Course No. AENG 151 (2+1)

Fundamentals of Soil and Water Conservation Engineering

Theory Lecture Outlines

S.No.	Topic	Page No.
1	Surveying – definition and objectives of survey, primary divisions of surveying, geodetic and plane surveys, classifications, uses of surveys.	3 - 5
2	Instruments used in chain survey -constructional details of metric chain, metallic and steel tapes, ranging rods, arrows, cross-staff, optical square, plumb bob and pegs.	6 – 14
3	Errors in length measurement due to incorrect chains, numerical problems on distance and area corrections; Ranging - definition and methods of ranging, procedure for direct and indirect ranging.	15 – 24
4	Chain triangulation – principle, survey stations, location of survey stations, baseline, check line, tie line, offsets.	25 – 27
5	Plotting procedure of chain survey, conventional symbols.	28 – 31
6	Areas of irregularly bounded fields - different methods.	32 – 35
7	Numerical problems on Simpson's, trapezoidal rules.	36 – 38
8	Leveling - definition, description of dumpy level and leveling staff. Terminology connected with leveling - datum, elevation, station, back sight, fore sight, intermediate sight, height of instrument, bench mark and its types, change point.	39 – 43
9	Leveling procedure - temporary adjustments in dumpy level, level field note book, recording procedure in level field note book.	44 – 46
10	Reduction of levels - height of collimation method, rise and fall method, and numerical problems connected with these two methods.	47 – 50
11	Types of leveling - simple, leveling, differential leveling and profile leveling.	51 – 54
12	Contour survey - definition, characteristics and uses of contours.	55 – 58
13	Irrigation - definition, classification of irrigation projects based on Culturable Command Area (CCA) and expenditure, benefits of irrigation, ill effects of irrigation, flow irrigation and lift irrigation. Water sources.	59 – 61
14	Water lifting devices - classification of pumps, centrifugal pump, principle of operation.	62 – 68
15	Pump characteristics - pump efficiencies, capacity calculation based on irrigation scheduling, power calculations of centrifugal pump.	69 – 73
16	Deep well pumps – turbine and submersible pumps, installation and working principles of these pumps.	74 – 78
17	Measurement of irrigation water – importance. Methods of measuring water – volumetric and area, velocity method.	79 – 80
18	Direct discharge methods - water meter, weirs, orifices.	81 – 86
19	Parshall flume - installation of these devices, conditions for weir installation.	87 – 88
20	Discharge calculation of rectangular and triangular weirs, advantages of parshall flume over the weirs.	89 – 90

21	Water conveyance systems - open channel, definitions of wetted perimeter, hydraulic radius, hydraulic slope, area of cross section and free board. Manning's formula for estimating mean velocity, side slopes of channels for different soils.	91 – 94
22	Capacity calculations of open channels.	95 – 96
23	Underground pipeline, advantages of earthen channels, disadvantages, type of pipes recommended for underground pipeline.	97 – 100
24	Components of underground pipe line, installation procedure, discharge calculation of underground pipe line.	101 – 105
25	Irrigation methods - sprinkler irrigation, scope, functional components of sprinkler system and their working.	106 – 110
26	Types of sprinkler irrigation, operation and maintenance of the system, cost economics.	111 – 114
27	Drip irrigation system - scope, functional components of drip system and their working principles.	115 – 120
28	Operation and maintenance of the drip system, cost economics.	121 – 125
29	Soil and water conservation - definition and scope, soil erosion - definition, types, geological and accelerated soil erosion, causes and ill effects of soil erosion.	126 – 129
30	Accelerated soil erosion - water and wind erosion definitions, rain drop (splash) erosion, sheet erosion, rill erosion, gully erosion, stream bank erosion and their stage of occurrence.	130 – 134
31	Erosion control measures – engineering measures, contour bunds, graded bunds.	135 – 137
32	Broad based terraces and bench terraces.	138 - 141

Lecture 1

Surveying – definition and objectives of survey, primary divisions of surveying, geodetic and plane surveys, classification, uses of surveys.

1. Surveying

It is the art of determination of horizontal distances, differences in elevation, directions, angles, locations, areas and volumes on or near the surface of the earth. It involves the measurement and recording of the size and shape (including the vertical shape) of an area on the earth's surface. The process of survey divided into two parts:

(a) **Field work-** taking measurements

(b) **Office work-** computing and drawing

1.1 Object of survey

The primary object of survey is the preparation of plan or map. The results of surveys when plotted and drawn on paper constitute a plan. A plan is, the representation to some scale, of the ground and the objects upon it as projected on a horizontal plane, which is represented by the plane of the paper on which the plan is drawn. The representation is called a map, if the scale is small. If the scale is large, it is called a plan. On plan, only horizontal distances are shown. The scale of a map is the fixed relation that, every distance on the map bears to the corresponding distance on the ground. Suppose, if one cm on a map represents 5 m on the ground, the scale of a map is 5m to 1 cm.

1.2 Primary division of surveying

Surveying may be divided into two general classes:

(a) Geodetic surveying

(b) Plane surveying

1.2.1 Geodetic surveying

It is also called **trigonometrical surveying.** The object of a geodetic surveying is to determine the precise positions on the surface of the earth of a system of widely distant points and the dimensions of areas. In this survey, the curvature of the earth is taken into account, since large distances and areas are covered. Artificial earth satellites have come into wide use in this survey.

1.2.2 Plane surveying

In this survey, the earth's surface is considered as a plane. The curvature of the earth is not taken into account, as the surveys extend only to small areas. The line joining any two points as a straight line, and all angles are plane angles. Surveys normally carried out for the location and construction of roads, canals and, buildings. In general, the surveys necessary for the works of man are plane surveys.

1.3 Classification: Surveys may be classified in a variety of ways.

I. Classification based upon the nature of the field of survey:

(a) Land Surveys.

(b) Marine or Navigation Surveys.

(c) Astronomical Surveys.

II. Classification upon the object of survey:

(i) Archaeological surveys.

(ii) Geological Surveys -for determining different strata in the earth's crust.

(iii) Mine Surveys- for exploring mineral wealth such as gold, coal, etc.

(iv) Military Surveys- for determining points of strategic importance both offensive and defensive.

III. Classification based upon the methods employed in survey:

(a) Triangulation Surveys.

(b) Traverse Surveys.

IV. Classification based upon the instrument employed:

(i) Chain Surveys.

(ii) Theodolite Surveys.

(iii) Tacheometric Surveys.

(iv) Compass Surveys.

(v) Plane Table Surveys.

(vi) Photographic and Aerial Surveys.

1.4 Agricultural surveying

It is a simple **plane surveying**. It includes laying out contour and terrace lines for soil conservation, drainage lines, profile lines for land leveling and ditch lines for irrigation, computing field and farm areas and laying out farm buildings and roads.

1.5 Uses of survey

The planning of all engineering and construction projects extending over large areas, such as highways, railways, irrigation, water supply etc., are based upon elaborate and complete surveys.

Lecture 2

Instruments used in chain survey -constructional details of metric chain, metallic and steel tapes, ranging rods, arrows, cross-staff, optical square, plumb bob and pegs.

2.0 Chaining: It is the method of measuring distance with a chain or tape. Of the various methods of determining distance, chaining is the most accurate and common method. For work of ordinary precision, a chain is used. But, where great accuracy is required, a steel tape is invariably used.

2.1 Instruments used in Chain survey

Instruments used for measuring distances

1. Chain
2. Tape

Instruments used for marking survey stations

1. Ranging rod
2. Offset rod
3. Laths and whites
4. Pegs

Instruments used for setting right angles

1. Cross staff
2. Optical square

Other instruments:

1. Arrow
2. Plumb bob

2.1.1 Chain

The chain is composed of 100 or 150 pieces of links, made up of 4 mm diameter galvanized mild steel wire. The ends of each link bent into a loop and connected together by means of three oval rings which offered flexibility to the chain and make less liable to become **kinked**. The joints of the links are usually open, but in the best chains they are welded so as to render the chain less liable to stretching. The ends of the chain provided with brass handles for dragging the chain on the ground, each with a swivel joint, so that the chain can be turned round without twisting. The length of a link is the distance between the centers of the two consecutive middle rings. The end links include the handles. Metallic tags or indicators of distinctive pattern are fixed at various distinctive points of the chain to felicitate quick reading of fraction of a chain in surveying measurements.

2.1.2 Metric chain

IS 1492-1956 covers requirement of chains in metric units. The chains are made in length of 20 and 30 meters .To enable the reading of fractions of a chain with out much difficulty, tallies are fixed at every five-meter length and small brass rings are provided at every metre length, except where tallies are attached. Connecting links between two large links are oval in shape, the central one being a circular ring. The length of the chain is marked over the handle to indicate the length and also to distinguish from non-metallic chains. The length of each link is 0.2 m (20cm) in 20m chain is provided with 100 links and 30 m chain divided into 150 links (Fig. 1).

The advantages of the chain are :

(i) it is very suitable for rough usage

(ii) it can be easily repaired in the field

(iii) it can be easily read.

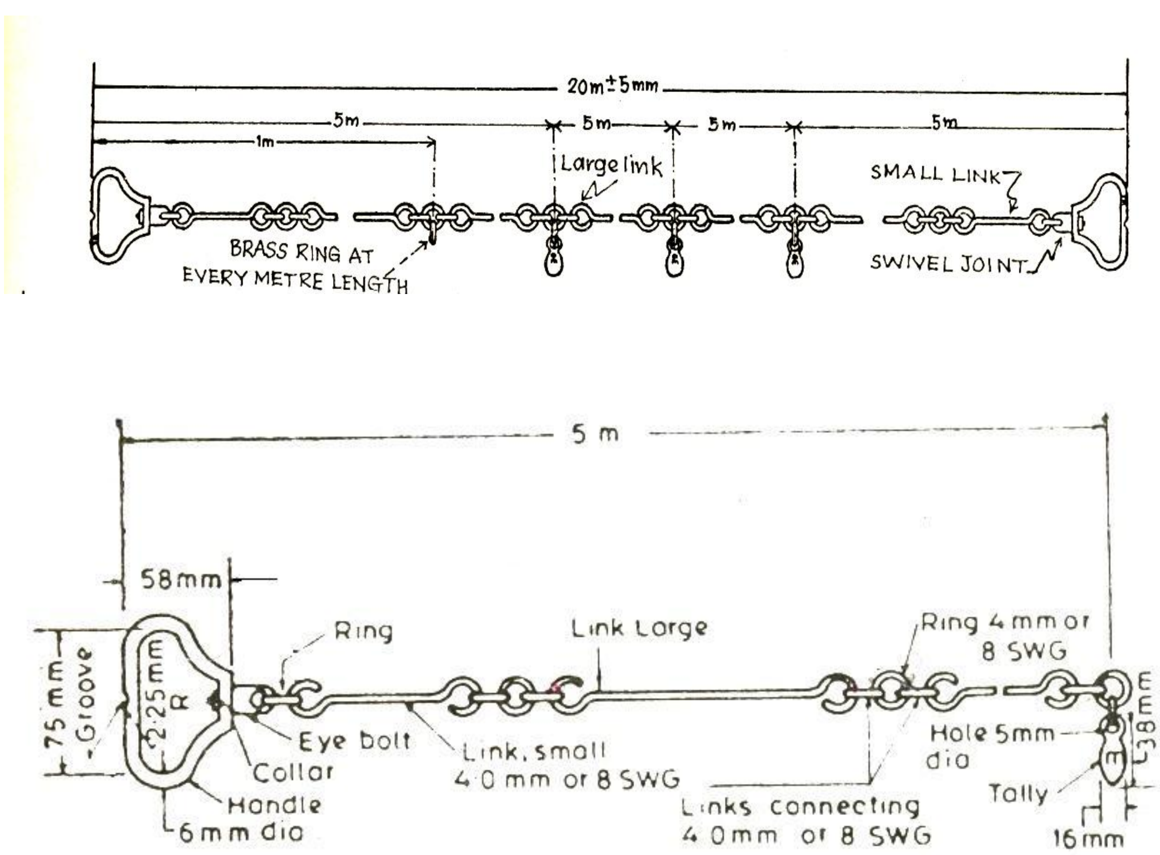


Fig. 1. Metric chain

2.1.3 Types of chains

(1) Gunter's Chain: It is also called surveyor's chain**.** The Gunter's chain is 66 ft. long and is divided into 100 links. Therefore, each end link is equal to 0.66 ft. long. It is very convenient for measuring distances in miles and furlongs and for measuring land when the unit of area is an **acre**, on account of its simple relation to the mile and the acre.

10 Guntur's chains – 1 furlong

80 Guntur's chains- 1 mile

10 square Guntur's chains – 1 acre

(2) Revenue Chain: The revenue chain is commonly used for measuring fields in cadastral survey. It is **33 ft. long and divided into 16 links**.

(3) Engineers' Chain: The engineer's chain is **100 ft.** long and is divided into 100 links each link is equal to 1 ft. The construction details are same as that of a Gunter's chain. It is used on all engineering surveys. The distances measured with the engineer's chain are recorded in feet and decimals.

Steel Band: The steel band, also called the band chain, consists of a ribbon of steel with a brass swivel handle at each end. It is 20 or 30 m long and 16 mm wide. It is wound on open steel cross, or on a metal reel in a closed case. The graduations are marked in two ways: (a) The band is divided by brass studs at every 0.2 m and numbered at every l m, the first and the last link being subdivided into cm and mm, (b) The graduations are etched as metres, decimeters, centimeters on one side and 0.2 m links on the other. Brass tallies are fixed at every 5 m length of the band. It is best adapted to general field work and rough usage. For accurate work, the steel band is now preferred. It is lighter and easier to handle than the chain. It is practically unalterable in length. It must be protected from rust by frequent cleaning and oiling.

2.1.4 Tapes: When greater accuracy is required in measurement and the ground to be surveyed is not very rough, the tapes can be used. Tapes are available both in ft. and metres. For surveying, mostly 30 m tape is used. Tapes made of various materials and are, therefore, divided into five classes: (1) cloth or linen, (2) metallic, (3) steel, (4) invar and (5) synthetic material.

(1) **Cloth or linen Tape**: It is made of varnished strip of woven linen 12 to 16 mm wide with a brass handle at zero ends, whose length is also included in the length of the tape. The tape is attached to a spindle and is wound in a leather case. It is very light and handy, but not so accurate. For very precise measurements, it is not used. The linen tape may be used for taking subsidiary measurements such as offsets. It is easily affected by damp. When the tape gets wet, it shrinks and care should be taken that it is not wound up until is cleaned and dried. It stretches easily and is likely to twist and tangle. It is therefore little used in surveying.

(2) **Metallic Tape**: It is made from good quality cotton or linen and is reinforced with fine brass or copper wires. This prevents stretching of fibres and is therefore, better than simple linen tapes. They are also not suited for very precise measurements. It is made in lengths of 2, 5, 10, 20, 30 and 50 metres.

(3) **Steel Tape**: It is made of steel ribbon or stainless steel, or may be provided with vinyl coating and is very accurate. It is used for very precise measurements and for checking the accuracy of chain lengths. The denominations of the tape measures are 1, 2, 10, 30, and 50 m. The outer end of the tape is provided with a ring or other device facilitating withdrawal. The ring or the device is fastened to the tape by a metal strip of the same width as the tape. The length of the tape includes the metal ring when provided (Fig.2).

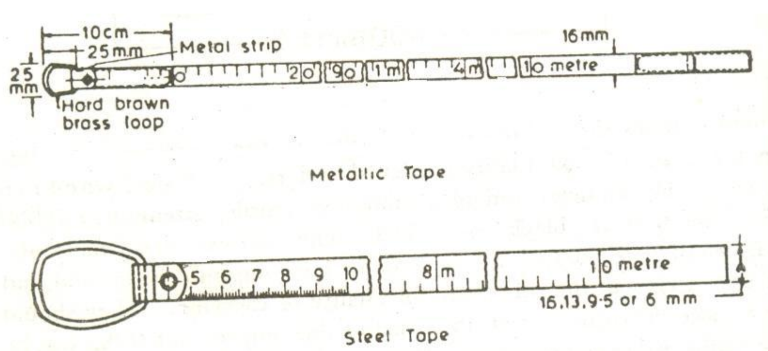


Fig.2. Steel tape

(4) **Invar Tape**: For work of the highest precision, the invar tape is generally used as in measurement of base lines in triangulation and in city work. It is made of an alloy of steel (64%) and nickel (36%) and possesses a very low coefficient of thermal expansion (0.6×10^{-4} for 1°C). It is 6 mm wide and may be obtained in lengths of 30 m, 50 m and 100 m.

(5) **Synthetic Tape**: The tapes are manufactured of glass fibre having a PVC coating. They are graduated every 10 mm and figured every 100 mm whose metric figures are shown in red at every metre. The tapes maintain their lengths well and are convenient for measuring short lengths.

2.1.5 Ranging Rods: The ranging rods are used for ranging lines and to mark stations which are at greater distance (Fig.3). They are made of well seasoned straight grained timber of teak, blue pine, sisso or deodar. They are circular or octagonal in cross section of 3 cm nominal diameter and pointed metal shoe of 15 cm long is provided at the lower end to facilitate fixing in the ground. They are made of two sizes namely one of 2 m and the other of 3 m and are divided into equal parts each 0.2 m long. In order to make them visible at a distance, they are painted alternately black and white, or red and white or red, white, and black successively. When they are at a considerable distance, red and white and yellow flags about 25 cm square be fastened at the top to improve the visibility.

2.1.6 Arrows (Chain pins): Accompanying each chain are 10 arrows. They are also called marking or chaining pins, and are used to mark the end of each chain during the process of chaining. They are made of good quality metallic wires of 4 mm (8 s. w. g.) in diameter and of a minimum tensile strength of 700N/ mm^2. The wire is black enameled. The arrows are made 400 mm in length, are pointed at one end for inserting into the ground and bent into a ring at the other end for facility of carrying. They should have a piece of white or red tape tied to the ring so that they can be made easily visible at a distance. To mark the end of each chain length, the arrow is inserted in the ground, but when the ground is hard, a scratch may be made with the pointed end (Fig.4).

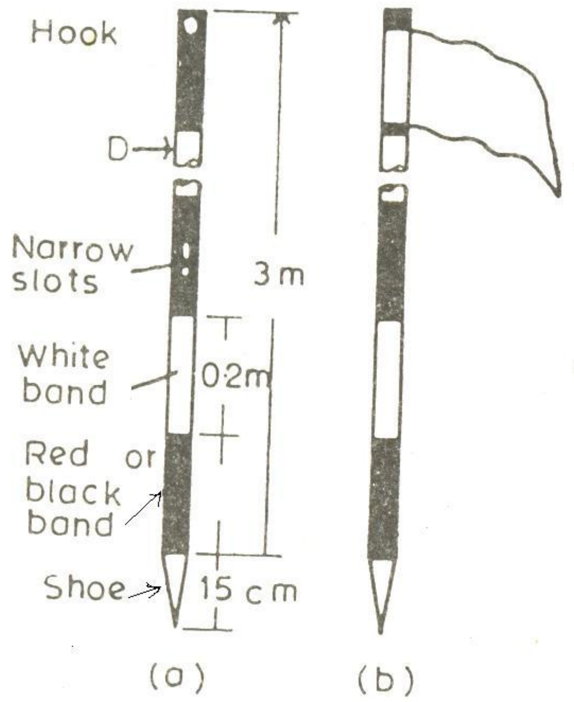


Fig. 3. Off-set rod (a) and Ranging rod (b)

2.1.7 Plumb bob: A plumb bob consists of a metal weight made of brass with a pointed end (Fig.5). It is suspended by a string and is used to locate points directly below or above another point. It is also used for accurately centering of compass or level or theodolite over a station mark, and for testing the verticality of ranging poles.

