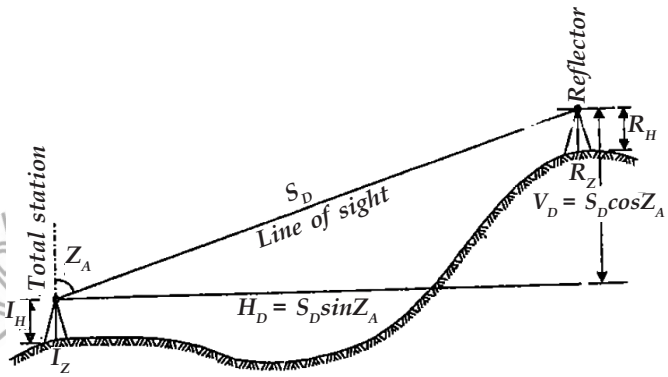
All the numbers that may be provided by the total station are derived from these three fundamental measurements.

1. Horizontal Angle

The horizontal angle is measured from the zero direction on the horizontal scale (or horizontal circle). When the user first sets up the instrument the choice of the zero direction is made - this is Instrument North. The user may decide to set zero (North) in the direction of the long axis of the map area, or choose to orient the instrument approximately to True Magnetic or Grid North. The zero direction should be set so that it can be recovered if the instrument was set up at the same location at some later date. This is usually done by sighting to another benchmark, or to a distant recognizable object. Using a magnetic compass to determine the orientation of the instrument is not recommended and can be inaccurate. **Most total stations can measure angle to at least 5 seconds, or 0.0013888°.** The best procedure when using a Total Station is to set a convenient "north" and carry this through the survey by using backsights when the instrument is moved.

2. Vertical Angle :

- The vertical angle is measured relative to the local vertical (plumb) direction. The vertical angle is usually measured as a zenith angle (0° is vertically up, 90° is horizontal, and 180° is vertically down), although one is also given the option of making 0° horizontal. The zenith angle is generally easier to work with. The telescope will be pointing downward for zenith angles greater than 90° and upward for angles less than 90°.
- Measuring vertical angles requires that the instrument be exactly vertical. It is very difficult to level an instrument to the degree of accuracy of the instrument. Total stations contain an internal sensor (the vertical compensator) that can detect small deviations of the instrument from vertical. Electronics in the instrument then adjust the horizontal and vertical angles accordingly. The compensator can only make small adjustments, so the instrument still bas to be well leveled. If it is too far out of level, the instrument will give some kind of "tilt" error message.



Geometry of the instrument (total station) and reflector

Where,

- I = Instrument ; R = Reflector; S_D = slope distance; V_D = Venical distance between telescope and reflector; H_D = Horizontal distance; Z_A = Zenith angle; I_H = Instrument height; R_H = Reflector height; I_Z = Ground elevation of total station; R_z = Ground elevation of reflector.

for example, industrial buildings. A typical interior bay (between two successive columns) is selected and its total cost worked out.

Then, the approximate cost of building = Number of bays in the building × cost of one bay.

Suitable correction factors may have to be used to take into account the dissimilarities in end-bay (and in different floors, if applied to multistoreyed construction).

Approximate Quantities Method

In this method, the main items are taken into account using short-cuts in the approximate calculation of quantities of main items such as walls, roofs, doors and windows, and finishes, and the cost is computed by adopting current unit costs for these items. The grouping of items and fixing their approximate cost requires good judgement and experience. This method though time-consuming, is more accurate than any of the above approximate methods.

VALUATION

Value :

Value means the present saleable value of the property. It may be more or less than the cost of property or its original cost. The value of the property mainly depends of its structure, life of building, location of property, maintenance, rent if may fetch etc.,

Cost :

Cost means the original cost invested towards the purchase of property or construction of building. The cost of an old building becomes less due to its age and changes in fashion.

Price :

The amount of money expected, required, or given in payment to the owner for purchasing the property. For less demand the selling price may have to be fixed lower and vice-versa.

Difference between Cost and Value :

The difference between these terms are explained with an example :

For an example, suppose a person has constructed a cottage at the remote area according to his willingness at a cost of Rs. 20 lakhs. But just after some period he wants to sell the property which has less value to the others utility and he gets a maximum of Rs. 12 lakhs. The owner was about to sell his property, but just at that time there is a proposal to develop that area as Hi-tech city and subsequently growth of population starts. So due to the higher demand the cottage becomes valuable and he sells it a price of Rs.40 lakhs. So the value of the property varies from Rs. 12 lakhs to Rs. 40 lakhs, but the cost remains the same as Rs. 20 lakhs. Therefore, the value depends on demand and supply whereas cost is a constant amount.

Normally, the value of the land is increasing day by day whereas the building is decreasing due to depreciation.

Valuation :

Valuation is the art of assessing or estimating the present fair value of a property such as a building, a factory, other engineering structures of various types, land, etc., By valuation the present value of a property is determined. The present value of the property may be decided by its selling price, or income or rent it may fetch.

Purpose of Valuation :

The main purpose of valuation are as follows :

- Buying and Selling of the properties.
- Taxation
- Rent fixation
- Security of loans or mortgage
- Compulsory acquisition for public use
- Insurance purpose

Definition of terms :

Capital cost :

Capital cost is the total cost of construction including land, or the original total amount required to possess a property and does not change.

Gross income :

It is the total income or receipt from all sources without deducting the outgoings necessary for taxes, maintenance, replacement or loss of rent, etc., whatever it may be.

Outgoings :

Outgoings are the expenses which are required to be incurred to maintain the property.

The various types of outgoings are as follows :

- Taxes (Municipal tax, Property tax, Wealth tax, Income tax, etc.,)
- Repairs (annual repairs 1% to 1.5% of total cost of construction may be taken)
- Sinking fund
- Management and Collection charges (5% to 10% may be taken for rent collector, watchman, liftman, Sweeper, etc.,)
- Insurance
- Loss of rent (the property may not be fully occupied)
- Miscellaneous (running lift, electricity, pump, lighting in common places, etc.,)

Net income or Net return :

It is the income or amount left after deducting all outgoings from gross income.

i.e. Net income = Gross income − Out goings

Year's Purchase :

It is defined as the capital amount required to invest in order to receive an income of ₹ 1.00 per annum at the rate of certain simple interest.