2.1.8 Pegs: Wooden pegs are used to mark the positions of stations. They are made of hard timber and are tapered at one end (Fig.6). They are usually, 2.5 cm square and 15 cm long, but in soft ground, pegs 40 to 60 cm long and 4 to 5 cm square suitable.

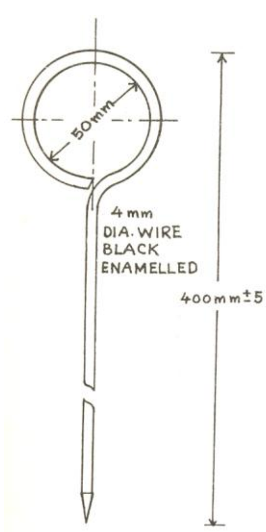


Fig. 4. Chain pin

Fig.5. Plumb bob

2.1.9 Off-set rod: The off-set rod is similar to the ranging rod but is usually 3 m long and is divided into parts each 0.2 m in length. It is chiefly used for aligning the off-set line and measuring short off-sets.

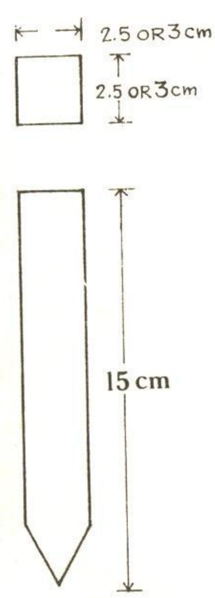


Fig. 6. Peg

2.2 Cross-Staff

Cross-staff is used for (i) finding the foot of the perpendicular from a given point to a line, and (ii) setting out a right angle at a given point on a line. There are two types of cross-staff, namely, (1) **the open** and (2) **the French**, the first one being in common use.

2.2.1 Open cross-staff: The simplest form of cross staff is the open cross staff**.** It consists of two parts (1) the head and (2) the leg. The head consists of four metal arms with vertical slits. The arms are rigidly fixed in such a manner so that the center of one pair of arms forming a straight line makes right angle with the other pair of arms. In one line, one of the slits is narrower than the other. One horse hair is fixed at the center of the wider slit. The object is sighted from the narrow slit in line with the hair. The cross staff is mounted on 25 mm diameter, about 1.5 metre long pole for fixing on the ground (Fig.7).

For laying out a right angle at a point on the chain line, the cross staff is held vertically on the supporting pole at the given point. Ranging rod is fixed on the chain line on either side of the cross staff and sighted through the slit and horse hair. The cross staff is turned till the ranging rod is visible. At this time, one sight through the other pair of slits and another person fixes a ranging rod in this line of sight. Foot of the cross staff joined with the ranging rod gives perpendicular line with the chain line.

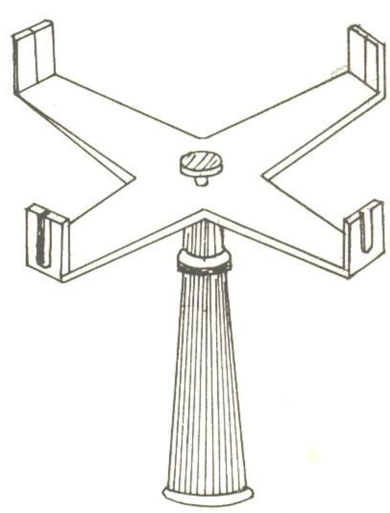


Fig. 7. Open cross-staff

2.2.2 Optical Square

It is more accurate than the cross staff and it can be used for locating objects situated at larger distances. It is small and compact hand instrument (Fig.8) and works on the principle of reflection. Generally it is a round brass box about 5 cm in diameter and 1.25 cm deep. There is also a metal cover to protect it from dust, moisture etc. As shown in fig. 8, it consists of horizontal mirror (H) and index mirror (1) placed at an angle of 45^0 to each other. The mirror H is half silvered and the upper half is plain while the mirror I is fully silvered. There are three openings a, b and c on the sides. Let AB is the chain line and it is required to locate an object O during the process of surveying. The optical square is held in such a manner that a ray of light from object O passes through slot c, strikes the mirror, gets reflected and strikes the silvered portion of the mirror H. After being reflected from H, the ray passes through the pin hole and becomes visible to the eye. The observer looking through the hole a can directly see the ranging rod at B through the un-silvered portion of the mirror H and he image of the ranging rod placed at O. Thus when both the ranging rods coincide, the line OD becomes perpendicular to the chain line. If they do not coincide, the optical square has to move back and forth to get the correct position of D.

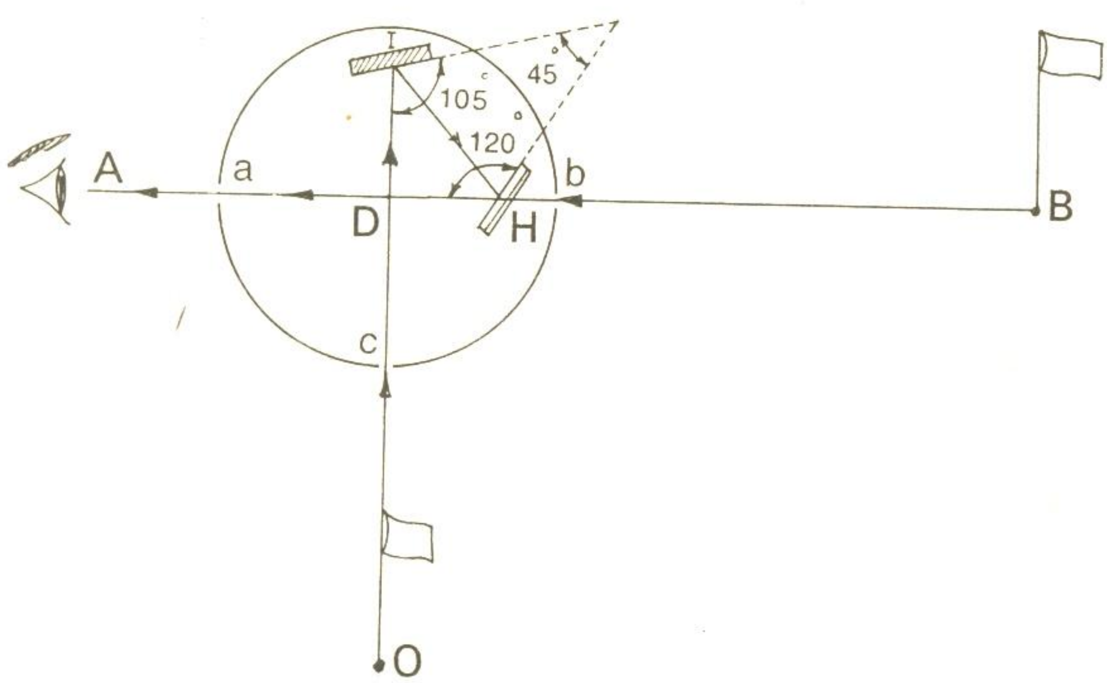


Fig. 8. Optical square

Lecture 3

Errors in length measurement due to incorrect chains, numerical problems on distance and area corrections; Ranging - definition and methods of ranging, procedure for direct and indirect ranging.

3.0 Chaining a line

In all chaining operations two men, called chainmen, are required. The chainman at the forward end of the chain is called the leader or head chainman, while the chainman at the rear end the chain is known as the follower or rear chainman. The duties of the leader are ; (i) to drag the chain forward, (ii) to insert arrows at the end of every chain, and (iii) to obey instructions of the follower, while the duties of the follower are; (i) to place the leader in line with the ranging rod or pole at the forward station, (ii) to call out instructions to the leader, (iii) always to carry the rear handle in his hand and not to allow it to drag on the ground, and (iv) to pick up the arrows inserted by the leader. The chainman who is more intelligent and experienced be selected as the follower, as upon his care and judgment depends the accuracy of measurements.

3.1 Unfolding the Chain

To lay out the chain on the ground, remove the leather strap, take both the handles in the left hand and throw the chain well forward with the right hand. The leader, taking one handle of the chain may then be examined to see if there are any kinks or bent links. This operation is also called unfolding the chain.

3.2 Testing of a chain

It is always necessary to check the length of chain before commencing each day's work and at frequent intervals; otherwise the measurement will become unreliable. Before testing the chain, the surveyor should see that the links and rings are free from mud that there are no links or bent links.

The chain is tested by comparing it with

(i) the chain standard (standard chain length)

(ii) with the steel tape which should be kept in the surveyor's office for this sole purpose.

If these are not available at hand, a test gauge may be established by driving two stout pegs in the required distance apart (20 m or 30m) and inserting nails into their tops to mark exact distance. It is advisable to have a permanent test gauge established in close proximity to the surveyors office.

During the first use, the links become bent and, consequently the chain is shortened. It is also shortened by mud clogging the links when working over muddy ground. On the other hand, it gets elongated due to wear of many wearing surfaces, stretching of the links and joints, and opening out of the small rings and rough handling in pulling it through hedges and fences.

3.3 Adjusting the chain

If the chain is found to be too long, it may be adjusted by

i) Closing up the joints of the connecting rings (that may be opened out)

ii) Hammering back to the shape of the elongated rings

iii) Replacing some of the worn out rings with new ones

iv) Removing one or more of the small rings.

If the chain is found to be too short, it may be adjusted by

i) Straightening any bent links

ii) Flattening some of the small connecting rings

iii) Replacing some of the worn out rings with new ones

iv) Replacing a few of the rings by those of the larger size

v) Inserting new rings as required

3.4 Errors in chaining

The errors that occur in chaining are classified as i.) compensating and ii) cumulative. These errors may be due to variation in temperature, defects in construction and personal defects in vision.

3.4.1 Compensating errors: are those which are liable to occur in either direction and hence tend to compensate i.e. they are not likely to make the apparent result too large or too small. Compensating errors are caused due to incorrect holding of the chain, fractional part of the chain may not be correct and during stepping operation, crude method of plumbing is adopted

3.4.2 Cumulative errors: are those which occur in the same direction and tend to add up or accumulate i. e., either to make the apparent measurement always too long or too short.

(i) Positive errors - These errors makes the measured length more than actual length.

(ii) Negative errors - making the measured length less than the actual.

3.5 Errors in measurement due to incorrect length of chain

The length of a chain may be correct at the beginning, but it may change with time as more and more used. Due to continuous use of the chain over rough ground, the oval shaped rings get elongated and thus the length of the chain increases. On the other hand some of the links may get bent for there may be kinks. As a result the chain length reduces. In a very old chain, some ring or links may be missing. Therefore, before the start of the work the correctness of the chain length should be tested with a steel or invar tape. If the chain is too long, measured distance will be less and if the chain is short, the measured distance will be more than the actual distance. However, the measured distance can be corrected by using the formula:

$$\text{Correct distance} = \left(\frac{L^1}{L}\right) \times \text{measured distance}$$

Where L'= incorrect length of a chain,

L= normal correct length of a chain which may be 20m, 30m,etc.

Therefore, correct distance ×correct length of chain= Incorrect distance × incorrect length of chain. If 'e' is elongation or shortening of chain length, L'=(L$\pm$ e) , plus sign is used when the chain is too long and minus sign is used when the chain is too short.

Example 1: The length of a line was found to be 600 m when measured with 20 m chain. If the chain is 15 cm short, find the correct length of line.

Solution:

True length of the chain, L = 20 m

The chain is 15 cm short.

Measured distance = 600 m

Incorrect length of chain, $L' = 20 - \frac{15}{100} = 19.85$ cm

(minus sign is used because the chain is short)

$\therefore$ Correct distance = $\left(\frac{L^1}{L}\right) \times$ measured distance

$$= \frac{19.85}{20} \times 600 = 595.5 \text{ m}$$

Example 2: The area of a field was found to be 4000 m^2 when measured with 30 m chain. If the length of the chain was 0.11 m too short, find the correct area.

Solution:

True length of the chain, L = 30 m

The chain is 0.11 m short.

Measured area = 4000 m^2

Incorrect length of chain, $L' = 30 – 0.11 = 29.89$ m

(minus sign is used because the chain is too short)

$\therefore$ Correct area = $\left(\frac{L^1}{L}\right)^2 \times$ measured area

$$= \left(\frac{29.89}{30}\right)^2 \times 4000 = 3970.72 \text{ m}^2$$

Example 3: A 20 m chain was found to be 0.05 m too long after chaining 1400 m. It was found to be 0.1 m too long after chaining 2200 m. If the chain was correct before commencement of work, find the true difference.

Solution:

As the chain length was correct i.e., 20 m long at the beginning and 0.05 m too long after measuring 1400 m, the increase in length was gradual.

$\therefore$ Mean elongation = $\frac{0+0.05}{2} = 0.025$ m

Measured distance = 1400 m

Incorrect length of chain, L' = 20 + 0.025 =20.025 m

(Plus sign is used because the chain is too long)

$\therefore$ Correct distance = $\left(\frac{L^1}{L}\right)$ × measured distance

Correct distance = $\frac{20.025}{20} \times 1400$ = 1401.75m

After measuring 2200 m, the chain is found to be 0.1 m too long.

The remaining distance = 2200 -1400 = 800 m

At the beginning, the chain was found to be 0.05 m too long and at the end of chaining (2200 -1400) 800 m, it was found to be 0.1 m too long.

$\therefore$ Mean elongation = $\frac{0.05+0.1}{2} = 0.075$ m

Incorrect length of chain, L' = 20 + 0.075 =20.075 m

Correct distance = $\frac{20.075}{20} \times 800 = 803$ m

Total true distance = 1401.75 + 803 = 2204.75 m

Example 4: A chain was tested before starting a survey of field and was found to be exactly 30 m. At the end of survey it was tested again and was found to be 30.16 m. The area of the plan drawn to a scale 1 cm = 60 m was 92.50 cm^2. Find the true area of the field.

Solution:

The scale of the plan being 1 cm to 60 m, 1 cm^2 = 3600 m^2 on the ground.

Area of the field = 92.50 × 3600 = 3,33,000 m^2

True length of the chain, L = 30 m

Incorrect length of chain, $L' = 30 + \frac{0.16}{2} = 30.08$ m

Measured area = 3,33,000 m^2

True area of the field = $\left(\frac{30.08}{30}\right)^2 \times 3{,}33{,}000 = 3{,}34{,}778.37\ m^2$

(1ha= 10,000m^2)
= 33.47 ha

3.6 Ranging: During measurement of the length of a line, it is necessary that the chain should be laid out on the ground in a straight line between the end stations. If the chain is long or end station is not clearly visible, it is necessary to place intermediate ranging rods to maintain the direction. The operation of establishing intermediate points on a straight line between the terminal points is known as ranging. Ranging should be done prior to chaining. Ranging is usually done by eye or by using instruments like line ranger and theodolite. Ranging is of two kinds, namely, direct and indirect ranging.

3.6.1 Direct ranging: When the end points are visible from one another, intermediate ranging rods are placed in line by direct observation, the process is known as direct ranging.

Procedure

Let us assume that A and B are end points of a survey line visible from one another. Fix two ranging rods vertically at stations A and B of survey line. The surveyor standing behind the ranging rod at A and looks towards B, directs the assistant to move in the chain line and establishes an intermediate station “P”. The point “P” should lie in the straight line joining AB. The surveyor then directs the assistant to move his ranging rod to right or left until the three ranging rods at A, P and B appear to be exactly in a straight line. Similarly, any number of intermediate stations can be established between two end stations. Measure the distance between A and B and record it in observation sheet.

3.6.2 Indirect ranging: When the end stations of a line are not intervisible due to high ground or intervening hill and also when the ends of a line are not distinctly visible from one another due to distance being too great, then indirect ranging can be adopted.

Various obstructions, such as ponds, hills, buildings, rivers are continuously come across in chaining process. It is however essential that chaining should be continued in a straight line, special methods are therefore employed in measuring distances across the obstructions. The various cases may be classified as:

i) Chaining is free, vision is obstructed, eg. raising ground (or) a hill intervening.

ii) Chaining obstructed but vision free, eg. pond, river, plantations, and tank.

iii) Both chain and vision are obstructed, eg. buildings.

i) **Chaining is free vision is obstructed**: In this case, the ends of a line are not inter visible. There are two cases to be considered.

Case-1: Both ends may be visible from intermediate points on the line.

Case-2: Both ends may not be visible from any intermediate point.

Procedure for case-1: Let A and B are the two stations across a hill. Ranging rods are placed at one of them is not visible from other. The following may be followed for ranging.

1) As shown in fig.9 (a), select two intermediate points C and D such that ranging rods at B and D are visible from C and ranging rods at A and C are visible from D. Also A, C, D, B should be nearly as possible in a straight line.

2) The person at C looks towards B and directs the man at D to fix his ranging rod in a manner such that C, D, B are in one straight line.

3) Now the person at D looks towards the ranging rod at A and directs the man at C to fix his ranging rod at a place such that A, C and D are in one straight line.

4) Steps 2 and 3 above are repeated till the person at C finds C, D,. B to form a straight line and simultaneously, the person at D finds A, C, D also to form a straight line, then all the four points A, C, D, and B are lie in straight line.

Fig. 9 (a). Indirect method of ranging

Procedure for case 2: This case occurs, when it desired to run a line across a wooded field, the trees and under-bush preventing the fixing of intermediate stations. In such a case, the method of random line is the most suitable.

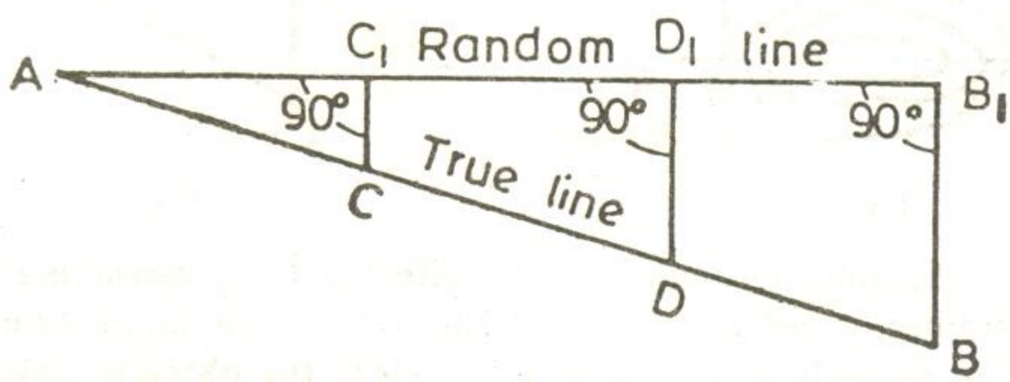


Fig. 9 (b). Random method of ranging

As shown in fig. 9 (b), let AB be the line whose length is required. From A, run a line (AB_1), called a random line in any convenient direction, but as nearly towards B as can be judged and continue until the point B is visible from B_1. Chain the line to B_1, where BB_1 is perpendicular to AB_1 and measure BB_1, then AB = $\sqrt{(AB_1)^2 + (BB_1)^2}$

Chaining obstructed, but vision free: This problem is to find out the distance between two convenient points on the chain line on either side of the obstruction. There are two cases:

Case-1: In which, it is possible to chain round the obstruction.

Ex: A thorny hedge, a pond, a bend in the river.

Case-2: In which, it is not possible to chain round the obstruction.

Ex: River

Procedure for Case-1: Select two convenient points A and B on the chain line PR and on either side of the obstruction (Fig.10). Then, erect equal perpendiculars AC and BD and measure the length CD. Then AB=CD.

Procedure for Case-2: Select two points A and B on the chain line PR on opposite banks of river (Fig.11). Set out a perpendicular AD and bisect it at C. At D, erect a perpendicular DE and mark the point E in line with C and B. Measure DE, since the triangles ABC and CED are similar, then AB=DE.

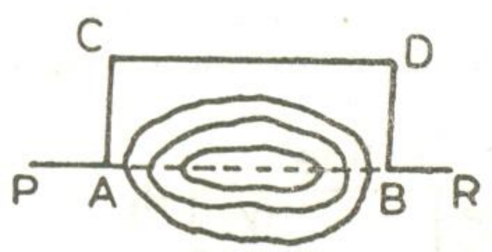


Fig. 10. **Chaining obstructed but vision free (Case-1)**

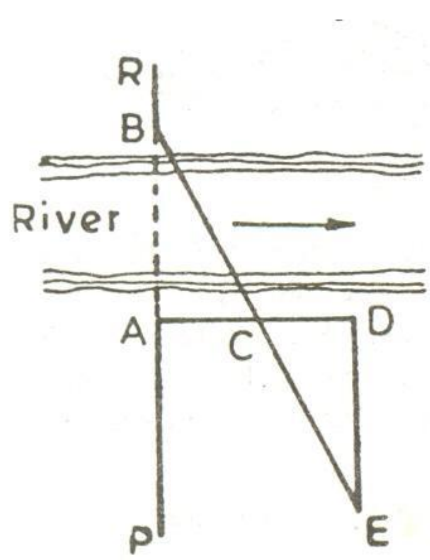


Fig. 11. **Chaining obstructed but vision free (Case-2)**

iii) **Both chaining and vision both obstructed**: In this case the problem consists in prolonging the line beyond the obstruction and determining the distance across it. A building is a typical example of this class of obstruction.

Procedure: Choose two points A and B on the chain line PR (Fig.12). At A and B, erect perpendiculars AE and BF of equal lengths. Check the diagonals BE and AF, which should be equal and also EF, should be equal to AB. Prolong the line EF past the obstruction and select two points G and H on it. At G and H, set out perpendiculars GC and HD are equal in length to AE. The points C and D are obviously on the chain line PR and BC=FG. Great care must be taken in setting out perpendiculars and to see that their lengths are exactly equal.

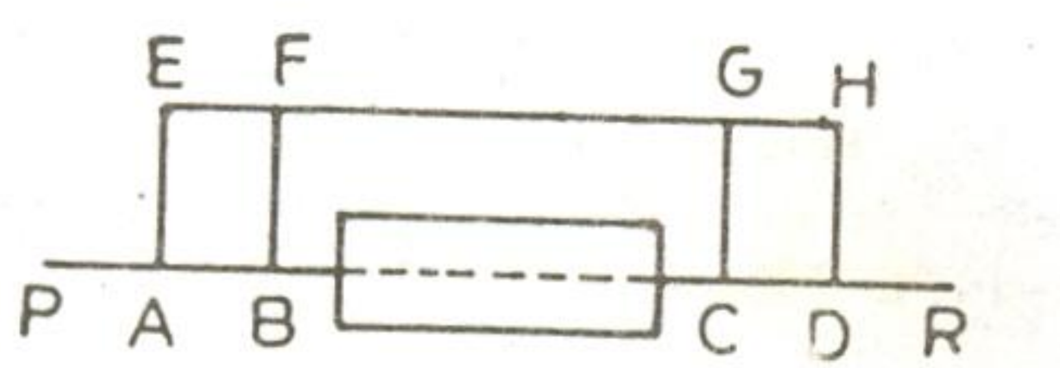


Fig. 12. Both chaining and vision are obstructed

Lecture 4

Chain triangulation – principle, survey stations, location of survey stations, baseline, check line, tie line, offsets.

4.0 Chain triangulation and Cross-staff survey

4.1 Measurement of areas

One of the main purpose of surveying is to measure the area of an agricultural farm, area of plots to be used for construction purposes, command area of tube wells, canals etc. Two general methods for measuring areas are: i) Triangulation, and ii) Traversing.

In traversing, the length of connected lines as well as their directions are measured by chain and compass respectively.

4.1.1 Triangulation survey

Triangulation is the basis of trigonometrical or geometric surveys. As such triangulation refers to a system of surveying in which one line is measured with a chain and all the three angles are measured correctly by compass or theodolite. In case, only the sides of the triangles are directly measured in the field and no angular measurement is taken, it is called triangulation (or) chain surveying. The whole area is suitably divided into number of triangles and computes the area of individual triangles and added to get total area. In dividing the total area into triangles, care should be taken to see that the triangles are almost equilateral as far as possible to minimum the errors. Although, the chain triangulation is very simple, but it is suitable only for small plane areas without much obstruction.

Survey stations

A survey station is a point of reference at the beginning and end of a chain line. Stations are of two types, they are:

i) Main stations

ii) Subsidiary on tie stations.

Main stations are the ends of the lines which connect the boundaries of the survey, and the lines joining the main stations are called the main survey or chain lines.

Subsidiary or tie stations are the points selected on main survey lines to run auxiliary lines to locate the interior details such as fences, hedges, buildings etc. when they are distant from the main lines. The symbol "O" is used to denote stations. Capital and small letters are used to represent main and tie stations respectively.

Selection of stations

While arranging the frame work of survey by selecting different stations, the following points should be kept in mind:

1)All the main stations should be inter-visible.

2)The first principle in surveying is the working from whole to part and not from part to whole. This should be strictly followed.

3)Generally, a long line (base line) should be run approximately through the centre and the whole length of the area.

4)All triangles should be well conditioned to make their sides almost equal.

5)Long offsets should be avoided.

6)As far as possible, the no. of survey lines should be minimized.

Base Line: The longest chain line in chain surveying is called the base line. This is the most important line and the whole framework of triangles is based on this line and therefore, the baseline should be very accurately measured (Fig.13). It should be passing through the centre of the area.

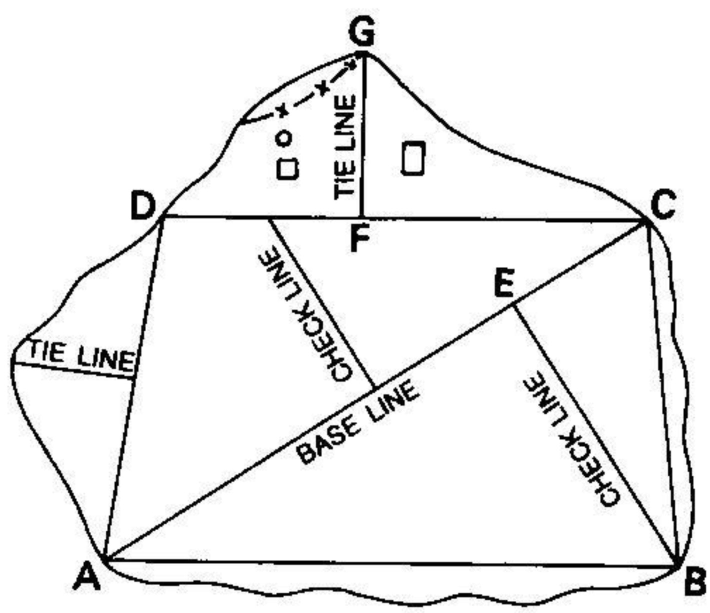


Fig. 13. Base, check and tie lines in triangulation survey

Subsidiary or tie lines: When numbers of features are to be located and they are far away from the main chain lines, then subsidiary or tie lines are used to locate such details. In fig.13., tie line FG is used to locate number of features. Tie line is obtained by joining two fixed points on the main survey line. Tie lines can also be used as check lines to check the accuracy of measurements and plotting.

Check lines: Check lines are also called as proof lines. The mistakes of the measurement and plotting can be easily checked with the help of check lines. The check line is a line joining the apex of a triangle to some fixed points on the opposite side, a line joining some fixed points on any two sides of a triangle. Every triangle should be provided with a check line.

Lecture 5

Plotting procedure of chain survey, conventional symbols.

5.0 A chain survey may be executed in the following steps:

5.1 Reconnaissance: The preliminary instruction of the area to be surveyed is called reconnaissance. It is essential that the surveyor should have a thorough knowledge of the ground to be surveyed and its principle features. On arriving at the ground, the surveyor should therefore, walk over the whole area and thoroughly examine the ground, so as to decide upon the best possible arriving of the work. The surveyor should note the various boundaries, the positions of buildings, roads, streams etc., various difficulties that may intervene the proposed chain lines and the suitable positions of the stations. During the reconnaissance, the surveyor should prepare a neat hand sketch called an index sketch or key plan fairly resembling the plan of the ground, showing the boundaries, the principles features such as buildings, roads, tanks, etc., the positions of the stations and chain lines. The sketch is drawn in the field.

5.2 Marketing stations: Having completed the reconnaissance and the index sketch, survey stations should be marked on the ground by fixing vertically a ranging rod or a pole at each station if the survey is only of a temporary character.

5.3 **Reference sketches**: After the stations are marked, they should be referred i.e., located the measurements called ties, taken from three permanent points which are definite and easily recognized i.e., corners of buildings, gate pillars, boundary stones, fence posts. Reference sketches in case the station marks are displaced or lost or required at a future data.

5.4 Running survey lines: Having finished the preliminary work, chaining may be commenced from the base line and carried through all the lines of the frame work as continuously as possible

5.5 Booking field notes

A field book is used for noting the readings when the survey is carried out. The field book is about 22.5 cm long and 12.5 cm wide and opens length wise. Generally single or double red lines are drawn in the middle. Chainage lengths are noted in between the two red lines and the space on either side is used for writing the offset lengths and for drawing rough sketches of figures. The booking is commenced from the bottom of the page and work upward. The initial and final chainage should be marked with a symbol Δ and capital letters like A, B, C etc., should be used to mark the stations. While noting the readings, the surveyor should face the direction of chaining and offsets should be entered on the left or right side as they are situated. The conventional symbols (Fig.14) should be used for recording different features. Each new chain line should be started from a new page. One sample page of a field book is shown in fig.15. At the commencement of the line in the book is written: the name (or) numbers of the survey line, the name (or) number of station, the symbol perpendicular donating the station, tie (or) subsidiary station should be indicated by a circle (or) a oval round their chainage figures, all around the chain line are entered in the central column and offset retain opposite them on the right (or) left of the column according as they are right (or) left of the survey line.

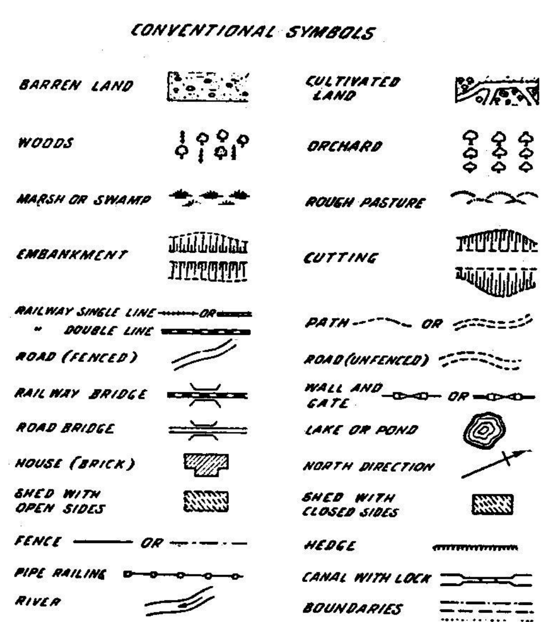


Fig. 14. Common symbols

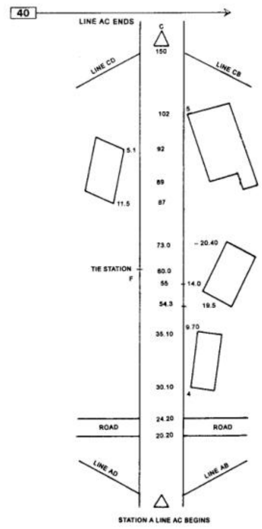


Fig.15. Field book entry

5.6 Plotting procedure of chain survey

After the survey is completed, the recorded information is taken to the office and they are plotted on a drawing sheet using a suitable scale. While plotting a chain survey, the following steps are to be followed:

(i) Depending upon the area covered in the survey and its importance, a suitable scale is chosen. Boundary lines are drawn leaving a suitable margin all around.

(ii) The base line which is the mainline in the survey should be suitably located in the map to accommodate the whole plotting easily in the drawing sheet. The base line should be most accurately plotted.

(iii) The intermediate stations are marked on the base line and the frame work of triangles is completed.

(iv) Chainage lengths are measured along the chain lines for various offsets and points are marked. From these points perpendiculars of suitable lengths are drawn to locate the offsets.

(v) The accuracy of plotted frame work may be checked by means of check and tie lines.

(vi) The field book should be kept side by side in the same direction as the survey proceeded in the field parallel to the chain line to be plotted.

(vii) For drawing different objects, conventional symbols should be used.

(viii) The title of the survey, name of the surveyor, date etc., should be written at the right hand bottom corner. The scale is drawn below the map.

5.7 Drawing instruments required

The following drawing instruments are generally used in drawing office works.

1. Drawing table (size 2.4 × 1.2m)
2. A drawing board of good quality (900 × 850m)
3. The square with ebony edge (lengths vary from 500 × 150m)
4. Set squares – required for drawing parallel and perpendicular lines.
5. An instrument box
6. Protractor
7. Four set of French curves – required for drawing irregular and curved figures.
8. A standard straight edge of 2m long for drawing long lines.

Lecture 6

Areas of irregularly bounded fields - different methods.

6.0 Measurement of areas of irregularly bounded fields

Various formulae such as Mid-ordinate rule or Average ordinate rule, Trapezoidal rule and Simpson's rule are applied for computation of areas of irregular bounded fields. All these methods are suitable for long narrow strips such as grounds occupied by a railway or road. A base line is drawn through the area and the area is divided into a number of equal parts. Simpson's rule assumes that the different parts are portions of parabolic areas, where as the other rules assume that the boundaries between the extremities are straight.

6.1 The Mid-ordinate Rule: In this method, the ordinates are measured at the mid-points of each division (Fig.16) and the area is calculated by the formula,

Area (Δ) = $\dfrac{h_1 + h_2 + h_3 + \ldots\ldots\ldots\ldots. h_n}{n} \times l$

$= (h_1 + h_2 + h_3 + \ldots\ldots\ldots\ldots. h_n) \times d$

Where

h_1, h_2, h_3 etc., are the ordinates at the mid-points of each division

l = the length of the base line

n = the number of equal parts into which the base line is divided

d = the common distance between the ordinates = $\dfrac{l}{n}$

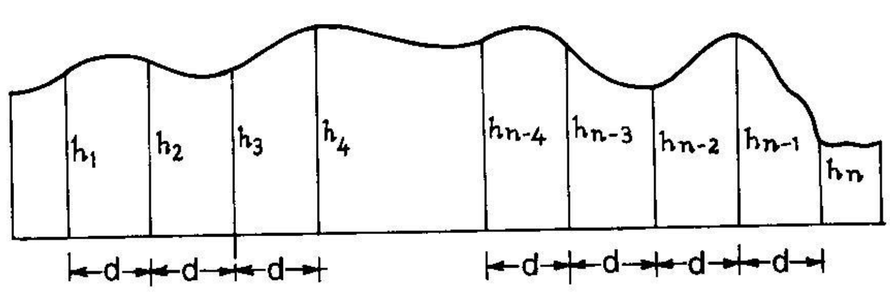


Fig.16. Mid ordinate rule

6.2 **The Average Ordinate Rule**: In this method, the ordinates are drawn and scaled at each of the points of division of the base line (Fig.17). The average of these ordinates multiplied by the length of the base line gives the required area.

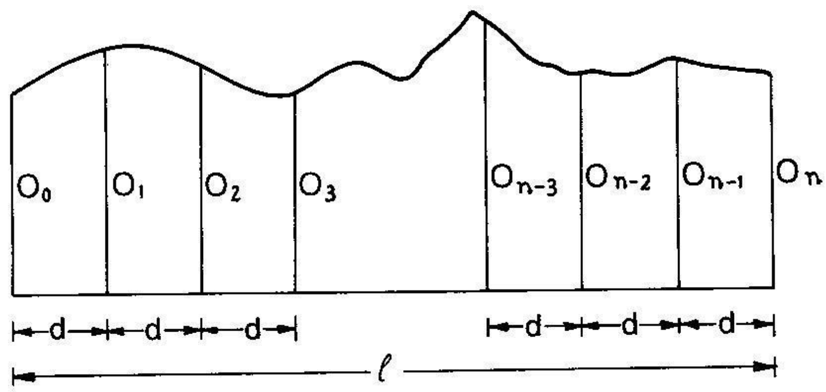


Fig.17. Average ordinate rule

Area (Δ) = $\left(\frac{O_1 + O_2 + O_3 + O_4 + ...O_n}{n+1}\right) \times l$

O_1, O_2, O_3 etc., are the ordinates at each of the points of division

l = the length of the base line

n = the number of equal parts into which the base line is divided

6.3 **The Trapezoidal Rule**: This rule is more accurate than the first two ones. In this method, the area is divided into a series of trapezoids (Fig.18). The rule may be stated as follows:

"To the sum of the first and the last ordinates, add twice, the sum of the intermediate ordinates. Multiply the total sum thus obtained by the common distance between the ordinates. One half of this product gives the required area."

i.e., Area (Δ) = $\left(\frac{O_0 + 2O_1 + 2O_2 + O_3 + ...+ 2O_{n-1} + O_n}{2}\right) \times \frac{l}{n}$

$$= \frac{d}{2}\left(O_0 + 2O_1 + 2O_2 + ...+ 2O_{n-1} + O_n\right)$$

$$= d \left\{ \frac{O_0 + O_n}{2} + O_1 + O_2 + ... + O_{n-1} \right\}$$

Note: When the base line cuts the boundary at one or both ends of the figure, O_0 or O_n or both are zero. However, they must not be omitted from the formula.

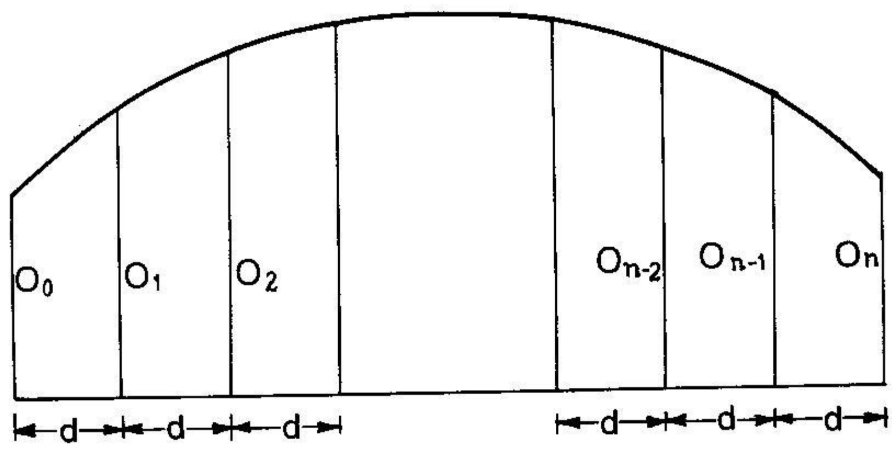


Fig. 18. Trapezoidal rule

6.4 Simpson's Rule: It may be stated as follows:

"To the sum of the first and the last ordinates, add twice the sum of the remaining *odd* ordinates and four times the sum of all the *even* ordinates. Multiply the total sum thus obtained by one-third of the common distance between the ordinates, and the result gives the required area (Fig.19)."