For 5% interest per annum (year), to get ₹ 5.00 it requires ₹ 100.00 to be deposited in a bank. To get ₹ 1.00 per year it will be required to deposit 1/5 of ₹ 100.00.

i.e., $\frac{100}{5}$ = ₹ 20.00

Thus, Year's purchase = $\frac{100}{\text{Rate of Interest}} = \frac{1}{i}$

i = rate of interest in decimal

Also, Year's purchase = $\frac{\text{Capital value}}{\text{Net income}}$

Capitalized value or Capital value :

The capitalized value of the property is the amount of a money whose annual interest at the highest prevailing rate of interest will be equal to the net income from the property.

i.e., Capital value = Net income × Year's purchase

Sinking fund (S) :

At the end of its useful life of the property, a property is either to be replaced or a structure is reconstructed. For this purpose the fund is gradually accumulated by way of periodic payments on annual deposit is termed as sinking fund.

The total amount of sinking fund required is given as follows:

S = Capital cost (or Original cost) − Scrap value (or Salvage value)

The amount of annual instalment (I) of the Sinking fund may be found by the formula :

$$I = \frac{Si}{(1+i)^n - 1}$$

I = Annual instalment

S = Total amount of Sinking fund

i = rate of interest in decimal

n = number of years required to create the Sinking fund

Co-efficient of Sinking fund (I_C) :

It is defined as the annual instalment for the redemption of ₹ 1.00 at the end of given period, at the rate of prescribed interest, i.e., when S = 1. Co-efficient of sinking fund I_C is given by,

$$I_C = \frac{i}{(1+i)^n - 1}, \quad \therefore I = S\ I_C$$

Depreciation :

Depreciation is the gradual exhaustion of the usefulness of a property. This may be defined as the decrease or loss in the value of a property due to structural deterioration, use, life, wear and tear, decay and obsolescence. Usually a percentage on depreciation per annum is allowed. The general annual decrease in the value of a property is known as annual depreciation.

Scrap value :

Scrap value is the value of dismantled materials of a property at the end of its life period. A certain amount can be fetched on sale of dismantled materials like bricks, steel, doors and windows, other wooden articles, etc.,. In the case of machine the scrap value is the value of the metal only or the value of the dismantled parts. **The scrap value of a building may be about 10% of its total cost of construction.**

The scrap value is obtained by deducting the expenditure incurred for dismantling and removal of the rubbish material from the total amount received by sale of its materials.

Salvage value :

It is the value at the end of the life period without being dismantled. A machine after the completion of its usual span of life or when it become uneconomic, may be sold and one may purchase the same for use for some other purpose, the sale value of the machine is the salvage value. It does not include the cost of removal, etc.,

Comparison between Scrap value and Salvage value

Sl. No.	Scrap Value	Salvage Value
1	It is the dismantled sale value of materials of an asset at the end of its useful life	This is the estimated value of an asset as a whole without dismantling at the end of its useful life
2	Scrap value is counted in the calculation of depreciation of the property	It is omitted in the calculation of depreciation
3	It is of an asset is merely sale of scrap and has limitation	Its deposition may take the form of a sale of the asset to a purchaser who will continue to use it for the function for which it was originally designed.
4	It is not counted as a minus quantity	There are times when it is a minus quantity

Obsolescence :

It is defined as the loss in the value of the property due to change in fashions, in designs, in structure, inadequacy in present needs, due to new inventions, poor original location, change in the nature of the district, etc.,.

Book value :

Book value is defined as the value of the property shown in the account book in that particular year. i.e., the original cost minus amount of total depreciation up to the previous year. Thus the book value of a property gradually reduces at a constant amount year after year up to the limit of scrap value, i.e., up to its life period. Book value is applicable on building and movable properties but not on land.

Market value :

It is the value of the property, which can be obtained at any time by selling the property in the open market. This value varies from time to time and depends on supply and demand, change in fashions, changes in industry, means of transport, cost of materials and labour, etc., in a particular place.

Difference between Market value and Book value

Sl. No.	Market Value	Book Value
1	The value is fixed by purchaser	The value is fixed by the rate of depreciation
2	The value may be constant for a period	The value cannot be constant, rather there is a gradual fall
3	This is applicable to any type of property	This is not applicable in case of land or metal article like steel, copper, gold etc.,
4	Market value is considered for valuation	It is considered for accounts book of a company
5	This depends on forces of demand and supply, development of the area etc.,	It is not variable due to its demand and supply or development of the area

Rateable value :

Rateable value is the net annual value of a property, which is obtained after deducting the amount of yearly repairs form the gross income. Municipal and other taxes are charged at a certain percentage on the rateable value of the property.

i.e., Rateable value = Gross income − Annual repair charges

Deferred value of land :

If a structure is standing on the land, the full value of the land alone can be realized only when the structure is demolished. For the purpose of valuation, the present cost of land is worked out and from the following formula, the deferred value of land upto the estimated life of the structure is obtained.

$$\text{Deferred value of land} = \frac{P}{(1+i)^n}$$

where, P = present cost of land

i = rate of interest in decimal on sinking fund or for redemption of capital

n = future life of the structure in years.

If the income is estimated to continue in perpetuity, the problem of deferred land value does not arise.

Lease :

It is a form of contract by which a land or building is given by its owner to any other person to use it for a term of period is called as lease. The person who takes lease is known as lessee or leaseholder and the owner who grants lease is known as lessor.

Mortgage :

The owner of a property can barrow loan on interest against the security of his property. Such advancement of money against any form of security is called as Mortgage. The transactions, the security and the conditions of loan are entered in a document known as Mortgage deed. The person who takes the loans is known as Mortgagor, and the person who grants the loan is known as Mortgagee.