Area (Δ) = $\frac{d}{3} \left(O_0 + 4O_1 + 2O_2 + 4O_3 + ... + 2O_{n-2} + 4O_{n-1} + O_n \right)$

Note: O_1, O_3, O_5, etc., (the 2^{nd}, 4^{th} , 6^{th}, etc., from the end) are even ordinates, and O_2 , O_4 , O_6 , etc., (the 3^{rd} , 5^{th} , 7^{th}, etc., from the end) are odd ordinates.

6.5 Comparison of Rules: The results obtained using Simpson's rule are greater or less than those obtained by using the Trapezoidal rule according as the curve of the boundary is concave or convex towards the base line. The results obtained by using the Simpson's rule are more accurate and, therefore, where great accuracy is required, it should be invariably used.

For the application of the Trapezoidal rule and Simpson's rules, the interval between successive ordinates must be uniform throughout the length of the base line. If it is not the same, the base line may be divided into different sections, each having the same interval.

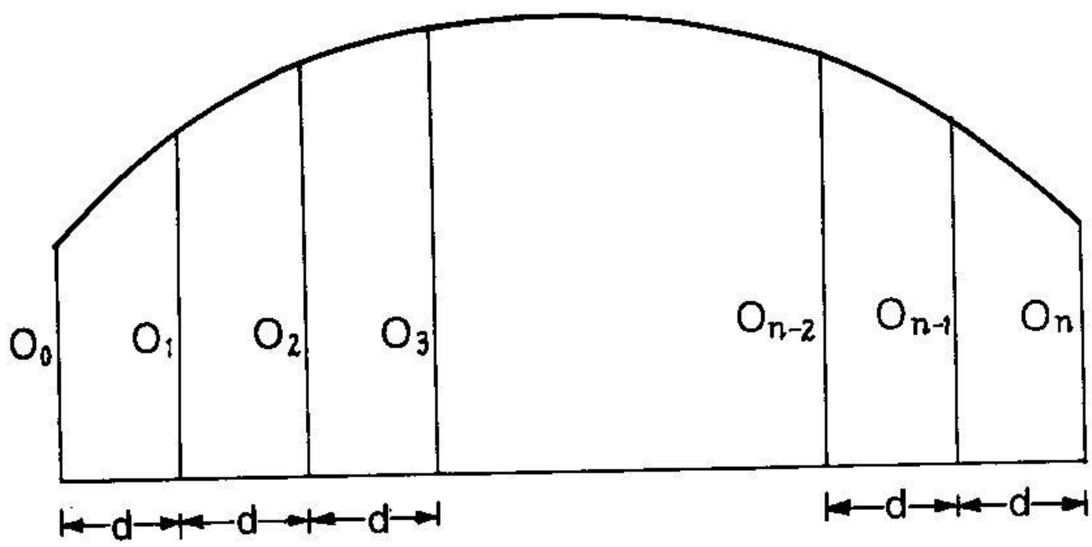


Fig. 19. Simpson's rule

Lecture 7

Numerical problems on Simpson's, trapezoidal rules.

Numerical problems on simpson's and trapezoidal rules

The following perpendicular offsets were taken at 10 m interval from a survey line to an irregular boundary line:

3.82, 4.37, 6.82, 5.26, 7.59, 8.90, 9.52, 8.42 and 6.43 m.

Calculate the area in m^2 enclosed between the survey line, the triangular boundary line and the and first and last offsets by the application of (a) Simpson's rule, (b) the Trapezoidal rule, and (c) the Average ordinate rule.

Solution:

Let d = the interval between the offsets = 10 m

Δ = the required area

(a) Simpson's rule,

$$\Delta = \frac{10}{3}\left[(3.82+6.43)+4(4.37+5.26+8.90+8.42)+2(6.82+7.59+9.52)\right]$$

$$= \frac{10}{3}\times\left[165.91\right] = 553.03 \text{ m}^2$$

(b) Trapezoidal rule

$$\Delta = \frac{10}{2}\left[\left(3.82+6.43\right)+2\left(4.37+6.82+5.26+7.59+8.9+9.52+8.42\right)\right]$$

$$= \mathbf{560.05\ m^2}$$

(c) Average ordinate rule

Interval between the offsets = d = 10 m.

Number of intervals = n = 8

$\therefore$ Number of offsets = n +1 = 8 +1 = 9

Length of the survey line = l = nd = 8 × 10 = 80 m

Now, $\sum O$ = 3.82 + 4.37+6.82+5.26+7.59+8.90+9.52+8.42+6.43=61.13 m

$$\Delta = \frac{\sum O\times l}{n+1} = \frac{61.13\times 80}{9} = \mathbf{543.38\ m^2}$$

Example 2: The following offsets were taken from a survey line to a hedge.

Distance in m	0	5	10	15	20	30	40	55	70
Offset in m	3.29	4.05	6.23	5.75	4.76	5.26	4.32	3.92	2.91

Find the area between the survey line and the hedge using Trapezoidal, Simpson's rule and Average ordinate rule.

Solution:

The interval between the offsets is nor regular throughout the length of the survey line. Hence, the line may be divided into different sections, each having a uniform interval. The areas of the different sections may be calculated separately, and then added to obtain the required total area. In this case, the survey line is divided into three sections, the first one having 5m interval, the second one having 10 m interval, and the third one having 15 m interval between the offsets.

Let Δ = the required total area

$\Delta_1 =$ the area of the first section

$\Delta_2 =$ the area of the second section

$\Delta_3 =$ the area of the third section

d_1 = the interval between the offsets in the first section = 5 m

d_2 = the interval between the offsets in the second section =10 m

d_3 = the interval between the offsets in the second section =15 m

Then

(a) Trapezoidal rule

$$\Delta_1 = 5\left\{\left(\frac{3.29+4.76}{2}\right)+(4.05+6.23+5.75)\right\} = 5 \times 20.06 = 100.30 \text{ m}^2$$

$$\Delta_2 = 10\left\{\left(\frac{4.32+2.92}{2}\right)+5.26\right\} = 10 \times 9.8 = 98.0 \text{ m}^2$$

$$\Delta_3 = 15\left\{\left(\frac{4.32+2.92}{2}\right)+3.92\right\} = 15 \times 7.54 = 113.1 \text{ m}^2$$

Total = $\Delta_1 + \Delta_2 + \Delta_3 = 100.3 + 98.0 + 113.1 = 311.4 \text{ m}^2$

$\therefore \Delta = 311.4 \text{ m}^2$

(b) Simpson' rule

$\Delta_1 = \frac{5}{3}\left[3.29 + 4.76 + 4(4.05 + 5.75) + 2(6.23)\right] = \frac{5}{3} \times 59.71$ = 99.52 m^2

$\Delta_2 = \frac{10}{3}\left[4.76 + 4.32 + 4(5.26)\right] = \frac{10}{3} \times 30.12$ = 100.4 m^2

$\Delta_3 = \frac{15}{3}\left[4.32 + 2.91 + 4(3.92)\right] = \frac{15}{3} \times 22.51$ m^2

Total = $\Delta_1 + \Delta_2 + \Delta_3$ = 99.52 + 100.4 + 114.55 = 314.47 m^2

$\therefore$ Δ = 314.7 m^2

(c) Average ordinate rule

First section:

Interval between the offsets = d = 5m.

Number of intervals = n = 4

$\therefore$ Number of offsets = 4 +1 = 4 +1 = 5

Length of the survey line = l = nd = 4 × 5 = 20 m

Now, $\sum O$ = 3.29+4.05+6.23+5.75+4.76=24.08 m

$\mathbf{\Delta_1} = \frac{\sum O \times l}{n+1} = \frac{24.08 \times 20}{5}$ **= 96.32 m^2**

Second section:

Interval between the offsets = d = 10m.

Number of intervals = n = 2

$\therefore$ Number of offsets = n +1 = 2 +1 = 3

Length of the survey line = l = nd = 2 × 10 = 20 m

Now, $\sum O$ = 4.76+5.26+4.32=14.34 m

$\mathbf{\Delta_2} = \frac{\sum O \times l}{n+1} = \frac{14.34 \times 20}{3}$ **= 95.6 m^2**

Third section:

Interval between the offsets = d = 15m.

Number of intervals = n = 2

$\therefore$ Number of offsets = n +1 = 2 +1 = 3

Length of the survey line = l = nd = 2 × 15= 30 m

Now, $\sum O$ = 4.32+3.92+2.91=11.15 m

$\mathbf{\Delta_3} = \frac{\sum O \times l}{n+1} = \frac{11.15 \times 30}{3}$ **= 111.5 m^2**

Total = $\Delta_1 + \Delta_2 + \Delta_3$ = 96.32 + 95.6 + 111.5= 303.42 m^2

$\therefore$ Δ = 303.42 m^2

Lecture 8

Leveling - definition, description of dumpy level and leveling staff. Terminology connected with leveling - datum, elevation, station, back sight, fore sight, intermediate sight, height of instrument, bench mark and its types, change point.

Levelling may be defined as the art of determining the relative heights or elevations of points or objects on the surface of the earth. Therefore, it deals with measurements in vertical plane. Levelling has wide applications in the field of agriculture. Construction of irrigation and drainage channels, terraces, bunds, reservoirs, outlet structures, etc, require the knowledge of surveying. For any soil conservation and land levelling work, levelling is the first job to be taken up.

8.0 Levelling instruments

Two instruments are required to determine the reduced levels of points. They are: (i) a level and (ii) a levelling staff. The level is used to provide a horizontal line of sight and the levelling staff which is a graduated rod is used to read the vertical height of the line of sight above the selected station.

8.1 The level

Various types of levels are used for surveying *viz.*(i) Hand level, (ii) Farm level, (iii) Wey level, (iv) Tilting level and (v) Dumpy level etc. The dumpy level is widely used for levelling works. For small and rough levelling works, the hand levels and farm levels are used. The dumpy level is very sturdy, compact and stable equipment. The telescope is rigidly fixed to the frame. Therefore, the telescope cannot be rotated about the longitudinal axis and also cannot be removed from the support. Because of its simple features and versatile usefulness, it is widely used.

8.1.1 Dumpy level

The dumpy level is simple, compact and stable. Main parts of a dumpy level are shown in fig.20. A levelling instrument essentially consists of tripod or three legged stand, levelling head mounted on the tripod, the limb, telescope and the bubble tube. The most important part is the telescope which may be either internal focusing or external focusing type.

A levelling head is mounted on the tripod stand having two parallel plates and three or four foot screws. The limb, consists of the vertical axis and a horizontal plate, connects the levelling head with the above telescope.

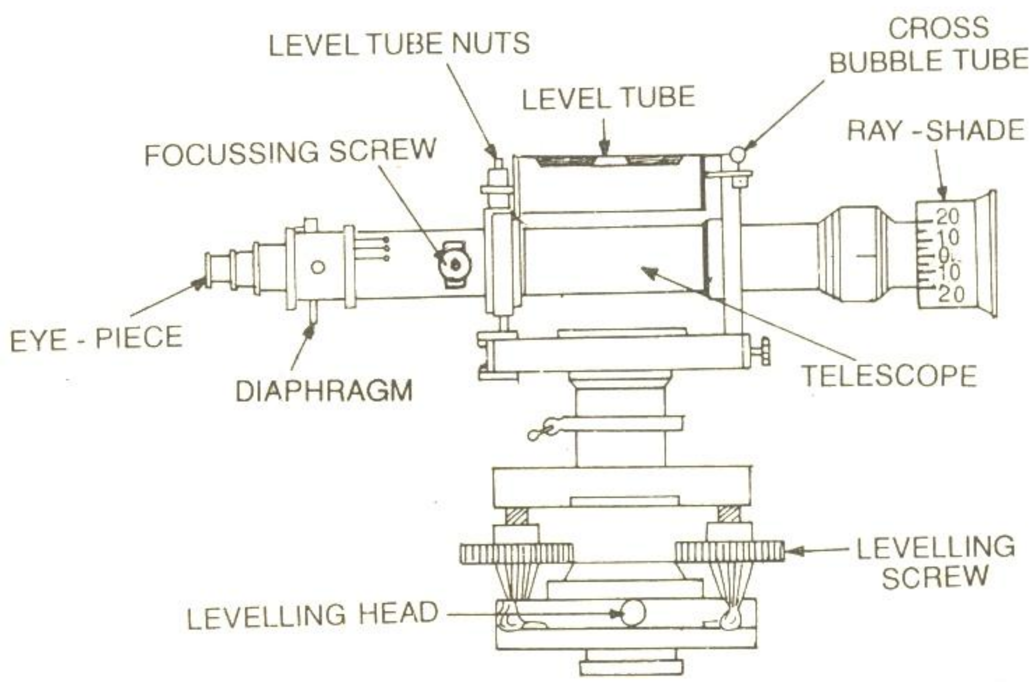


Fig. 20. Dumpy level

The telescope has an object glass at the forward end and eye piece at the rear end. The eye piece magnifies the image of the object formed by the object glass. All the parts above the levelling head are capable of rotating round the vertical axis. One or two bubble tubes are provided for leveling the instrument. The bubbles can be brought to the centre of the bubble tubes by adjusting the foot screws, which support the upper parallel plate.

The diaphragm is fixed a little beyond the eye-piece inside the main tube. The diaphragm houses a brass ring which is fitted with cross hairs. There are three sets of horizontal hairs. The central cross hair gives the line of sight. The line joining the intersection of the central cross hair to the optical centre of the object glass and its continuation is the line of sight. When sighted through the eye piece, continuation of the above line meets the leveling staff at a point denotes the staff reading.

8.2 The levelling staff

There are various types of graduated staves. Out of all, the "sop with telescopic staff" is commonly used. The purpose of a levelling staff is to determine the amount by which the station (foot of the staff) is above or below the line of sight.

8.2.1 Sop with telescopic staff

It is a straight, rectangular, graduated rod with the foot of the staff representing the zero reading. The width and the thickness of the staff are 75 mm and 18 mm respectively. It is made of well seasoned wood such as cypress, blue pine or deodar free from any defect.

It is arranged in three telescopic lengths. It is usually 5 m long when fully extended (Fig.21). The solid top length of 1.5m slides into the central box of 1.5 m, which in turn slides into lower or bottom box of 2.0 m length. Each length when pulled out to its full length is held in position by means of a brass spring catch. Each metre is subdivided into 200 divisions, the thickness of graduation being 5mm. Spaces indicating the decimetre readings are marked in red while all other spaces are marked in black against a white background. Each decimetre length is figured with the corresponding numerals, the metre numeral is in red and marked to the right and the decimetre numeral in black and marked to the left. When viewed through the telescope, the staff appears inverted and therefore, readings are taken from top to downwards.

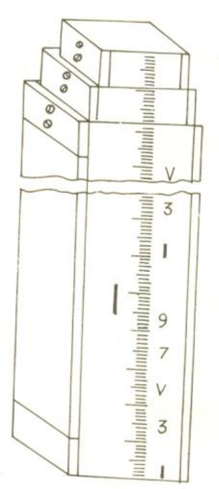


Fig. 21. Levelling staff

8.3 Terminology connected with leveling

Datum: It is also called datum plane or only datum. A datum surface is usually an imaginary level surface or arbitrarily assumed level surface, from which vertical distances are measured. Its elevation is zero. In India, the datum adopted for the Great Trignometrical survey (GTS) bench mark is the mean sea level at Karachi, now in Pakistan. At present, the mean sea level at Madras is used.

Elevation: It is the vertical distance above or below the datum. It is also known as reduced level (R.L.) The elevation of a point is plus or minus according as the point is above or below the datum.

Bench Mark (B.M.) : It is a fixed point of reference of known or assumed elevation with respect to which other elevations are calculated. It is a starting point for leveling. Temporary bench marks are selected at the end of a day's work. There are four kinds of Bench marks.

(a) G.T.S (Great Trigonometrical Survey) Bench Mark: These bench marks are established with very high precision at intervals all over the country by Survey of India department. Their position and elevation above the standard datum are given in the catalogue published by the department.

(b) Permanent Bench Mark: These are the fixed points of reference established between the GTS bench marks by Government agencies such as PWD. On clearly defined and permanent points such as top of the parapet wall of a bridge or culvert, corner of a plinth of a building, gate pillars etc.,

(c) Arbitrary bench Marks: These are the reference points whose elevations are arbitrarily assumed. They are used in small levelling operations.

(d) Temporary Bench Marks: These are the reference points established at the end of day's work or when there is a break in the work. The work, when resumed, is continued with reference to these bench marks.

Line of collimation: It is the line joining the intersection of the cross hairs to the optical centre of the object glass and its continuation. It is called the line of sight.

Axis of telescope: It is a line joining the optical centre of the object glass to the center of the eye piece.

Axis of the level tube or bubble tube: It is an imaginary line tangential to the longitudinal curve of the tube at its middle point. It is also known as bubble line. It is horizontal, when the bubble is centered.

Height of the instrument: It is the reduced level (R.L.) of the plane of sight when the leveling instrument is correctly leveled. It is also called the "height of the plane of the collimation" or the collimation. The line of collimation will revolve in a horizontal plane known as plane of collimation or the plane of sight.

Back sight: It is a staff reading taken on a point of known elevation, as on a bench mark or a change point. It is also called a plus sight. It is the first staff reading taken after the level is set up and levelled.

Foresight: It is the last staff reading denoting the shifting of the level. It is the staff reading taken on a point whose elevation is to be determined. It is also termed as a minus sight. It is the last staff reading, denoting the shifting of the instrument.

Change point: It is the point on which reading is taken just before and after shifting the instrument. That means both back sight and fore sight readings are taken on this point. It is also called a turning point. It should be taken on a firm, well-defined object.

Station: A station is a point whose elevation is to be determined or a point which is to be established at a given elevation.

Lecture No.9

Leveling procedure - temporary adjustments in dumpy level, level field note book, recording procedure in level field note book.

9.0 Taking out the instrument from the box

Before taking out the instrument from the box, mark the positions of (a) the object glass, (b) eye-piece (c) clamp and tangent screws so that while keeping back it can be placed in the box in proper position without any difficulty.

9.1 Adjustment of the level

The adjustments of a level are of two kinds: (a) Temporary adjustments

And (b) Permanent adjustments

9.1.1 Temporary Adjustments: The temporary adjustments are those, which have to be done at each set-up of the level. They are necessary adjustments to take readings. They are:

(a). Setting up the level, which include

(i) Positioning the tripod, and

(ii) Levelling up

(b). Focussing the eye-piece and object glass to eliminate parallax.

9.1.2 Setting up the level

9.1.2.1 Fixing the instrument on the tripod: Release the clamp screw of the instrument, hold the instrument in the right hand and fix it on the tripod by turning round only the lower part with the left hand. Screw the instrument firmly.

9.1.2.2 Leg adjustment: Plant the instrument at the desired point at a convenient height for sighting. Spread the tripod legs well apart and tri-brach sprang as nearly level as can be judged by the eye. Bring all foot screws in the centre of their run. Fix any two legs firmly into the ground by pressing them with the hand and move the third leg to the right or left until the main bubble is approximately in the centre. Then move it in or out until the bubble of the cross level is approximately in the centre. It is only approximate levelling.

9.1.2.3 Levelling up: Place the telescope parallel to a pair of foot screws and bring the bubble to the centre of its run by turning these screws equally either both in wards or both outwards. Turn the telescope to 90^0 so that it lies over the third foot screw and centre the bubble by turning this screw. Repeat the operations until the bubble remains in the centre of its run in both positions. Once this operation is complete, the bubble should remain in the centre for all directions of the telescope, provided the instrument be in correct permanent adjustment.

9.1.2.4 Focussing the eye piece: Remove the lid from the object glass and hold a white paper in front of it. Move the eye piece in and out until the cross hairs on the diaphragm are seen distinctly.