The amount of loan will depend on the valuation of the property, usually 50 to 70% of the valuation is granted as loan. The interest should be paid by regular instalments, and the loan also may be repaid by regular instalments over the specified period of the mortgage. When the loan is fully repaid together with interest, the mortgager has got the right to free his property from the mortgage and this is known as equity of redemption. Factors causing reduction in market value :

Annuity :

Annuity is the annual periodic payments for repayments of the capital amount invested by a party. These annual payments are either paid at the end of the year or at the beginning of the year, usually for a specified number of years.

Though annuity means annual payment, the amount of annuity may be paid by twelve monthly instalments or quarterly or half-yearly instalments.

The following are the different types of annuities.

1 **Annuity certain** : If the amount of annuity is paid for a definite number of periods or years, it is known as Annuity certain.

2 **Annuity due** : If the amount of annuity is paid at the beginning of each period of year and payments continued for definite number of periods, it is known as annuity due.

3 **Deferred Annuity** : If the payment of annuity begins at some future date after a number of years, this is known as deferred annuity.

4 **Perpetual Annuity** : If the payments of annuity continue for indefinite period, it is known as perpetual annuity.

Amortization :

When the payment of a debt is made by a series of equal periodic payments, it is known as the amortization. Each periodic payment includes two provisions.

1 a certain portion of the principal, and

2 an account of interest on the outstanding debt.

Factors affecting the value of a property :

The following are the factors which affect the value of a property.

1. Factors causing reduction in market value :
   - Property is near hospital for health reasons.
   - Property is near to factory, tanning industries, air port, etc.,

- Water, Sewer, electric lines are much away from the site of the property.
- It is situated on narrow lanes away from the main road.
- It is situated in flood prone area.
- It is situated in low lying area.
- It is irregular in shape.
- It has block cotton soil in it.

2. Factors increasing the value of a property :

- It is in vacant possession. i.e. without tenant.
- It is at the junction of roads or corner plot.
- It is on the main road.
- It has more width on the road.
- It has hard soil for foundations.
- It is in the developed area with all facilities such as water, sewer and electricity.
- It has raised level, has no fear of flooding.
- Shopping centre, school, colleges, railway stations, bus stop, etc., are within reasonable short distances.
- The environment of the locality is good.
- Building materials and labour are easily available.
- Classification of properties :

Classification of properties :

For the purpose of classification, all the properties may broadly be divided into two categories, namely, land (immovable) and properties other than land (movable).

1. **Immovable property** : Land is an immovable property and it is also known as the real estate or real property or realty.

2. **Movable property** : A property other than land is known as movable property or personal property of personality or chattel.

The distinction between real estate and personal property is not very sharp. Everything firmly fixed to the soil is to be treated as land e.g. foundations, buildings, trees, etc., But the things which can easily be moved are to be treated as personality. Thus, the building materials are personality till they are not incorporated in the structures standing firmly on the soil. But they become realty when used in the construction of such structures. Similarly, coal, oil, etc., are realty till they are hidden in the earth. But they become personality when they are released or brought to the surface of the earth. The ornaments, furniture, etc., are other examples of the personal property.

According to the valuer, for the purpose of valuation the properties in land or land and buildings can be divided into two categories.

1. Freehold properties
2. Leasehold properties

1. **Freehold property** : A freehold property means that the owner is absolute possession of the property, and the owner can utilize the same in any manner, he likes, subject to the rules and regulations of government and local authorities. He may use the property by himself, he may grant leases, or tenancies for a short period or any period.

2 **Leasehold property** : It indicates the physical possession of the property and the use of it may be allowed by the original owner (lessor) as per lease document. The owner of a freehold property may give permission to any other person to use his freehold which is known as giving property on lease. The person who takes lease is known as lessee or leaseholder and the owner who grants lease is known as lessor.

Types of leases :

The main types of leases are :

1. Building lease
2. Occupation lease
3. Sub - lease
4. Life lease and
5. Perpetual lease

1. Building lease : The owner of a freehold land leases out his plot of land to somebody to construct a building, on payment of a yearly ground rent by the leaseholder. The leaseholder constructs the building and maintains it at his own expenses and earns some rent from the building. The net income to the leaseholder will be net rent minus the ground rent he pays to the lesser. As the leaseholder has to invest sufficient money in constructing the building, such lease is granted for long period for 99 or 999 years. At the end of the lease period the lesser has got the right on his land together with the structure on the land.

2. Occupation lease : In this type of lease the building or the structure is constructed by the owner (freeholder) and the constructed property is given to the lease for the purpose of occupation for a specified period on payment of certain amount of annual rent. The occupation lease may be for residential, office, factory, shop, etc.,. The lease period will depend on the purpose for which the building or structure has been constructed. If for a factory, the lease period should be 10 to 30 years, for other cases it may be less. In occupation lease the maintenance of the building or structure is usually done by the leaseholder which may be provided in the lease deed.

3. Sub - lease : A leaseholder may give the property as sub-lease to other persons subject to the terms and conditions in the original lease and be allowed by local regulations or court of law. The period of sub-lease shall be lesser than the original lease period. There may be more than one sub-leases of lease.

4. Life lease : When the duration of lease for a property is given until death of a person or persons, this is called "life lease".

5. Perpetual lease : When the lease of a property is given for a number of years providing a condition that the lease is renewable time to time, according to the desire of the leaseholder, such type of lease is called as "perpetual lease".

Air Pollution may also be defined as the **presence of one or more contaminants** like dust, smoke and odour in the atmosphere which are injurious to human beings, plants and animals.

The following are the causes of air pollution

1. Increase in population and traffic
2. Development of industries.
3. Development of automobile engineering
4. Development of agricultural.
5. Worldwide arms race.
6. Thermal and nuclear power generation.

SOURCES OF AIR POLLUTION:

Sources of air pollution may be classified into two groups

- ✦ Natural Sources
- ✦ Man made sources

1. Natural Sources:

Dust Storm:

Dust storms are produced due to wind circulation around the planet Earth. Global metrological processes make the environmental with dust pollution in some areas.

Forest Fire:

Huge quantities of smoke (Carbon particles) are liberated during forest fires.

Volcanoes:

Volcanoes (eruption of lava from earth's core) release lot of solid particles, gases like sulphur – di- oxide and radiation. Heat waves may be spread up to several kilometers.

The surrounding areas are greatly affected with heavy dust and heat pollution.

Sea Spray:

Sea spray is a continuous phenomena, which is a major source of particulate (liquid droplets) pollution in the atmosphere.

Plant Pollen:

During spring season, lot of plant pollen is produced and due to wind motion, it is spread very fastly, which makes the atmosphere with dust pollution. Many gaseous carbon compounds such as methane, carbon dioxide, carbon monoxide, etc are emitted into atmosphere through biological processes, volcanic eruptions, forest fires and natural gas seepage.

2. Man made sources

These may be classified into the following **four broad categories**.

- ✦ Industrial processes
- ✦ Combustion
- ✦ Motor vehicles
- ✦ Miscellaneous.

a. Industrial processes

In recent years, many types of industries such as chemical industries, metallurgical industries, oil refineries, fertilizer factories, etc. have sprung up. All these have contributed their might to air pollution.

b. Combustion

Industrial and domestic combustion of coal, oil and other fuels is another source of smoke, dust and sulphur-dioxide.

c. Motor vehicles

Motor vehicles are a major source of air pollution throughout the urban areas. Motor vehicles, ships, trains, air crafts and other forms of transports contribute to air pollution. They emit hydro – carbons, carbon- monoxide, lead, nitrogen – oxides and particulate matters. In strong sunlight, certain of these hydrocarbons and oxides of nitrogen may be converted into a photochemical pollutant of oxidizing nature. In addition, diesel engines, when misused or badly adjusted are capable of emitting black smoke and malodourous fumes.

d. Miscellaneous.

Burning of refuse, agricultural activities like crop spraying, pest control and nuclear energy programmers also contribute to air pollution.

Effects of Air Pollution:

Effects of air pollution are grouped as below.

1. Effects on human being
2. Effects on animals
3. Effects on plants
4. Effects on materials

1. Effects of air pollution on human beings

Air pollutants cause acute as well as chronic effect on human health. There is,

1. Irritation of the respiratory tract.
2. Irritation of eyes, nose and throat.
3. Lead Particles,(from automobile exhaust) cause lead poisoning in convulsion, delirium, coma and even death.
4. Cadmium particles (through cigarette smoking) cause cardio vascular disease, kidney and liver damage and even death.
5. Niickel particles (in tobacco smoke) result in respiratory damage.
6. Mercury (combustion of fossil fuels, plants) result in nerve, brain and kidney damage.
7. Radio-active fallout has some genetic effects on future generations.

S.No	Pollutant	Health Effect
1.	Lead	Bone troubles, liver and kidney damage, gastro intestinal damage, mental health effect in children and abnormalities in fertility and pregnancy.
2.	Particulates and sulphur oxides	Severity of respiratory disease, chronic bronchitis and lung cancer.

3.	Carbon mono oxide	It inhibits oxygen uptake of hemoglobin in the blood and is dangerous. Head ache and nousia.
4.	Nitrogen compounds	Severely irritating and excess illness in all family.
5.	Photochemical	Aggravation of asthma attacks and eye irrigation.
6.	Ozone	Irritation of nose and throat, Headache and dryness of mouth and throat.

2. Effects of air pollution on animals:

1. Animals, particularly the farm animals, get poisoned when they eat contaminated vegetation.
2. Plants sprayed with insecticides containing arsenic can lead to the poisoning of cattle.
3. Pet animals are found to suffering from bronchitis, asthma and lack of appetite.

Air pollution effect on animals

S.No	Pollutant	Health Effect
1.	Hydrogen sulphide	Respiratory, directory and pulmonary diseases.
2.	Fog and smog	Respiratory track affected and lassitude
3.	Ozone and photo chemical oxidants	Skin troubles, cancer and tumor on animals, ozone alone produce pulmonary troubles.
4.	Fluoride (produces from cement zinc and aluminum industries.). It is also found in soil dust.	Pulmonary disturbances, decay of bones, diarrhea, loss of weight, loss in milk production, fertility and tooth of animals get affected.
5.	Radio – active pollutants	Decrease the life span, genetic effect and blood cancer (leukemia)
6.	Fluorine, arsenic, Lead	Affect livestock

3. Effects of air pollution on plants

The following are the effects of air pollution on plants :

1. Necrosis
2. Chlorosis
3. Leaves abscission
4. Epinastly.
5. Acute injury
6. Chronic injury

- **Necrosis** is the death of internal cells of plants due to high concentration of pollutants of plants for short time.
- **Chlorosis** is the loss of pigment causing colour due to low concentration of pollutants on plants for long time.
- **Leaves abscessan** is falling down of leaves. This is due to necrosis and chlorosis.
- **Epinastly** is the bending down of leaves. This is due to necrosis and chlorosis.
- **Acute injury** is the severe visible damage to leaf tissues. It results due to short time exposure of pollutants of relatively high concentrations.
- **Chronic injury** is the injury due to long term exposure of pollutants of low concentration.

Air pollution effect on plants

S.No	Pollutant	Effect on plants
1.	Ozone	Affect the growth of tobacco plant.
2.	Ethylene	Affect orchides.
3.	Photochemical oxidants	A variety of tobacco is highly sensitive to this pollutant and get affected.
4.	Fluoride	Tobacco and gladiola plants are affected by fluoride.
5.	Smoke, smog, fog etc	Affect forests
6.	Sulphur-di-oxide	Even short time exposure give great damages to plants

4. Effects of air pollution on materials

Materials are affected by air pollutants in the following five ways.

1. Corrosion
2. Abrasion
3. Direct Chemical attack
4. Indirect chemical attack
5. Deposition and removal

These actions are added by temperature, moisture, wind, sunlight and position of materials.