9.1.2.5 Focussing the object glass: Direct the telescope towards the staff and on looking through the eye-piece, bring the image of the staff between two vertical hairs of the diaphragm by lightly tapping the telescope. Adjust the objective by turning the focusing screw until the parallax error is eliminated.

Focussing: Adjusting of the eye-piece and the objective at the proper distance apart for the clear vision of the object sighted is known as focusing. First, focus the eye-piece by holding a white paper in front of the telescope and move the eye- piece in and out until the cross hairs appear distinct and clear. Then focus the object glass by directing the telescope towards the object and turn the focusing screw until the image appears clear and sharp. By focusing, the focus of the objective and that of the eye-piece coincide with cross hair of the diaphragm as the diaphragm is placed at the common focus.

Parallax: The apparent movement of the image relatively to the crosshairs when the image formed by the objective does not fall in the plane of the diaphragm is called "parallax" and the process of precise focusing on the staff is often called "adjusting for parallax". If the image appears to move in the same direction as that of eye, it is in front of the diaphragm and the focusing screw must therefore move the objective inwards. If however, the image appears to move in the direction opposite to that of the eye, it is beyond the diaphragm towards the eye piece and the objective therefore to be moved outwards by the focusing screw. It may be noted that parallax error can be eliminated wholly by slightly turning the focusing screw backwards or forwards until such motion no longer exists.

9.2 Holding the staff: While reading the staff, care should be taken in holding the staff in vertical. The staff man stands behind the staff, heels together, with the heel of the staff between his toes and holds it between the palms of his hands at the height of his face in a vertical position. The readings will be too high, if the staff is not vertical. Special care must be taken with the larger readings, since the errors due to a given deviation from the vertical vary with the readings. The staff should be very slowly waved forward towards the level and backwards away from it. The person reading the staff should record the lowest reading which will be the correct reading.

9.3 Reading the staff:

Direct the telescope towards the staff held vertically on the station after the instrument is leveled. Bring the staff between the two vertical hairs and use the portion of the horizontal cross hair between them in reading the staff. Bubble should be in the centre of its run while reading the staff.

9.4 Booking staff readings in field book:

The readings should be entered in the respective columns and in the order of their observation. The first reading is obviously a back sight and should be entered in that column. A remark should be made in the remarks column describing weather back sight (B.S.) is taken on a permanent or temporary or arbitrary bench mark (B.M.) and its value should be noted. If more than one reading is taken from the same position of the instrument, all the subsequent readings should be recorded in the intermediate sight column. The last reading is a change point (C.P.) and recorded in foresight column (F.S.). The foresight and back sight of the change point should be written in the same horizontal line. The R.L of the plane of collimation should be written in the same horizontal line opposite to B.S. If the last entry at the bottom of the page happens to be an intermediate sight (I.S.), it should be repeated as the first entry on the next page and should be recorded both in I.S and F.S columns. The arithmetic checks should be made and written at the bottom of every page at home, the same day the levelling is done, so that if any discrepancy is found, it can be checked the next morning in the field.

Lecture No.10

Reduction of levels - height of collimation method, rise and fall method, and numerical problems connected with these two methods.

10.0 Determination of reduced level

Whenever any leveling is to be carried out, the first reading is taken on a point of known elevation. This is called back sight (B.S.) reading. Before shifting the instrument one reading is taken on a firm object whose elevation is to be determined. This is known as fore sight (F.S.) reading. Between the B.S and F.S numbers of readings known as intermediate sights (I.S) are taken. All these readings are required to be tabulated and converted to reduced levels (R.L) for practical use. There are two systems of working out the reduced levels of points from the staff readings in the field: (i) the collimation or the height of instrument (H.I.) and (2) the rise and fall system.

10.1 **The collimation system**: At first, the R.L. of the plane of collimation i.e., height of instrument (H.I) is calculated for every setting of the instrument and then R.L. of different stations re calculated with reference to the height of the instrument. In the first setting, the H.I. is calculated by adding the B.S. reading with the R.L. of the bench mark. By subtracting all the readings of all the intermediate sights and that of the first change point from the H.I. , then their reduced levels are calculated. The new H.I is calculated by adding the B.S. reading with the R.L. of the first change point. The process is repeated till the entire area is covered.

Arithmetical check: The difference between the sum of back sights and the sum of fore sights should be equal to the difference of first and last R.L.

10.2 **Rise and fall system**: The level readings taken on different stations are compared with the readings taken from the intermediate proceeding stations. The difference in the readings indicates rise or fall depending upon whether the staff reading is smaller or greater than that of the preceding reading. The rise is added and fall is subtracted from the R.L. of a station to obtain the R.L. of the next station.

Arithmetical check: The difference between the sum of back sights and the sum of fore sights is equal to the difference between the sum of the rise and fall and should be equal to the difference of first and last R.L.

If the R.L. of A is known, the R.L. of B may be found by the following relation:

R.L of B = R.L. of A + ∑ B.S. - ∑ F.S.

The R.L's of the intermediate points may be found by the following relation:

R.L. of a point = R.L of B.M + B.S. - I.S

The difference of level between A and B is equal to the algebraic sum of these differences or equals the difference between the sum of back sights and the sum of the foresights (∑B.S - ∑ F.S.). If the difference is positive, it indicates that the point B is higher than the point A, while if the negative, the point B is lower than the point A.

Example1:

The following consecutive readings were taken with a dumpy level:

0.565, 0.854, 0.940, 1.005, 0.640, 0.660, 0.785, 0.800, 0.635, 1.135, and 1.420

The level was shifted after the fourth and the seventh readings. The first reading was taken on the bench mark of R.L. is 100.565. Calculate the reduced levels of the change points, and the difference of level between the first and last points.

Solution:

The level was shifted after the fourth and the seventh readings. Hence, the fourth (1.005) and seventh readings (0.785) are fore sight readings. Where as the fifth (0.640) and eight reading (0.800) are back sight readings. The starting reading is back sight reading. The last reading is fore sight reading.

B.S **F.S** **B.S** **F.S** **B.S**

0.565, 0.854, 0.940, <u>1.005</u>, <u>0.640</u>, 0.660, <u>0.785</u>, <u>0.800</u>, 0.635, 1.135, and 1.420

F.S

(i) Collimation or Height of instrument (H.I.) method

Station	Readings, m			R.L. of plane of collimation (H.I.), m	Reduced level (R.L.), m	Remarks
	B.S	**I.S**	**F.S**			
	0.565			100.565	100.000	B.M
		0.854			99.711	
		0.940			99.625	
	0.640		1.005	100.200	99.560	C.P. 1
		0.660			99.540	
	0.800		0.785	100.215	99.415	C.P. 2
		0.635			99.580	
		1.135			99.080	
			1.420		98.795	Last point
	$\sum$ B.S =2.005		**$\sum$ F.S =3.210**			

Arithmetical check: The difference between the sum of back sights and the sum of fore sights should be equal to the difference of first and last R.L.

$\sum$ B.S =1.365; $\sum$ F.S =3.210; Ist R.L. =100.000; Last R.L.=98.795

2.005 – 3.210 = 98.795 – 100.000

- 1.205 = -1.205 (Checked)

(i) Rise and fall method

Station	Readings, m			Rise, m	Fall, m	Reduced level (R.L.), m	Remarks
	B.S	**I.S**	**F.S**				
	0.565					100.000	B.M
		0.854			0.289	99.711	
		0.940			0.086	99.625	
	0.640		1.005		0.065	99.560	C.P. 1
		0.660			0.020	99.540	
	0.800		0.785		0.125	99.415	C.P. 2
		0.635		0.165		99.580	
		1.135			0.500	99.080	
			1.420		0.285	98.795	Last point
	$\sum$ **B.S =2.005**		$\sum$ **F.S =3.210**	$\sum$ **rise=** 0.165	$\sum$ **fall=** 1.370		

Arithmetical check: The difference between the sum of back sights and the sum of fore sights is equal to the difference between the sum of the rise and fall and should be equal to the difference of first and last R.L.

$\sum$ B.S =1.365; $\sum$ F.S =3.210; Ist R.L. =100.000; Last R.L.=98.795;

$\sum$ rise = 0.165; $\sum$ fall = 1.370

2.005 – 3.210 = 0.165-1.370 =98.795 – 100.000

- 1.205 = -1.205 = -1.205 (Checked)

Lecture No.11

Types of leveling - simple, leveling, differential leveling and profile leveling.

11.0 Types of Levelling

11.1 Simple levelling: It is the simplest operation in leveling when it is required to find the difference in elevation between two points, both of which are visible from a single position of the level.

If the two points are so close that they can be seen from a single set up, their level difference can be determined easily.

Procedure: If the two points are so close that they can be seen from a single set up, their level difference can be determined easily. Let A and B be two points (Fig.22) located closely and it is desired to know their elevation difference. The level can be set up anywhere from where both the stations are visible i.e., at "O". But to eliminate the effect of any instrumental error, it is advisable to place the instrument at equal distance from both the stations, but not necessarily in the same line. Staff readings are taken on both the stations. The difference in reading gives the elevation difference between the points.

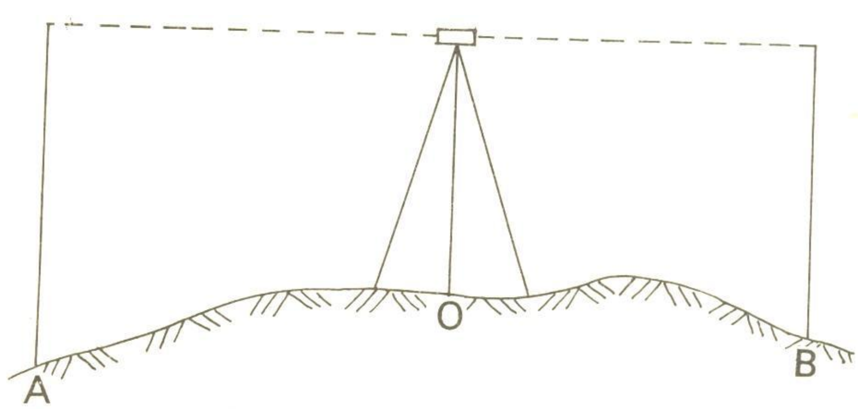


Fig. 22. Simple levelling

11.2 Differential levelling: It is the method of levelling to determine the elevation of points located at some distance apart or to determine the elevation difference between two points or to establish bench marks. The method is used in order to find the difference in elevations between two points: (i) if they are far apart, (ii) the difference in elevation between two points is too great and (iii) if there are obstacles intervening. The method of simple leveling is employed in each of the successive stages. The process is also known as compound or continuous leveling. Suppose, it is required to find the difference of level between two points A and B, which are too far apart as shown in fig.23.

Procedure

When two points are located at a distance so that they cannot be viewed from a single set up of the level, then it is required to take a number of change points. Let A and B are two such points (Fig. 23) whose elevation is to be found out. First, the instrument is set up between A and B and the instrument is leveled and focused. Reduced level of A is assumed and is taken as bench mark. From the same set-up, the staff reading (B.S.) at A is taken. The instrument remains in its position and staff is shifted towards B and fore sight (F.S.) reading is taken on this point, which is the first change point. The distance of the change point from the level should not exceed 100m. The level is shifted towards B and set up at a convenient point to keep its distance from the first change point approximately same as before. The process of taking B.S and F.S. reading is repeated till the point B is reached. Enter last station reading in the fore sight. The readings are tabulated and the reduced levels of all stations can conveniently be calculated following the collimation or rise or fall system.

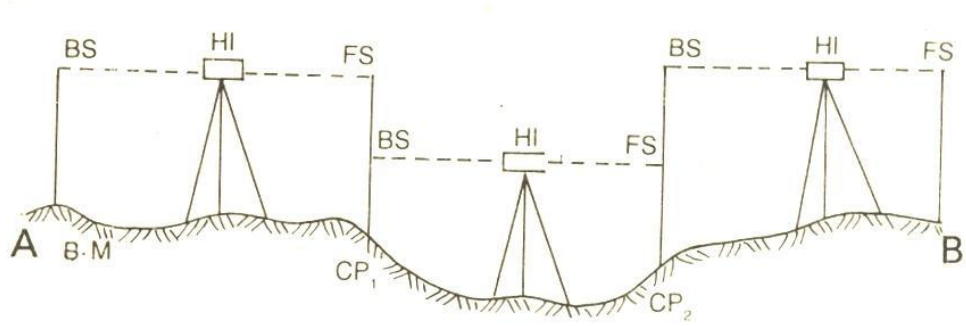


Fig. 23. Differential levelling

11.3 Profile leveling: It is the method of determining the level of ground surface along a predetermined line which may be the centre line of a road, canal, railways or pipeline. The predetermined line may be a single straight line or a series of connected straight lines. The method is also known as longitudinal leveling or sectioning. Sectioning is useful for laying out roads, canals, terrace lines, contour bunds etc.

Procedure for profile leveling: The leveling operation should start from a bench mark. If no bench mark is available nearby, fly levels may be taken to establish temporary bench marks. Depending upon the precision required, the interval at which level should be taken is decided. The fixed interval may be 10, 20, 25 m etc. But apart from this fixed interval, level readings must be taken at all points where there is abrupt change of slopes. If these points are omitted, there will be serious misrepresentation of the nature of slope. The line AH (Fig.24) along which profile leveling will be carried out is located and the points are marked by pegs. Here the R.L. of the bench mark (A) is known and A is also the first point of the line through which profile will be run. The fore bearing of the line should be measured at A by using a prismatic compass. The magnetic compass fitted with the dumpy level may also be used for measuring the bearing of the line. If there are number of connected lines, then the bearings of each line should be measured as the survey progresses. For taking levels, the instrument is set up on a firm ground at M located outside the line AH. Back sight reading is taken on the staff held at A (bench mark). This is a plus sight as this reading added with the R.L. of A gives the H.I. Now the staff is shifted to different points already marked and numbers of I.S. readings are taken. The reading of the last clearly visible station (station no.6) is the F.S. reading. This is used as the first change point. After taking the F.S. reading on the first change point, the instrument is shifted to a new position (N) from where maximum number of stations can be covered. The staff-man continues to hold the staff at the same position (C.P. 1) till B.S. reading on it is taken. After this, the staff is shifted to different stations and intermediate sights (I.S.) are taken as long as the stations are visible from this set up of the leveling instrument. At last, a change point (C.P.2) is selected on a firm ground and the F.S. reading is taken. The instrument is shifted and the process is continued till all the stations are completed.

Whenever there is a change in the direction of the profile line, at the point of change, the back bearing of the preceding line and the fore bearing of the succeeding line must be taken. The chainage of all the staff points should be taken continuously from the starting point to the last point. As far as possible the B.S. and F.S. distances should be approximately equal. In addition to the profile readings, staff readings should also be taken on all important features. Also the positions of the features like road, canal, river, fences etc. may be located by taking offsets or by some other means. The level readings should be checked by connecting it with a nearby permanent bench mark. If, no such bench mark is available, the work can be checked by taking fly levels to the original bench mark.

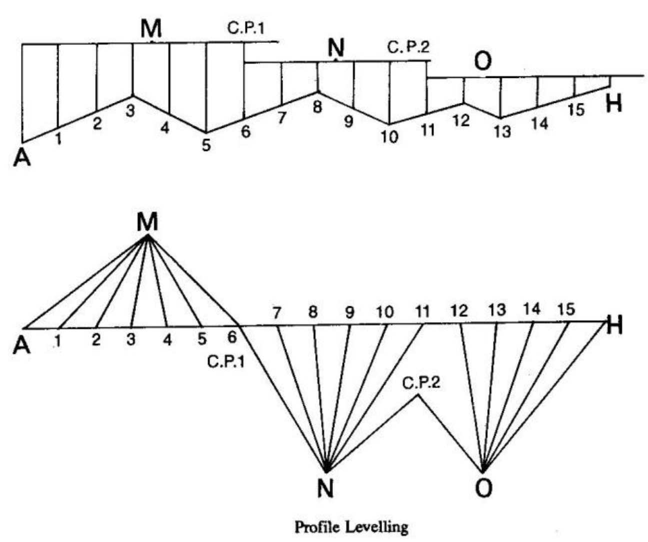


Fig. 24. Profile leveling

Lecture 12

Contour survey - definition, characteristics and uses of contours.

12.0 Contouring

A contour or contour line is defined as a line of intersection of level surface with the surface of the ground. Thus, every point on a contour line has the same elevation. Therefore, contour line may also be defined as a line joining the points of equal elevation. The shore line of a reservoir with still water represents a contour line of fixed reduced level. As the water level changes, the new shore line represents another contour of a different R.L. The contour lines of an area are presented in a map known as a contour map or topographic map. In addition to contour lines, a topographic map includes the features like streams, rivers, reservoirs, valleys, hills, bridges, culverts, roads, fences etc.

12.1 Contour interval. The constant vertical distance between two consecutive contour lines is called the contour interval. The contour interval is kept constant; otherwise the map will be misleading. The horizontal distance between any two consecutive contour lines is known as the "horizontal equivalent". The horizontal equivalent, for a given contour interval depends on the nature of the ground. The contour interval depends upon the following factors:

(i) time and fund available for field and office work.

(ii) purpose and extent of survey.

(iii) nature of the ground, and

(iv) scale of the map.

The following contour intervals are generally used:

(i) for flat agricultural land, calculation of earthwork, land leveling etc. 0.15 to 0.50 m,

(ii) for construction of reservoirs and town planning 0.5 to 2m,

(iii) for location surveys 2 to 3 m, and

(iv) for small scale topographic map of hilly area 3m to 25m.

12.2 Characteristics of contour lines:

(i) All points of contour line have the same elevation.

(ii) Uniformly spaced contour lines indicate uniform slope whereas, straight, parallel and equally spaced lines indicate a plane surface.

(iii) Widely spaced contour lines indicate a flat ground and closely spaced contour lines indicate steep ground.

(iv) A series of closed contours with the higher values inside indicate a summit or hill (fig.25).

(v) A series of closed contours with the higher values outside indicate a depression (fig.25).

(vi) Contour lines cross a ridge or a valley line at right angles.

(vii) If the contour lines form U-shaped curves and higher values of contour are inside the loop, then it indicates a ridge line (fig.25).

(vii) If the contour lines form V-shaped curves and the lower values of contour are inside the loop, it indicates a valley line (fig.25).

(viii) Contour lines cannot cross one another or merge on the map except in case of an over hanging cliff (fig.25).

(ix) If several contour lines coincide i.e. the horizontal equivalent is zero then it indicates a vertical cliff (fig.25).

(x) Four sets of contours shown in fig. 26 represent a saddle i.e. a depression between summits. It is a dip in a ridge or the junction of two ridges. Line passing through the saddles and summits give watershed line.

12.3 Use of contours

(i) By inspection of a contour map, information regarding the characters of the terrain is obtained, whether it is flat, undulating or rolling etc.

(ii) Contour map is very useful for taking up land leveling works.

(iii) With the help of contour map, suitable site for reservoirs, canal, drainage channels, roads, railway etc. can be selected.

(iv) Total drainage area and capacity of reservoirs can be determined with the help of contour map.

(v) Computation of earth work is possible from contour map.

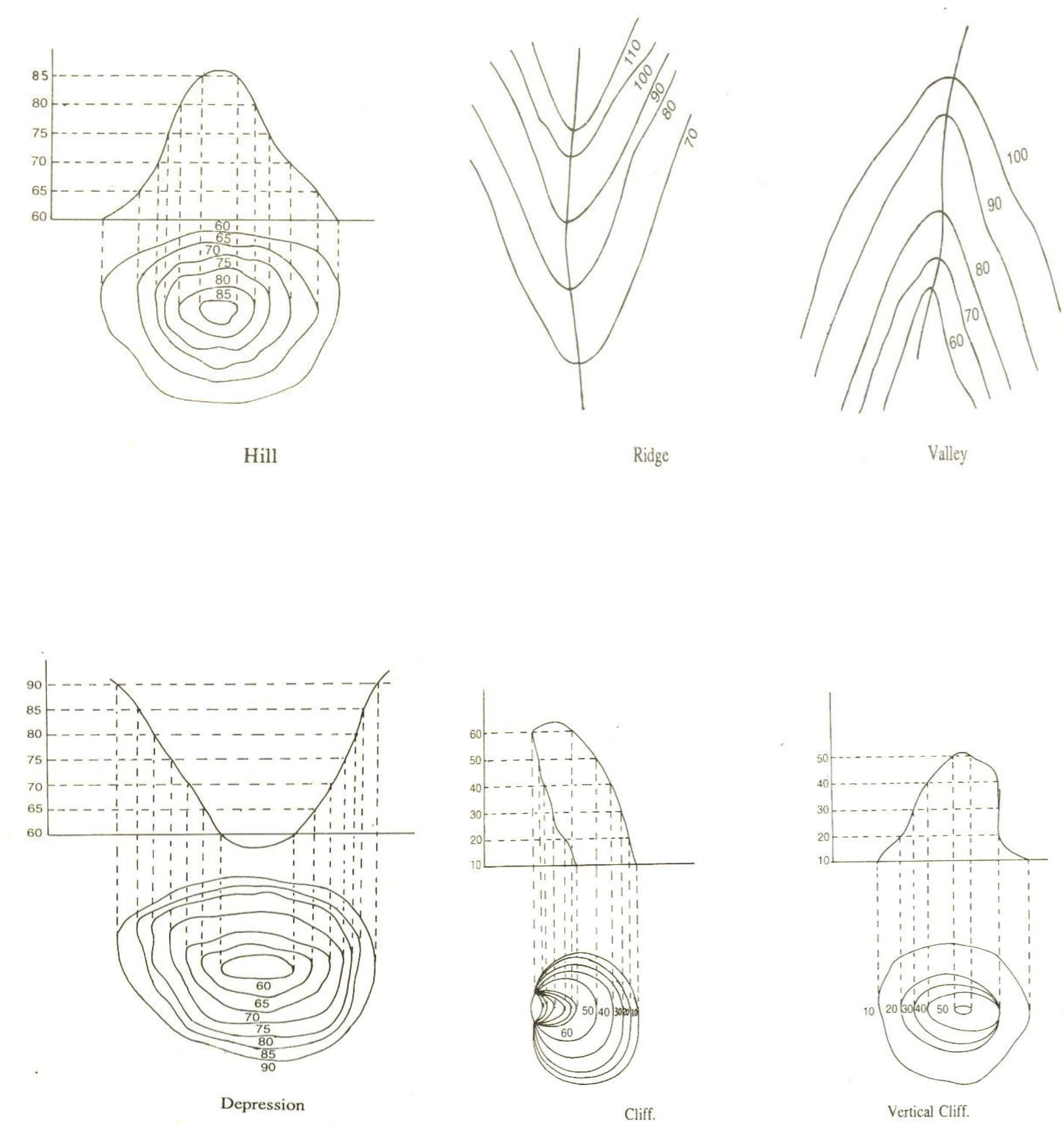


Fig. 25. Characteristics of contour lines

(vi) Contour maps are essential for taking up any soil conservation works like terracing, bunding, construction of structures and spillways.

(vii) In coastal areas for construction of brackish water fish farm contour map is required to decide about the type of farm to be constructed i.e. tide-fed or pump-fed farm.

(viii) Intervisibility of any two points can be known from the contour map.

(ix) From the contour map of agricultural land, most suitable method of irrigation for a particular crop can be decided.

(x) Section can easily be drawn from contours.

(xi) A route with a given slope can be traced on a contour map.

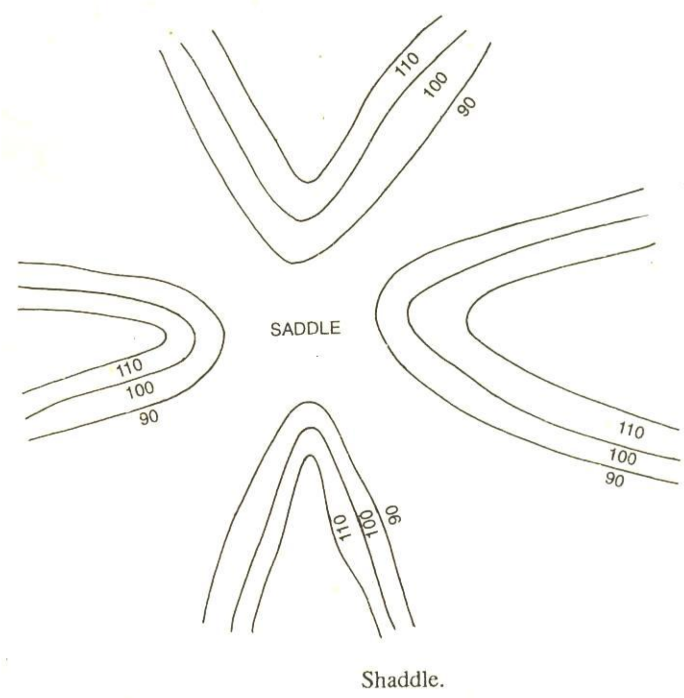


Fig. 26. Characteristics of contour lines

Lecture 13

Irrigation - definition, classification of irrigation projects based on Culturable Command Area (CCA) and expenditure, benefits of irrigation, ill effects of irrigation, flow irrigation and lift irrigation. Water sources.

13.0 Irrigation

Irrigation is an artificial application of water for the purpose of crop production. Irrigation water is supplied to supplement the water available from (i) rainfall and (ii) contribution of soil moisture from ground water.

In many areas, the amount and timing of rainfall are not adequate to meet the moisture requirement of the crops. Hence irrigation is essential. Scientific management of irrigation water provides best insurance against weather induced fluctuations in total food production. Water is being a limited source, it should not only meet the requirement of crop production, but also meet the requirement of (i) growing industry (ii) human and live stock consumption (iii) hydro electric power generation and (iv) navigation.

13.1 Classification of irrigation works

Irrigation projects are classified into three categories based on culturable command area (CCA) and the financial limits on expenditure involved in project cost.

Based on CCA, the irrigation projects are classified into:

(ii) Major irrigation projects: Irrigated area of > 10,000 ha.

(ii) Medium irrigation projects: Irrigated area between 2000 to 10,000 ha.

(iii) Minor irrigation projects: less than < 2,000 ha.

Based on financial limits on expenditure involved in the project, irrigation works are classified into:

(i) Major irrigation project: Project cost above Rs. 50 million

(ii) Medium irrigation project: Project cost in between Rs. 2.5 to 50 million

(iii) Minor irrigation project: Project cost less than Rs. 2.5 million.

Major and medium irrigation projects are generally ground together for the purpose of execution. Mostly the project execution is taken up by state irrigation departments. These projects comprise of dams, network of canals and related structures. They require substantial financial investments and are therefore, constructed only by government organizations. The minor irrigation projects consist of irrigation tanks, canals, diversion works, anti-sea intrusion works and almost all the ground water schemes.

Main types of irrigation:

I Direct Irrigation or river - canal irrigation phases:

(a) Diversion of water from river

(b) Conveyance of water to land

(c) Application of water to land

II. Storage Irrigation phases:

(a) Diversion of water from river

(b) Conveyance of water to land

(c) Application of water to land

III Sub soil water irrigation phases:

(a) Lifting of water from wells

(b) Application of water to land

13.2 Benefits of irrigation

a) It assures proper and successful growth of crop because of assured supply of water.

b) Irrigation protects people from the occurrence of famines, when rain water is severely deficient.

c) The owner of agricultural land is a gainer as the value of the land increases if it is situated nearer to the canal.

d) Hydro-electric power can be generated from the falls on some canal or by the water stored in a storage reservoir.

e) Some large canals can serve the dual purpose of irrigation and land navigation purpose.

f) Irrigation works are a paying concern to the government.

13.3 Disadvantages of irrigation:

(i) The land become alkaline and water logged if excess irrigation water is applied to the land, as a result the land become infertile and barren.

(ii) Excess irrigation water remains into pools on the surface of the ground, will breed mosquitoes, and cause malaria in the nearby areas.

13.4 Water sources

Water for irrigation is obtained from natural streams or rivers, from surface reservoirs and from underground reservoirs. Flood water from rivers is collected in surface reservoirs by constructing dams at suitable sites. Runoff water from small areas can also be collected by constructing ponds or tanks. Water from underground reservoirs is utilized by constructing wells and installing pumps or other water lifts. Water from surface reservoirs is taken through canals. Canals run from higher to lower elevations, and water flows in them by the force of gravity.

Based on whether the source of water is above or below the field surface, irrigation is classified into two types: (i) flow irrigation and (ii) lift irrigation.

13.5 Flow irrigation

When irrigation water in canals is available at such a level that it can flow over the adjoining land by gravity is known as flow irrigation.

13.6 Lift irrigation

When water has to be lifted up before it could be applied on land by gravity is called lift irrigation.

Lecture 14

Water lifting devices - classification of pumps, centrifugal pump, principle of operation.

14.0 Pumps

Lift irrigation requires that water be raised from its source to the field surface. Whatever the source of water in a lift irrigation project, the efficiency of the system depends on the application of sound principles in the design and construction of utilization structure, usually the well, and the characteristics of the water lifting device in relation the source of water. Devices for irrigation water lifting range from age-old indigenous water lifts to highly efficient pumps. Pumps operated by electric motors or engines have come into prominence in all large scale lift irrigation schemes. This is because high output and efficiency levels can be more easily attained and controlled, using mechanically powered water lifts.

Basically, there are four principles involved in pumping water from source. These are atmospheric pressure, positive displacement, centrifugal force, and movement of columns of water caused by difference in specific gravity. Numerous kinds of pumps are available, all of which use one or more of these principles. The classification of commonly used irrigation water lifts is shown in fig.27. Selection of a suitable water lifting device for a particular situation depends on the characteristics of the source of water and the lifting device, the amount of water to be lifted, the depth to the pumping water level, type and amount of power available and the economic status of the farmer. Most commonly used pumps are centrifugal pumps, vertical turbine pumps, and submerged pumps.

Pump is a machine that lifts water from source (open wells, tube wells or deep wells) to ground surface.

Pumps are generally two types:

1) Indigenous water lifts.

2) Highly efficient irrigation pumps.

14.1 Centrifugal pumps

In modern times, centrifugal pump is most commonly used for irrigation purpose. During the last 60 years, centrifugal pumps have replaced most of the other types of pumps and today they are the most popular pumps. Centrifugal pumps usually give efficient operation over relatively wide range of operating conditions especially if the total head exceeds 4 meters. The centrifugal pump draws water from the source of supply to the pump. Therefore, its use is limited to locations where this distance is within the limits of suction. Where this limit exceeds, horizontal centrifugal pumps cannot be used and deep well turbine pumps or submersible pumps should be used.

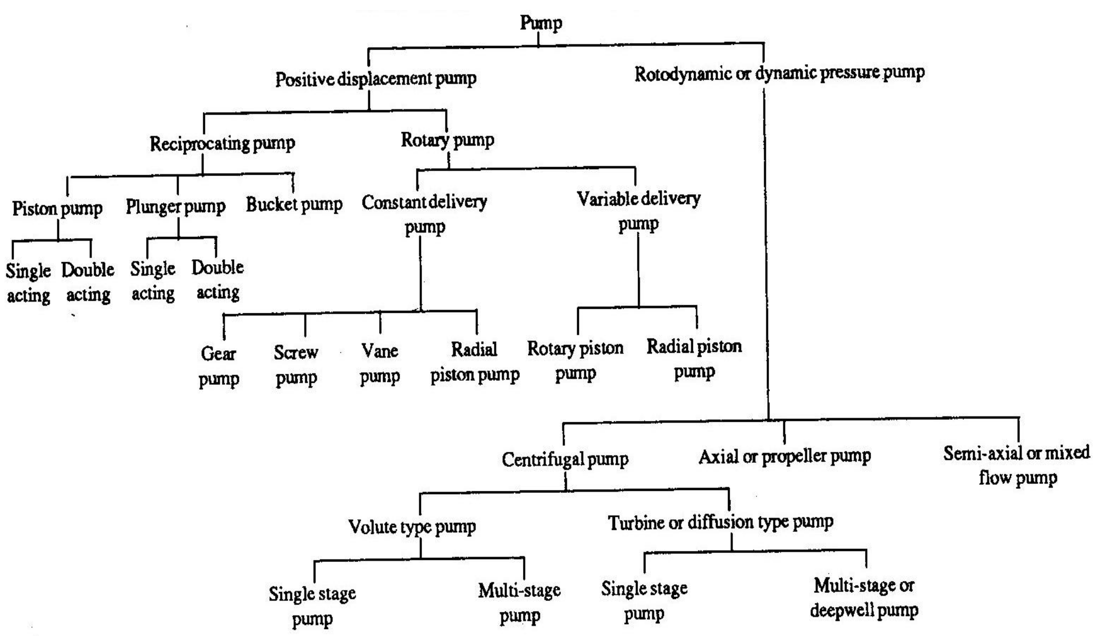


Fig. 27. Irrigation water lifts

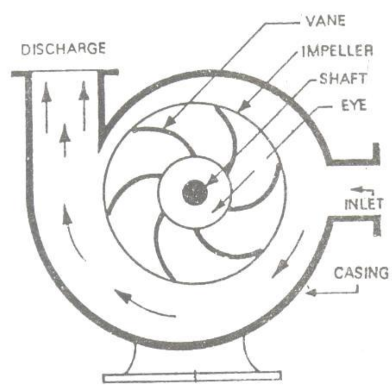
14.2 Advantages of centrifugal pump

This pump is very popular due to: (i) lower initial cost, (ii) greater flexibility in application, (iii) wide working range in size and capacity, (iv) simplicity in construction, (v) constant steady discharge, and (vi) easy in operation, and (v) easy in operation, maintenance and repair.

14.3 Principle of operation

The pump consists of two basic components: (i) Impeller, and (ii) Casing. The impeller is rotated at high speed by an electric motor or an engine. As soon as the impeller starts rotating, the blades cause the water to rotate with the impeller and impart high velocity to the water. Hence, water in the impeller (filled up by priming in the beginning) moves from the eye (centre of the impeller) to the periphery, negative pressure is created at the eye due to which water rushes from the water source to the eye or outside the casing where pressure head is built up. The static water in the well is at the atmospheric pressure, so the water rushes into the suction pipe due to difference of pressure. In this way, continuous flow of water is maintained in the pump. The centrifugal pump so called because the pressure increases with in the casing due to centrifugal forces (fig.28). The pump will not work until the casing and the suction pipe are full of water by priming.

Priming: It is the process of removing air from pump casing and suction pipe by filling water in the suction pipe. The ump will not work if there is any air left in the suction pipe.



Centrifugal pump

Fig. 28. Centrifugal pump

14.4 Classification of centrifugal pump

Centrifugal pumps can be classified on the following basis;

a) Type of energy conversion: (a) volute, and (b) diffuser
b) Working head: (a) low lift, (b) medium lift, (c) high lift.
c) Number of impellers per shaft: (a) single stage and (b) multi-stage.
d) Relative direction of flow through impeller: (a) radial flow, (b) mixed flow and (c)axial flow.
e) Type of suction inlet: (a) single suction and (b) double suction.
f) Axis of rotation: (a) horizontal and (b) vertical.
g) Impeller types: (a) closed impeller, (b) semi-open impeller, (c) open impeller.
h) Method of drive: (a) direct coupled, (b) gear-driven and (c) belt-driven.

14.4.1 Volute pump

It is named as volute pump because the casing takes the shape of a volute whose cross-sectional area gradually increases from the tongue towards the delivery pipe (Fig.29). As the water flows from the eye towards the periphery and finally to the discharge side, more and more water is added. The cross-sectional area at any point is made proportional to the discharge flowing across the section. This keeps the velocity constant and helps to avoid the kinetic head loss which would otherwise occur if just a circular section is used. Almost all horizontal centrifugal pumps used for irrigation are of the volute type.

14.4.2 Diffuser or turbine pump

Impellers are surrounded by stationary guide vanes or diffusers and provide outlets with cross-section gradually enlarging towards the periphery (Fig.29). Whirling motion is imparted to the water by the impeller and then it flows through the guide vanes. As the cross-sectional area increases, velocity reduces and pressure is built up. In this type of pump, velocity head of the liquid leaving the impeller is more completely converted into pressure head. The efficiency of diffuser pump is slightly higher but due to complicated construction, the cost is higher. Generally horizontal turbine pumps are not commonly used. Vertical turbine pumps are most commonly used for pumping water from deep tube wells. The volute type pump is preferred for large capacity, low head conditions, where as diffuser type pump used for high head conditions. Most of the centrifugal pumps used for pumping water from shallow tubewells, lakes, streams etc. are horizontal axis centrifugal pumps.

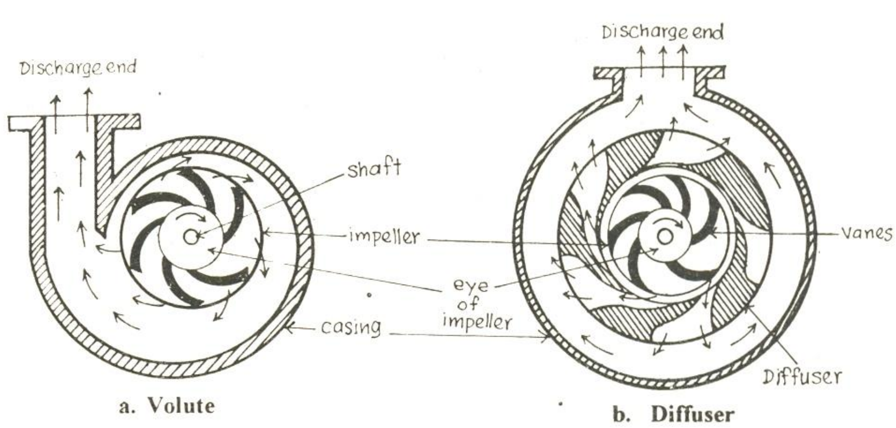


Fig. 29. Volute and diffuser type centrifugal pump

14.5 Components and accessories of centrifugal pump

The following are the important components and accessories of a pumping unit (Fig.30):

1. Impeller.
2. Impeller shaft.
3. Casing.
4. Stuffing box.
5. Suction pipe.
6. Foot valve.
7. Delivery pipe.
8. Delivery valve.
9. Bearings.

Impeller: It is a wheel or disc mounted on the dry shaft and provided with a no. of curved blades/ vanes. The impeller is fitted on the shaft with the help of suitable bearing. It is rotated at high speed with the help of mortar or an IC engine.

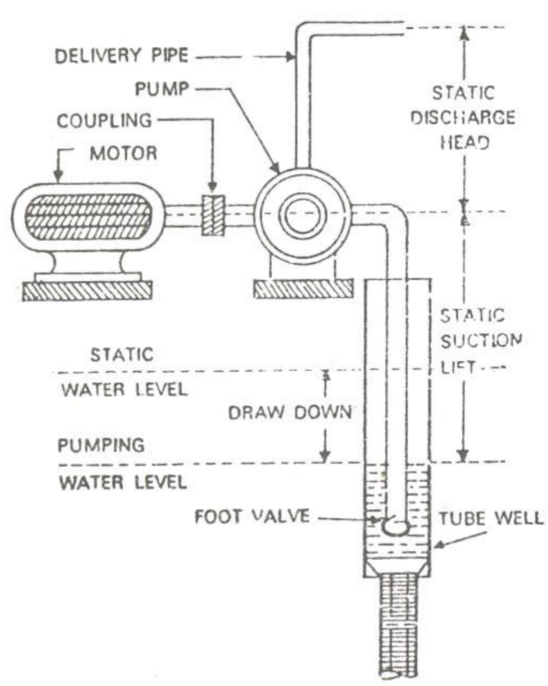


Fig. 30. Components of centrifugal pump

Types of impellers

Closed, Semi-open and Open impeller pumps

Depending upon the viscosity of the liquid and the solid matter content in the liquid, different types of impellers namely closed, semi-open and open types are used.