Air pollution effect on various materials

S.No.	Materials	Pollutant	Effect on materials	Other aiding factors
1.	Building Materials	SO_2 acid, gases and adhering particulates	Discolorations	Moisture
2.	Metals	SO_2 acid, gases	Tarnishing of surface, loss of metal	Moisture and temperature

3.	Paints	SO_2, H_2 and particulates	Discoloration, inhibits dyeing	Moisture and fungus
4.	Ceramics	SO_2 acid, gases	Discoloration material removal	Moisture
5.	Textiles	SO_2 acid, gases air borne particulates	Dye-fading reduction in tensile strength, additional cleaning is necessary in laundry.	Moisture, sunlight and wind
6.	Paper	SO_2 acid, gases	Embrittlement	Sunlight
7.	Rubber	Oxidants	Cracking	Sunlight
8.	Electric & electronic parts, microfilm	Air – borne ozone	Degradation	Wind

Air Pollution Control Equipment

The following are the common types of control equipment

- ✦ Settling chamber
- ✦ Inertial separator (other than cyclones)
- ✦ Cyclones
- ✦ Electrostatic precipitators.
- ✦ Scrubbers (or) wet collectors.

Control Devices For Particulate Contaminants:

Depending upon the collection efficiency, capacity and operation mode, the particulate collection equipments are divided into three types. They are

A. Internal separator

B. Wet collectors or scrubbers and

C. Electrostatic precipitators.

A. Internal separator

Internal separators are manufactures in various shapes and sizes. The following are the most common types.

1. Gravity settling chambers

2. Cyclone filters

3. Fabric filters.

1. Gravity settling chambers

Gravity settling chamber mainly consists of an enclosed chamber as in fig. The velocity of the gaseous matter is considerably decreased. Thus, the dust particles settle down by gravity. In these chambers, the horizontal gas velocity should be kept as low as possible. The condition allows tream line flow and surely creates optimum settling conditions. Practically, the gas velocities are kept between 0.3 to 3 m/s in the chambers. Such velocities allow only large particles of size 40 micron and above to be removed effectively. The settling time required for smaller particles is very long. Therefore , the use of this type of equipment is impractical in such cases.

Advantages:

1. Simple in construction.
2. Low initial cost and low maintenance cost.
3. Dry and continuous disposal of solid particles is possible.
4. Low pressure drop.
5. Efficiency is high for coarse particle.
6. No moving parts involved.

Disadvantages:

1. Equipment may be subjected.
2. Low efficiency for particles of size range 5 to 10 microns.
3. Low efficiency for low concentration suspensions.

Application:

Settling chambers are used to remove particulates above 40 micron in diameter. They are used in

1. Food process industries
2. Metallurgical industries.

2. Cyclone filters

The cyclone filters works on the principle of separating the particles from the gas by transforming the inlet gas velocity into a double vortex motion inside the chamber. The entering gas spirals down at the inner surface of the cyclone. Then it spirals upward the central portion of the cyclone. This vortex separates the particulate matter which either falls down into the receiver or tends to concentrate on the surface of the cyclone wall. The clean gas then leaves the top portion of cyclone. These filters are cheaper in cost and best suited to dry dust particles of size 10 to 40 microns.

The efficiency of the cyclone filter increases with the increase of the following :

1. Inlet velocity of the dust laden gas.
2. Diameter of the dust particle.
3. Density of the dust particle.
4. Dust concentration in the carrier gas.
5. Smoothness of the inner cyclone wall.

If the quantity of gas treated is large, multi cyclone separators can be used. In this cyclone, the gas enters at the top and is given a twisting or vortex motion by a number of stationary vanes provided in its path. The efficiency is about 90 % for particulates of size 5 to 10 microns.

Advantages:

1. It is simple in construction and design.
2. ow initial cost and low maintenance cost.
3. No moving parts.
4. Pressure drop is less (25 mm to 200 mm)
5. It can be constructed with different types of materials to meet high temperature and pressure.
6. Dry and continuous disposal of soli particles is possible in the size range of 5 to 40 microns.

Disadvantages:

1. Equipment may be subjected to abrasion.
2. Low efficiency for particles of size range 5 to 10 microns.
3. Low efficiency for low concentration suspensions.

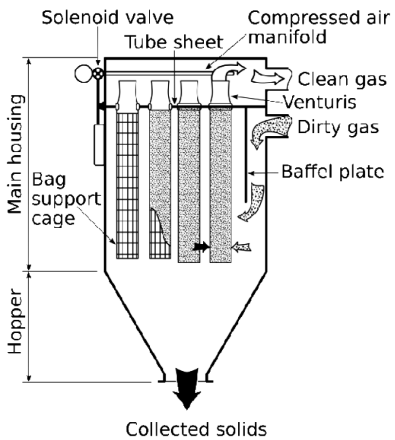
Application:

Cyclones are use to control the gas borne particulates. They are used in

1. Cement industry,
2. Grain processing,
3. Mineral processing, paper and
4. Textiles industries

3. Fabric filters. (Bag filters)

Bag filters are used for the removal of particles of size range of less than 10 microns. These are reliable and efficient system for particulate removals. These are arranged in an enclose called as **"bag house"**. The size of each bag is 120 to 400 m in diameter and 2 to 10 m long which are suspended. The outlet ends of the bags are open alternatively and attached to a manifold. The polluted gas enters through the inlet pipe. The large particles will fall into hopper by gravity. The gas flows into the bags and leaves through the outlet pipe. The particulate matter is retained on the inside of the bag and forms a cake. The cake will be cleaned with the help of the shaking mechanism, causing the filter cake is to be loosened. The loosened cake will fall into the hopper which is provided at the bottom of the bag house.



Fabric Filter

A wide variety of filter cloths are available commercially, which are given below.