Open impeller

The impeller is not provided with any side wall or shroud (Fig.31). They are used to handle where water is mixed with sand, gravel, clay, pebbles and other solid materials. It is generally made of forged steel and it has a short life. These are suitable for dredging works.

Semi-open impeller

The impeller is provided with side wall or shroud on one side only (Fig.31). The number of vanes is reduced and their length is increased to reduce the chance of impeller clogging. Such impellers are suitable for pumping viscous liquids such as paper pulp, molasses, and sewage water containing foreign materials.

Closed impeller

The impeller is provided with side wall or shroud on both sides of the vanes (Fig.31). All ordinary centrifugal pumps used to pump clear irrigation water have closed impellers. This is suitable for handling non-viscous liquids free from foreign materials such as ordinary water, acids, oils etc.

The efficiency of semi-open impeller pump is lower than the closed impeller pumps and higher than the open impeller pump.

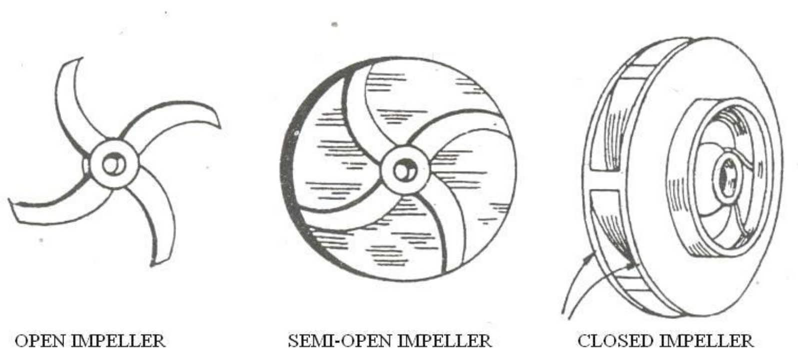


Fig. 31. Type of impellers

Casing: It is a spiral shaped cover having gradually increasing cross sectional area towards the discharge end. The casing receives water from the impeller and discharges it to the delivery pipe.

Suction pipe: It is a suitable pipe for limiting water from the well or stream. It is fitted with suitable foot valve with strainer.

Stainer with foot valve: It is a non return or one way type valve operating towards. The water will pass through the valve upwards and it won't allow water to move downwards. It is fitted at the bottom of the suction pipe which remains submerged in water. A suitable strainer is provided at the bottom of the foot valve to prevent floating bodies like leaves or wooden pieces from entering into suction pipe.

Stuffing box: It is a portion of casing through which the pump shaft extends and in which the packing and mechanical seal is placed to prevent the leakage.

Delivery pipe: Delivery pipe is a pipe used to deliver water from pump to the desired or delivery place.

Delivery valve: It is a regulating valve used on the delivery side of the pump. It remains closed at the start of the pump.

Bearings: Bearings are used to keep the shaft of the pump in correct position.

Couplings are most commonly used to connect pump shaft to motor or engine shaft.

Lecture 15

Pump characteristics - pump efficiencies, capacity calculation based on irrigation scheduling, power calculations of centrifugal pump.

15.0 Pump characteristics

A pump operates most satisfactorily under a head and at a speed for which it is designed. The operating conditions should therefore be determined as accurately as possible to select pumps well adapted to the particular conditions of operation.

Capacity: It is the volume of water pumped per unit time. It is generally measured in litres per second.

Suction lift: Suction lift exists when the source of water supply is below central line of pump.

Static suction lift: It is the vertical distance from the free suction water level to the central line of the pump (Fig.30).

Total suction lift: It is the sum of static suction lift, friction and entrance losses in the suction pipe.

Suction head: It exists when the source of water is above the central line of pump. This case normally exists in case of vertical turbine pumps (Fig.30).

Static suction head: It is the vertical distance from the central line of pump to the free water level in the well.

Static discharge head: It is the vertical distance between the centre line of the pump and the point of free delivery of water (Fig.30).

Static head: It is the vertical distance from suction water level to the discharge water level.

Static head = Static suction head + Static discharge head

Friction head: It is the energy or head required to overcome the resistance of the pipeline and fittings (including strainer, elbows, bends, tee joins, valves etc.) in the pumping system. Friction head exists on both the suction and discharge sides of a pump.

Total head: It is the energy imparted to the water by the pump.

Velocity head: It is the pressure expressed in metre of water required to create the velocity of flow.

Water horsepower (WHP): It is the useful horsepower expended in pumping water or theoretical horsepower required for pumping.

$$\text{WHP} = \frac{\text{Discharge in litres per second} \times \text{total head in m}}{76}$$

Where total head is the sum of static head, friction and velocity head.

Shaft horsepower (Shaft HP): It is the power required at the pump shaft.

$$\text{Shaft horsepower} = \frac{\text{Water horsepower}}{\text{Pump efficiency}}$$

Note: Shaft horse power is always greater than water horsepower.

Brake horsepower:

(i)With direct drive (If drive efficiency is 100%):

$$\text{Brake horsepower} = \frac{\text{Water horsepower}}{\text{Pump efficiency}}$$

(ii) With belt or other indirect drives:

When drive efficiency is not 100%

$$\text{Brake horsepower} = \frac{\text{Water horsepower}}{\text{Pump efficiency} \times \text{drive efficiency}}$$

Overall efficiency = Pump efficiency × drive efficiency

Horse power input to electric motor (Input HP):

$$\text{Input HP} = \frac{\text{Brake horsepower}}{\text{Motor efficiency}}$$

$$= \frac{\text{Water horsepower}}{\text{Pump efficiency} \times \text{Drive efficiency} \times \text{Motor efficiency}}$$

Kilowatt input to motor = $\dfrac{\textbf{BHP} \times \textbf{0.746}}{\text{Motor efficiency}}$

15.1 Discharge capacity of pump based on crop requirements

The pump discharge should meet the peak demand of water for the selected cropping pattern. The rate of pumping depends on the area under different crops, the water requirement of crops, rotation period (interval between two successive irrigations of a crop) and the duration the pump is operated each day. It may be computed by the following relationship:

$$q = \frac{Ay}{RT} \times \frac{1000}{36} = 27.78\frac{AY}{RT}$$

Where, q = rate of discharge of pump, lt/s

A = area of land under the crop, ha

Y = Depth of irrigation, cm

R = Rotation period, days

T = Duration of pumping, hrs/day

Example: A farmer wishes to have his own pump set for the following cropping pattern to be followed in his holding of three hectares and his brother's holding of 2 ha. Calculate the right size of the centrifugal pump he should have.

Solution:

Season	Crop	Area to be irrigated, ha	Intensity of irrigation, cm	Rotation period, days	Period of work, hrs/day
Rabi	1.Wheat	2.0	7.5	12	10
	2.Cotton	0.4	7.5	20	10
	3. Vegetables	0.5	8.0	12	11
	4.Mustard	2.2	5.0	40	10

Discharge rate of the pump = $27.78\frac{AY}{RT}$

Wheat:

A = 2.0, y = 7.5, R= 12, T = 10

q = $27.78\frac{AY}{RT} = 27.78\times\frac{2\times7.5}{12\times10}$ = 3.47 lt/s

Cotton:

A = 0.4, y = 7.5, R= 20, T = 10

q = $27.78\frac{AY}{RT} = 27.78\times\frac{0.4\times7.5}{20\times10}$ = 0.42 lt/s

Mustard:

A = 0.5, y = 8.0, R= 12, T = 11

q = $27.78\frac{AY}{RT} = 27.78\times\frac{0.5\times8.0}{12\times11}$ = 0.84 lt/s

Wheat:

A = 2.2, y = 5.0, R= 40, T = 10

q = $27.78\frac{AY}{RT} = 27.78\times\frac{2.2\times5.0}{40\times10}$ = 0.76 lt/s

Discharge capacity of the pump = 3.47+0.42+0.84+0.76 = 5.49 lt/s

Problem 2: What are the power requirements for pumping 450 lt/min against a head of 50 m, assuming a pump efficiency of 65%. What size electrical motor is required to operate the pump.

Solution:

$$\text{WHP} = \frac{\text{Discharge in litres per second} \times \text{total head in m}}{76}$$

Discharge = 450 lt/min = $\frac{450}{60}$ **= 7.5 lt/s**

Total head = 50 m

WHP = $\frac{7.5\times50}{76}$ **= 4.93**

$$\text{Shaft horsepower} = \frac{\text{Water horsepower}}{\text{Pump efficiency}} = \frac{4.93}{\frac{65}{100}} = 7.59 \cong 7.6$$

7.5 HP size electrical motor is required to operate the pump.

Example 3: A pump lifts 45,000 lts/hr against total head of 18 m. Compute the Water horsepower. If the pump has an efficiency of 65%, what size of prime mower is required to operate the pump? If a direct driven electrical motor, having an efficiency of 80%, is used to operate the pump, compute the cost of electrical energy in a month of 30 days. The pump is operated for 8 hours daily for 30 days. The cost of electrical energy is Rs. 2.50 per unit.

Solution:

Discharge = 45000 lts/hr = $\frac{45000}{3600}$ = 12.5 lts/s

Total head = 18 m

WHP = $\frac{12.5 \times 18}{76}$ = 2.96

Output power of motor = Input power of pump

SHP = $\frac{2.96}{\frac{65}{100}}$ = 4.55

Since the pump is direct driven, the shaft horsepower is the same as the brake horsepower of the prime mower. An electric motor of 5 HP is suitable.

Kilowatt input to motor $= \frac{BHP \times 0.746}{Motor efficiency}$ = $\frac{5 \times 0.746}{0.8}$ = 4.66 kW

Total energy consumption per month = 4.66 × 8 × 30

=1118.4 Kilowatt-hours

(Electrical units)

Cost of electrical energy per month = 1118.4 × 2.50 = Rs. 2796=00

Lecture 16

Deep well pumps – turbine and submersible pumps, installation and working principles of these pumps.

16.0 Vertical turbine pump

A vertical turbine pump, also called a deep well turbine pump, is a vertical axis centrifugal or mixed flow type pump. The vertical turbine pump operates on the centrifugal principle but differs from ordinary centrifugal pump because the water thrown from the periphery of the impeller blades is directed upward by stationary guide vanes surrounding the impeller. The gradually enlarging vanes guide the water to the casing and the kinetic energy is converted into pressure. For high lifts, several impellers placed in series with each successive bowl attached directly one above or below. The bowl are so designed that the water discharge from a lower impeller is directed vertically upward to the centre of the next higher impeller. The vertical turbine pump consists of number of rotating impellers are arranged in series to create high head. Total head developed is proportional to the number of impellers (stage). The vertical turbine pumps are specially adapted to tube wells, where the pumping water level is below the practical limits of a volute centrifugal pump. These are adapted to high lifts and have high efficiencies under optimum operating conditions. However, higher initial cost and difficult to repair and install as compared to volute centrifugal pump. The maximum impeller diameter of the turbine pump is fixed by the diameter of the bowl, which in turn is limited by the well diameter. The well diameter is small, generally ranges from 200 to 500 mm.

16.1 Pump construction:

The turbine pump has three main parts (Fig.32): the pump element, discharge column and the discharge head.

1) The pump element: It is made up of one or more bowls or stages. Each bowl assembly consists of an impeller, a diffuser and a bearing. It has a screen (or) strainer fixed to its bottom to keep course sand and gravel from entering the pump. Impellers used are either closed a semi-open type.

2) The discharge column: The discharge column connects the bowl assembly and pump head assembly and conducts (discharge head) water from the bowl assembly to the discharge column. It consists of the discharge (or) column pipe and the line shaft with its coupling and bearings.

2) Discharge head: The discharge head assembly consists of the base from which the discharge column, bowl assembly and shaft assembly are suspended. The discharge head elbow directs the water into the delivery piping system.

The pump shaft is the centre of the discharge column pipe surrounded by the discharge water. The shaft is usually made of stainless steel rod of 3 m long each and connected by sockets. The turbine pump shaft may be either oil lubricated or water lubricated. The bearings of the oil lubricated shaft are enclosed in a small diameter cover pipe. But a part of the oil gets mixed with water. Therefore, oil lubricated shafts should not be used for turbine pumps used to supply water for domestic use. Well producing fine soil particles (or) clay, oil lubricated shafts used for turbine pumps are preferred.

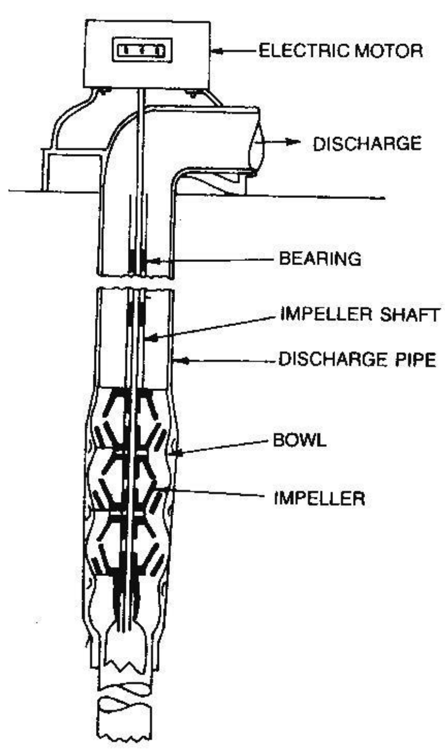


Fig. 32. Vertical turbine pump

16.2 Installation

The vertical turbine pump is driven by connecting it directly to a vertical type electrical motor installed on the ground at the top of the impeller shaft. When installed, the deep well turbine pump must be in correct alignment between the pump and power unit. The pump should be so aligned that no part of it touches the well casing. The pump must be mounted on a good foundation so that the alignment between pump and power unit, pump and well casing will be always maintained. Concrete foundations are preferred. The well strainer should be at least 1.5m above the bottom of the well to avoid sucking sand. The motor is suitable protected against water. The complete pumping unit is lowered into the well below the pumping water level for satisfactory performance of the turbine pump.

16.3 Submersible pumps

A vertical turbine pump close coupled to a small diameter submersible electric motor is termed a submersible pump, in which both motor and pump are installed inside the well (Fig.33). The motor is fixed directly below the intake of the pump. The pump element and the motor operate entirely submerged. The submersible pump has special advantage in a location where theft is a problem. The principal advantage of the submersible pump is that it can be used in a very deep tube well where a long shaft would not be practical. These pumps are also less affected by deviations in vertical alignment of wells. As the submersible pump has no above-ground working parts, it can be used where flooding may be a hazard. It is suitable for installation in small diameter wells of up to a minimum 100 mm. In India, private tube wells constructed by the farmers are of shallow type with their diameters in the range of 75 to 100 mm. They are generally operated by centrifugal pumps installed on the ground surface. The performance characteristics of the submersible pump are similar to the vertical turbine pump.

16.4 Pump construction

It consists of a Pump and motor assembly, a head assembly, a discharge column and a water proof cable to supply power to the submerged motor.

Pump element:

The construction of the pump element is similar to the vertical turbine pump. The propelling shaft, usually made of stainless steel, is very short and on which the bronze impellers are mounted. The impellers may be closed semi-open or open. The closed impeller is generally used where it is necessary for the pump to develop high pressure. Water enters the pump through a screen located between motor and the pump.

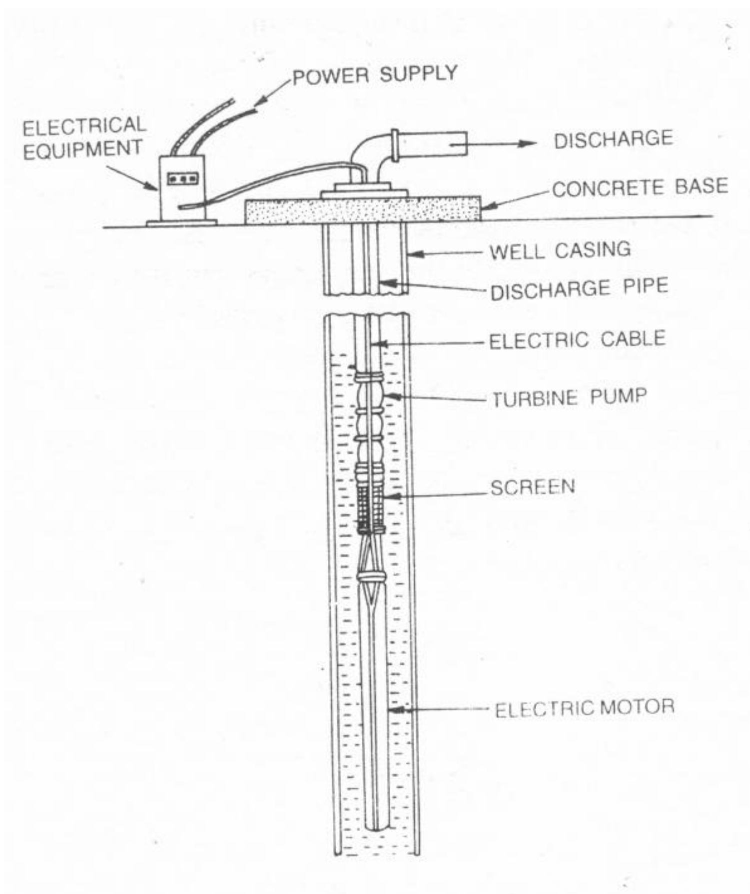


Fig. 33. Submersible pump

Electric motor

The submersible electric motor has the same diameter as the pump bowl, but it is longer than the ordinary motor. These motors usually are of dry type. The dry motor is enclosed in a steel case filled with a light oil of high dielectric strength. A mercury seal placed directly above the armature prevents oil leakage or water entrance at that point where the drive shaft passes through the case to the impellers. Submersible electrical motors are designed for long service without attention. If the motor failure occurs, the entire pump must be lifted from the well.

The stator windings are continuous for the whole length of the motor. The electrical cables, leading from the motor to the starting box on the ground surface, are water-proof and are placed outside the discharge pipe.

16.5 Installation

A concrete base is constructed on the surface which covers the well casing and the head assembly rests on it. The head assembly is connected to the pump with the help of the discharge pipe. The pump assembly should be sufficiently lowered inside the well by using a long pipe so that it is always submerged. No pump-house is required as the pump and motor assembly remains in the well. The control panel consisting of the switch, meter, and starter are enclosed in a water-proof box.

Lecture 17

Measurement of irrigation water – importance. Methods of measuring water – volumetric and area, velocity method.

7.0 Water measuring devices

Day to day water is becoming a costly input in agriculture and other enterprises. The knowledge of soil, water and plant is highly essential to apply water to the crops precisely as per required quantity. The planning of cropping system of irrigation project and design of irrigation method is depends upon the available discharge. Most of the drainage projects and public health engineering water supply system require discharge measurement. The measurement of discharge is also essential, if the government agencies desire to charge the water rates to the farmers on volume basis.