Materials	Temperature range °C
Cotton (Cellulose Fiber)	80 - 85
Wool (animal fiber)	90 - 95
Nylon (Synthetic polyamide)	100 - 105
Darcon (poly ester fiber)	125 - 135
Fibre glass (Inorganic polymer)	250
Teflon	250

Advantages:

1. High collection efficiencies for all particle size. Particles of even 0.01 microns can be effectively removed (high efficiency for small particles)
2. Disposal of collected materials is done in dry condition.
3. Nominal power consumption.
4. Simple construction and operation.

Disadvantages:

1. High pressure drop and high maintenance cost.
2. Clogging of filters takes place, hence required frequent cleaning.
3. Filters work up to moderate temperature.

Application:

1. Cement factory.
2. Brick industry.
3. Ceramic industry chalk and lime plants
4. Foundries.

B. Wet collectors or Scrubbers

The removal of dust particles from the gas streams is assisted by wetting the particles with liquid droplets or impinging the gas stream on a collecting surface.

Principle involved in collecting particles by wet scrubbers:

- **Movement**: The particles must move to the vicinity of the water droplets.
- **Collision**: The particle must collide with water droplets.
- **Adhesion**: It is promoted by the property of surface tension.
- **Precipitation**: Removal of the droplet containing the dust particle from gas phase.

The following are the **common wet collection devices.**

1. Cyclone scrubbers or wet cyclones
2. Spray chambers
3. Venture scrubbers
4. Packed towers

1. Cyclone scrubbers or wet cyclones

These are also known as wet cyclones. The principle of operation is exactly the same as that of dry cyclone. The difference being moisture conditions are prevalent inside the cylinder scrubber because of the water spray introduced at the entrance.

The efficiency of collection is more than the dry cyclone. These scrubbers are designed for an air velocity of 2000 litres/minute and the water requirement ranging from 10 to 50 litres for every 40 litres of gas treated. The particles removal efficiency is 90%.

2. Spray Chambers

This is a simple gravity settling chamber with liquid sprays. Here, the fine water Spray washes the gas stream with water and settles the dust as sludge in the bottom of the chamber. The liquid droplets entangle the dust particles within them and fall down.,

Chemical composition

Constituents	Percent (Max.)
Carbon (For thickness/diameter 20 mm and below)	0.23
Carbon (For thickness/diameter over 20 mm)	0.25
Sulphur	0.055
Phosphorus	0.055

IS : 226–1975 structural steel (standard quality)

The mild steel is designated as St 44-S for use in structural work. This steel is also available in copper bearing quality in which case it is designated as St 44-SC. The copper content is between 0.20 and 0.35 per cent. All designs and examples have been worked out for the steel, conforming to IS : 226–1975. The physical properties of structural steel are given as under:

- Unit weight of steel 78.430 to 79.000 kN/m^3
- Young's modulus of elasticity, E = 2.04 to 2.18 × 10^5 N/mm^2
- Modulus of rigidity, G = 0.84 to 0.98 × 10^5 N/mm^2
- Coefficient of thermal expansion (or contraction), $\alpha = 12 \times 10^{-6}$/°C, $\alpha = 6.7 \times 10^{-6}$/°F.

The tensile strength, yield stress and percentage elongations for IS : 226–1975 structural steel standard quality, determined in accordance with IS : 1608–1960. Method for tensile testing of steel products other than sheets, strips, wires and tubes are given in Table as per IS : 226–1975.

Mechanical properties

Class of steel product	Nominal thickness diameter mm	Yield stress min. N/mm^2	Percentage elongation min.
Plates, Sections e.g., angles, tees, beams, channels etc., and flats	6 upto and including 20	260	23
	over 20 upto and including 40	240	23
	over 40	230	23
Bars (Round, squares and hexagonals)	10 upto and including 20	250	23
	over 20	240	23

The steel conforming to IS : 226 is suitable for all types of steel structures subjected to static, dynamic and repeated cycles of loadings. It is also suitable for welding upto 20 mm thickness. When the thickness of elements is more than 20 mm, it needs special precautions while welding.

IS : 1977–1975 structural steel (ordinary quality)

The steel which did not comply with IS : 226, was formerly called as steel of untested quality. The standards for such steel have been laid down in IS : 1977–1975 (Ordinary quality). There are two grades in this standard which are designated as St 44.0 and St 32.0. The steel St 44.0 is intended to be used for structures not subjected to dynamic loading other than wind loads e.g., platform roofs, office buildings, foot over bridge. The copper bearing quality is designated as St 44.OC.

The steel conforming to IS : 1977 is not suitable for welding and for the structures subjected to high seismic forces. The steel structures using steel conforming to IS : 1977 must not be analysed and designed by plastic theory.

IS : 2062–1984 weldable structural steel

This structural steel is intended to be used for members in structures subjected to dynamic loading where welding is employed for fabrication and where fatigue (wide fluctuation of stress, reversal of stress), and great restraint are involved e.g., crane gantry girder, road and rail bridges etc. It is designated as St 42–W and copper bearing quality is designated as St 42–WC.

It is suitable for welding the elements of thickness between 28 mm and 50 mm. When the thickness of elements is less than 28 mm, it may be welded provided the limiting maximum carbon content is 0.22 per cent.

High Tensile Steel

The high tensile steel forms a specific class of steel in which enhanced mechanical properties and in most of the cases increased resistance to atmospheric corrosion are obtained by the incorporation of low proportions of one or more alloying elements, besides carbon. These steels are generally intended for application where saving in weight can be effected by reason of their greater strength and atmospheric corrosion resistance. Standards of high tensile steel have been given in IS : 961–1975. It has been classified into two grades designated as St 58–HT and St 55–HTW. St 58–HT is intended for use in structures where fabrication is done by methods other than welding. St 55–HTW is intended for use in structures where welding is employed for fabrication. The high tensile steel is also available in copper bearing quality and two grades are designated as St 58–HTC and St 55–HTWC.

IS : 961–1975 (High tensile steel)

Chemical composition

Constituents	Steel Designation	
	St 58–HT	St 55–HTW
Carbon	0.27% max.	0.20% max.
Sulphur	0.055% max.	0.055% max.
Phosphorus	0.055% max	0.055% max.

The tensile strength, yield stress and percentage elongation for IS : 961–1975 high tensile steel, determined in accordance with IS : 1608–1960 method for tensile testing of steel products other than sheets, strips, wires and tubes are given in below table as per IS : 961–1975.

The steel conforming to IS : 961 is suitable for bridges and general building construction.

Mechanical properties

Class of steel product	Nominal thickness diameter mm	Tensile strength (N/mm^2)	Yield stress min. (N/mm^2)	Percentage elongation min.
Structural steel (St. 58–HT) For Plates, Sections, Flats and Bars	6 upto and including 28	570	350	20
	Over 28 upto and including 45	570	340	20
	Over 45 upto and including 63	570	320	20
	Over 63	540	290	20
Structural steel (St. 55–HTW) For Plates, Sections, Flats and Bars	6 upto and including 16	540	350	20
	Over 16 upto and including 32	540	340	20
	Over 32 upto and including 63	510	330	20
	over 63	490	280	20

The tensile and yield properties of steel may be increased by using increasing contents of carbon and manganese, but its ductility will be reduced. The welding is also difficult for such steel. The increased sulphur and phosphorus beyond 0.06 percent will give brittleness and affect weldability and fatigue strength. The chrome and nickel (if added) give corrosive resistance and resistance to high temperature.

The tensile and yield strengths are also increased and the ductility is maintained by other alloying elements.

The tensile strength, yield strength, ductility and weldability are the properties of steel which depend on the chemical composition of steel. The fatigue strength of steel members depends on their shape and surface characteristics. These five properties are the important properties of steel and while selecting the material, the effect, of different alloys must also be borne in mind.

Any structural steel other than those specified above may also be used provided that the permissible stresses and other design provisions are suitably modified and the steel is also suitable for the type of fabrication adopted.

IS : 8500–1977 Weldable structural steel (medium and high strength qualities)

Various medium and high strength qualities of weldable structural steel i.e., Fe 440 (HT1 and HT2) Fe 540 (HT and HTA and HTB), Fe 570 HT, Fe 590 HT and Fe 640 HT have been developed.

Chemical composition

Constituents	Steel Designation		
	Fe 440 HT	Fe 490 HT	Fe 590 HT
Carbon	0.25	0.25	0.25
Sulphur	0.055	0.040	0.050
Phosphorus	0.055	0.040	0.050
Manganese	1.5	1.5	1.5

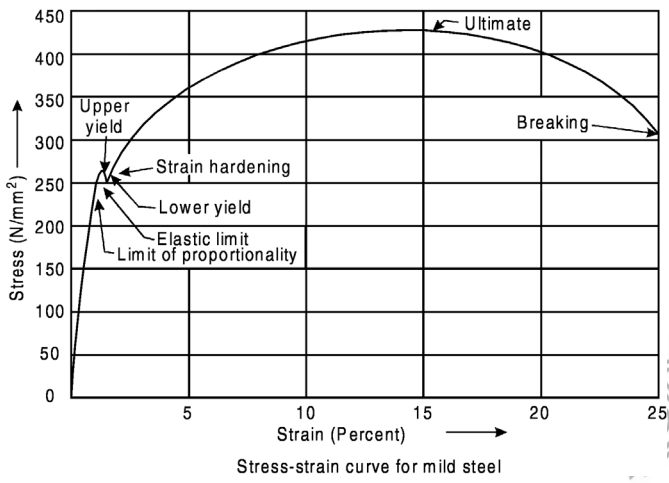
STRESS–STRAIN RELATIONSHIP FOR MILD STEEL

When a mild steel bar is subjected to a tensile load, it elongates. The elongation per unit length is known as strain. The stress is proportional to strain within limit of proportionality. The stress-strain relationship for mild steel can be studied by plotting stress-strain curve. The stress and load on some suitable scales may be plotted on y-axis, and strain on some suitable scale may be plotted on x-axis.

When the tensile load increases with increases in strain, stress–strain curve follows a straight line relationship upto 'Limit of proportionality'. The limit of proportionality is defined as stress beyond which straight line relationship ceases between stress and strain. Beyond the limit of proportionality stress approaches the elastic limit. The elastic limit is defined as the maximum stress upto which a specimen regains its original length on the removal of the applied load. There is hardly any distinct difference in the positions of limit of proportionality and

elastic limit. Practically, position of limit of proportionality coincides with the elastic limit. When the specimen is loaded beyond the elastic limit, the specimen does not resume its original length on the removal of applied load and a little strain is left in the specimen. This little strain is known as residual strain or permanent set. When the tensile load further increases the stress–reaches 'yield stress' and material starts yielding. The stress–strain curve suddenly falls showing a decrease in stress. The distinct position from where sudden fall of curve occurs marks the upper yield point and the position upto which fall of curve occurs is known as lower yield point. The material of bar stretches suddenly at constant stress. The adjustment of stress takes place in the elements of material in between upper yield point and lower yield point. On further increase of load, stress increases with the increase of strain. However, strain increases more rapidly. Finally the load reaches the value of 'ultimate load'. The ultimate load is defined as maximum load, which can be placed prior strain increases more rapidly. Finally the load reaches the value of 'ultimate toad'.

The ultimate load is defined as maximum load, which can be placed prior to the breaking of specimen. The stress corresponding to the ultimate load is known as 'ultimate stress'. The stress–strain curve suddenly falls with rapid increase in strain and specimen breaks. The load corresponding to breaking position is known as "breaking load'. The cross-section of specimen decreases. If actual breaking stress is computed on the basis of decreased (reduced) cross-sectional area, the breaking stress will be found to be more than the ultimate stress.



Stress–strain curve

Significance of Upper Yield Point

The boundaries of grains of mild steel are composed of brittle material. This forms a rigid skeleton. The rigid skeleton prevents plastic deformation of the grains at low stress, and shows upper yield point in stress-strain curve. At upper yield point, this rigid skeleton breaks down. As a result of this, the stress in material drops down without elongation from upper yield point to lower yield point. This is followed by sudden stretching of the material at constant stress from lower yield point upto strain hardening.

TENSILE STRESS

When a structural member is subjected to direct axial tensile load, the stress is known as tensile stress (σ_{at}). The tensile stress is calculated on net cross-sectional area of the member

$$\sigma_{at} = \left(\frac{P_t}{A_n}\right)$$

where Pt is the direct axial tensile load and An is the net cross-sectional area of the member.

COMPRESSIVE STRESS

When a structural member is subjected to direct axial compressive load, the stress is known as compressive stress, (σ_{ac}). The compressive stress is calculated on gross cross-sectional area of the member

$$\sigma_{ac} = \left(\frac{P_c}{A_g}\right)$$

where, P_c = direct axial compressive load

A_g = gross-sectional area of the member.

BEARING STRESS

When a load is exerted or transferred by the application of load through one surface for the another surface in contact, the stress is known as 'bearing stress' (σ_p). The bearing stress in calculated on net projected area of contact

$$\sigma_p = \left(\frac{P}{A}\right)$$

where, P = load placed on the bearing surface

A = net projected area of contact

WORKING STRESS

The working stress is also termed as allowable stress or permissible stress. The working stress is evaluated by dividing yield stress by factor of safety. For the purpose of computing safe load carrying capacity of a structural member, its strength is expressed in terms of working stress. The working stress is the stress which may be developed or set up in the member without causing structural damage to it. The actual stresses resulting in a structural member from design loads should not exceed working stresses. This ensures the safety of the structural member. The maximum working stresses are adopted from IS : 800–1984.

IS : 800–1984 specifies a number of grades of steel with different yield strengths, the design parameters and the geometrical properties. There are also developments in the design of steel structures. In view of these, the permissible stresses have been revised in general. These permissible stresses have been expressed to the extent possible in terms of the yield strength of the material. However, the specific values have also been given in IS : 800–1984 for steels commonly used.

INCREASE IN PERMISSIBLE STRESSES

A structure may be subjected to the different combinations of loads. These loads in such combinations do not act for long period. Most of the national codes allow some increase in permissible stresses. Increases in permissible stresses as per IS : 800–1984 is taken as follows :

- When the effect of wind or seismic load is taken into account, the permissible stresses in steel are increased by $33\frac{1}{3}$ per cent.
- For rivets, bolts and tension rods, the permissible stresses are increased by 25 per cent, when the effect of wind or seismic load is taken into account.

The increased values of permissible stresses must not exceed yield stress of the material.

FACTOR OF SAFETY

The factor of safety is defined as the factor by which the yield stress of the material is divided to give the working stress (permissible stress) in the material. A greater value of factor of safety used to be adopted formerly and as such the working stresses computed were small. As a result of this a large cross-section of the member had to be adopted in design. From experience gained and experiments made in laboratories, it has been seen that such a large section of the structural member is not essential. Hence, factor of safety adopted now-a days is comparatively small. This has resulted in appreciable saving in the material. The value of factor safety is decided keeping in view of the following considerations.

- The average strength of materials is determined after making tests on number of specimens. The strengths of different specimens of given structural material are not identical. Some of the specimens may show relatively large deviations in strength from the average.
- The values of design loads remains uncertain. The values of dead loads can of course be determined correctly. But live load, impact load, wind load, snow load etc. cannot be determined with certainty since these depend upon statistics available. The probable values of these loads are only determined.
- The values of internal forces in many structures depend upon the methods of analysis. The degree of precision of different method varies. The methods involving detailed analysis are more precise. In case, analysis of the structure is done precisely, a small value of factor of safety may be adopted.
- During fabrication, structural steel is subjected to different operations. The punching of a hole in a structural element distorts the surrounding material and causes high residual stresses. The warping and buckling of elements may take place during welding. The welding leaves high residual stresses. Structural elements are subjected to uncertain erection stress.
- The variations in temperatures and settlement of supports are uncertain. Many times, a well designed structure is damaged because of these effects. The strength of materials decreases because of corrosion. The extent of corrosion is more, when a structure is located in industrial areas and exposed to chemical wastes.
- The failure of some small structures or some elements of a structure is less serious and less disastrous than the failure of large structure or a main element of a structure.

The minimum value of factor of safety, m_{min} may be found by defining it in a rational method. The factor of safety may be defined as the ratio of computed strength, P of the structure or the structural member to the respective computed internal load, F. Therefore,

$$m = \left(\frac{P}{F}\right)$$

The magnitude of lowest probable strength, P is influenced by the uncertainties in the mechanism failure, properties of material and workmanship. The magnitude of highest probable internal load, F is influenced by the uncertainties in loading conditions and the structural behaviour. The probable values deviate from the computed value because of these uncertainties. The minimum probable value of strength is given by

$$P_{min} = (P - \Delta P) \qquad \ldots(i)$$

The maximum probable value of the internal load is given by

$$F_{max} = (F + \Delta F) \qquad \ldots(ii)$$

where, ΔP = Maximum probable deviation of actual value from the computed value of strength

ΔF = Maximum probable deviation of actual value from the computed value of internal load

When the minimum probable value of strength is atleast equal to or slightly more than the maximum probable value of the internal load, then the failure of structure is just prevented under most severe conditions. Therefore,

$$(P - \Delta P) \geq (F + \Delta F) \qquad \ldots(iii)$$

or $$P\left(1 - \frac{\Delta P}{P}\right) \geq F\left(1 + \frac{\Delta F}{F}\right)$$

The minimum value of factor of safety is given by

$$m_{min} = \left(\frac{P}{F}\right) = \left(\frac{\left(1 + \frac{\Delta F}{F}\right)}{\left(1 - \frac{\Delta P}{P}\right)}\right)$$

Assuming the values of maximum deviations ΔP and ΔF to 25 percent of the computed values of P and F respectively, the minimum value of factor of safety is given by

$$m_{min} = \left(\frac{P}{F}\right) = \left(\frac{1 + 0.25}{1 - 0.25}\right) = 1.67$$