7.1 Units of measurement

Water can be measured on volume basis if it is at rest or on discharge basis if it is in motion. Volume is measured in litres, milliliters, ha-cm, ha-m, cubic metre etc., depending upon the magnitude and purpose of measurement. Large quantity of water present in a reservoir may be measured in m^3. Volume of water applied to a field can be suitably measured as ha-cm. Water in motion or discharge can be measured as litres per second (lps), litres per minute (lpm), cubic metre per hour (m^3/hr) etc. It is the volume of water passing through a section per unit time.

7.2 Methods of measuring water

Different methods are used for measurement of water and they depend on the size of the stream and the available facility. The commonly used methods are (i) volumetric method, (ii) velocity-area method in which velocity is measured by using float, current-meter etc., (iii) measuring structures like weir, orifice, parshall flame etc.

7.2.1 Volumetric method of water measurement

This is the most simple and accurate method and can be used to measure small discharge flowing through a channel or a pipe. In case of flow through a channel, some drop is necessary to allow the container to be placed below the channel level for collection of the discharge. Time to fill a known volume of the container is noted with the help of a stop watch. Discharge is obtained by dividing the volume of fill by the required time (Fig.34). For example, if a 210 litres capacity barrel is filled in 30 seconds, the discharge is 7 lps.

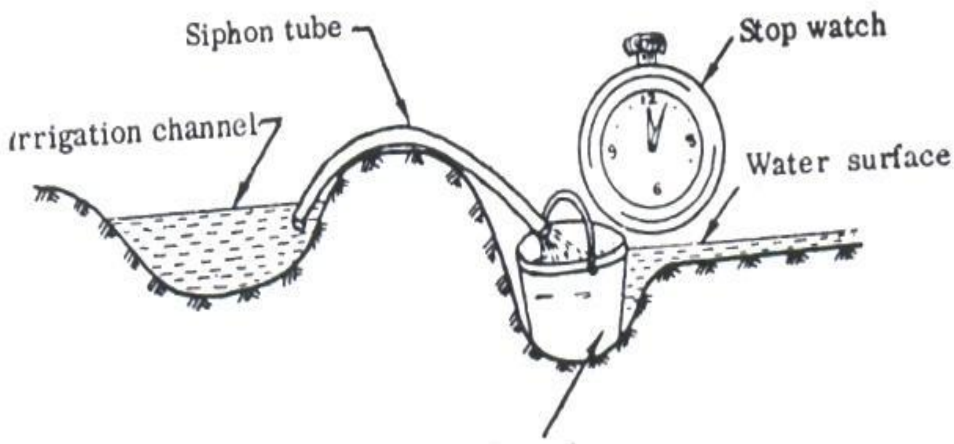


Fig. 34. Volumetric method of water measurement

7.2.2 Float method

This is one of the simplest methods and gives appropriate velocity of flow in a channel if no other means is available. Any object that flows in water but does not obstruct wind or get carried away by it, can be used as a float. A dry wood of about 1 cm^3 size serves the purpose best. A straight section of the channel of about 30 meter length is selected such that the cross-section is almost uniform through the length. The float is allowed to move from the upstream to the downstream end and time taken to move this 30 meter distance is measured. Several measurements are taken and the average time is noted. The distance divided by the time gives the average surface velocity. The surface velocity is always higher than the average stream velocity. Therefore, the surface velocity is multiplied by a factor of 0.85 to get the average velocity.

The cross-sectional area of the stream is measured at least in 3 places and the average is taken. The average velocity is multiplied by the average cross-sectional area gives the discharge:

$$Q = A \times V$$

Where, Q= discharge, m^3/s,

A= cross-sectional area, m^2

V= average velocity of flow, m/s.

Lecture 18

Direct discharge methods - water meter, weirs, orifices.

18.1 Current meter method

Two types of current meters namely; the cup type (Fig.35) and the propeller type (Fig.36) are used for measurement of velocity in irrigation channels, flumes, streams or rivers. The cup type current meter consists of a wheel having several cups and the propeller type consists of vanes or propeller attached to a rod. When the meter is placed in flowing water, the velocity of water rotates the wheel or the vane. In case of shallow streams, the current meter is suspended from a rod and for measurement in deep water, a cable is used to suspend the meter. In large rivers, a boat is used to take readings inside the river. Sometimes the current meter is suspended from a bridge if available. As the wheel rotates, the revolution is recorded in a counter. A calibration chart or a graph gives the relationship between the revolution per minute and the velocity. The average velocity is obtained by taking the average of the velocities at 0.8 and 0.2 of the depth from the top. In case of shallow stream, if it is not possible to take the reading at 0.8 of the depth from the surface, only one reading may be taken at 0.6 of the depth from the surface.

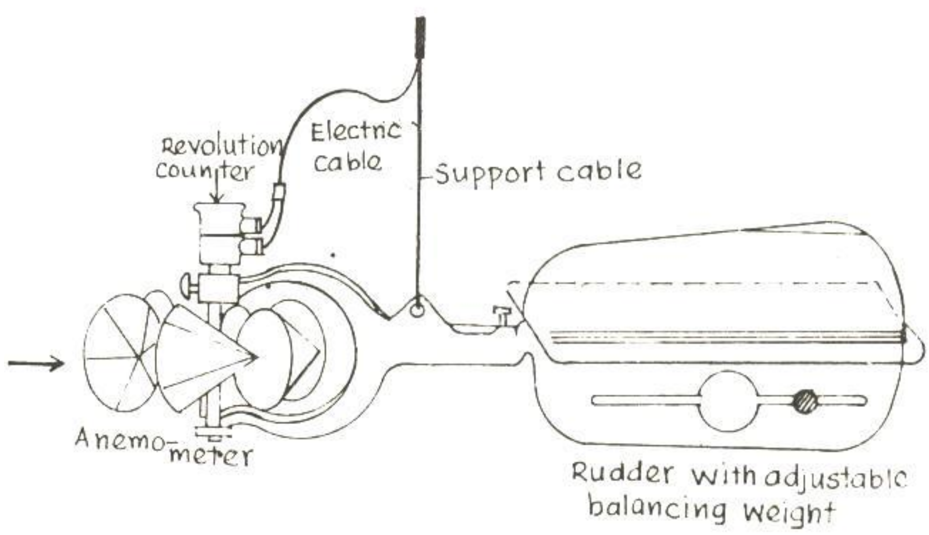


Fig. 35. Cup type current meter

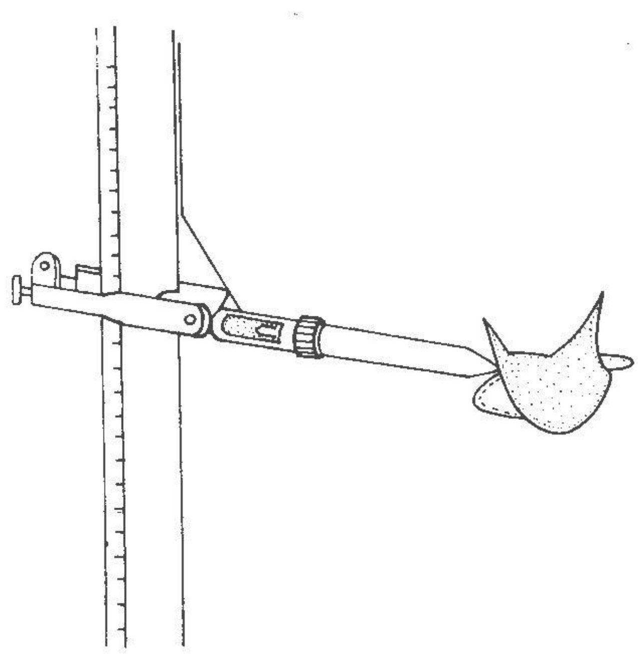


Fig. 36. Propeller type current meter

18.2 Weirs

A weir is a notch or opening of some definite shape installed on a channel or a stream through which water falls. May materials like wood, concrete, mild steel, rigid PVC etc. can be used for construction of a weir. Mainly a cut on a sheet metal is used for fabrication of weirs, to be installed at various locations in a channel. Weirs can be classified as (i) broad crested and (ii) sharp crested weirs. The sharp crested weir is mostly used for measurement of irrigation water. It is nothing but, a weir with thin edge such that the sheet of water flowing over it has the minimum contact area with it.

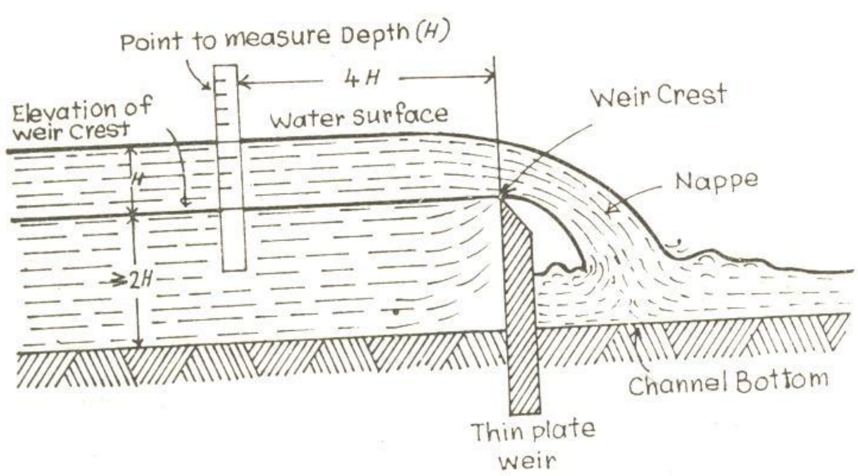


Fig. 37. Weir parts

The bottom most portion of the weir in touch with the water is called the ***weir crest***. The sheet of water flowing over the weir is called the **nappe (Fig.37)**. The top surface is the upper nappe and the bottom surface is the lower nappe. The depth of flow over the crest is known as head (H). It is measured at a minimum distance of 4 H upstream from the crest. The horizontal distance from the end of the crest to the side of the channel is known as **end contraction.** If both ends of the crest are away from the sides of the channel, then there are two end contractions. If the length of the crest is same as the width of the channel, then there is no end contraction. The weir is said to have free flow condition, if the surface of water downstream is below the crest level so that the nappe is surrounded by air. If the downstream water level is higher than the weir crest level then it is a submerged flow condition.

Apart from being classified as sharp crested and broad crested, weirs can also be classified according to the shape of the notch.

18.2.1 Rectangular weir

The rectangular weir (Fig.38) is used to measure high discharge. Its crest is horizontal and the sides are vertical. In case, the crest length is same as that of the channel width, it is known as suppressed weir, otherwise contracted weir.

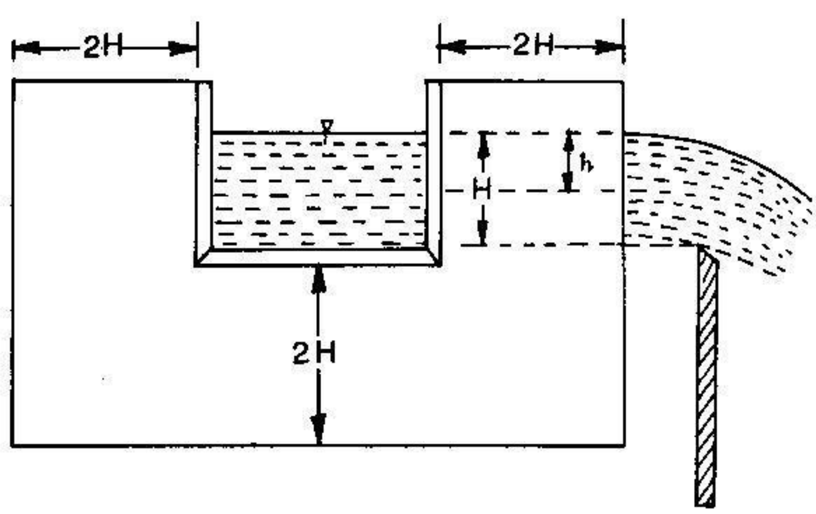


Fig. 38. Rectangular weir

18.2.3 Trapezoidal weir

The trapezoidal weir (Fig.39) has a horizontal crest and the slides slope outward to give the notch a trapezoidal cross-section Commonly a side slope of 1 horizontal to 4 vertical is used and it is named as **cipoletti weir.** It does not require any correction for end contractions and is used for measurement of medium discharges. Normally it is a sharp crested weir.

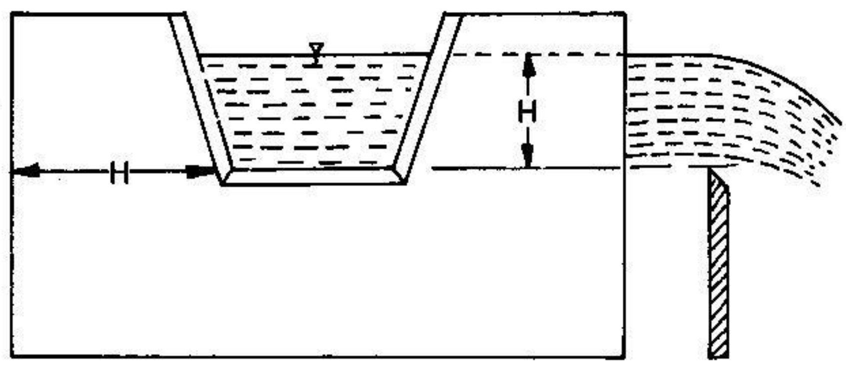


Fig. 39. Trapezoidal weir

18.2.4 Triangular or V-notch weir

It is used to measure small to medium discharges. The 90º V-notch weir (Fig.40) is used to measure low discharges accurately. Thus the sides of the notch make an angle 45 º with the vertical which gives a slope of 1 horizontal to 1 vertical.

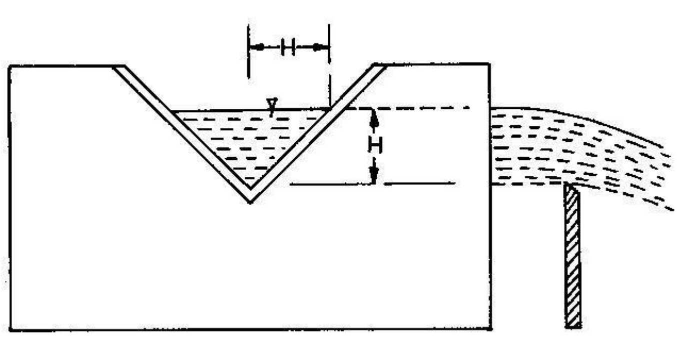


Fig. 40. V-Notch weir

Discharge formulae for weirs. The basic equation for calculating the discharge through a weir is

$$Q = CLH^m$$

When Q is the discharge, C is the coefficient which depends upon the nature of the crest and approach condition, L is the length of the weir crest, H is the head on the crest and m is an exponent which depends upon the type of weir opening.

The formula for calculating discharge through rectangular weirs with *n* number of end contractions is

$$Q = 0.0184 (L - 0.1 nH) H^{3/2}$$

Where Q is the discharge in litre per second., L is the length of crest in centimeter and H is the head on the crest in centimeter.

In case of suppressed weir, number of end contraction is zero and obviously equation is changed to

$$Q = 0.0184 LH^{3/2}$$

The formula for calculating discharge over a Cipoletti weir is

$$Q = 0.0186 LH^{3/2}$$

In case of 90 ° triangular weir, the discharge equation is

$$Q = 0.0138 H^{5/2}.$$

18.3 Orifices

An orifice (Fig.41) is an opening in a bulk-head with closed perimeter usually circular or rectangular cross-section through which water flows. For measurement of water, orifices are fabricated by making an accurate cut of proper size and shape in a mild steel sheet, aluminum plate etc. Proper machining is done to have a sharp edge through which water flows. The orifice flow formulae can be applied only when the orifice flows fully. If it flows partially, it behaves like a weir.

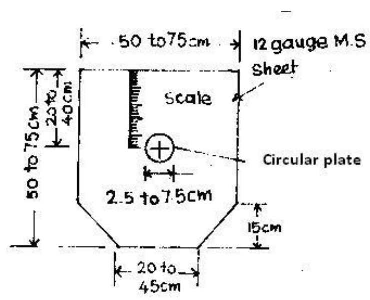


Fig. 41. Orifice plate

If the downstream water level is lower than the bottom of the orifice opening, the water jet discharges freely into the air and then it is said to have a free discharge. If the orifice discharges under a condition of submergence, it is called submerged weir. In case of free discharge, the depth of water on the upstream side of the orifice that causes the flow is called the **head.** In case of submerged office, the difference of water level in the upstream and downstream sides is known as the head. No drop as in case of a weir is required for installation of orifices and therefore, this can be used more widely. The submerged orifice generally has a rectangular shape.

The discharge through an orifice can be calculated by the following formula:

Q = $C_d \times 10^3 \times a\sqrt{2gh}$

Q = discharge, litres per second

C_d = Coefficient of discharge, usually taken as 0.62 for sharp edged orifices

a = Cros-sectional area of orifice, cm^2

g = acceleration due to gravity, cm/s^2

H = head of water causing the flow, cm

Lecture 19

Parshall flume - installation of these devices, conditions for weir installation.

19.0 Parshall flume

Parshall designed this flume in which the discharge is measured by allowing the stream of water to flow through a converged section of a flume with a depressed bottom. The loss of head which is very small due to this flow condition is measured accurately to obtain the discharge. It consists of (i) a converging upstream section, (ii) a throat which is a constricted section and (iii) a diverging downstream section (Fig.42). The floor of the upstream covering section is level and the walls converge towards the throat. The floor of the throat is inclined downwards, but the walls are parallel. The floor of the diverging section slopes upwards and the walls diverge downstream. The throat width specifies the dimensions of the parshall flume.

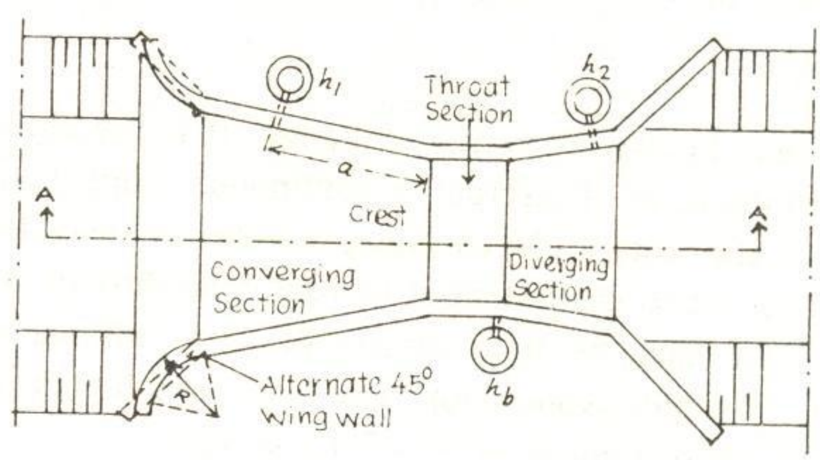


Fig. 42. Parshall flume

The parshall flume can be constructed of G.I. sheet, aluminum sheet, M.S.sheet, brick masonry, reinforced concrete or timber. Flumes made of G.I. or aluminum sheets are easily portable. Brick masonry and concrete flumes are permanently constructed in the channels. Stilling wells should be constructed at the side to take measurements.

19.1 Conditions for installation and limitation of use of weirs

(i) The weirs require a considerable loss of head which is achieved through drops in the channel. Such drop is often not available.

(ii) The weir should be set at the lower end of a long pool sufficiently wide and deep give an even and smooth flow and the velocity should not exceed 15 cm/s.

(iii) The crest of the weir box should be level.

(iv) The face of the weir should be vertical.

(v) The centre of the weir box should be parallel to the direction of flow.

(vi) For accurate measurements, the depth of water over the crest should not be less than 5 cm.

(vii) The crest should be high enough to allow free flow condition.

(viii) The scale used for measurement of head should be located at a distance of about 4 times the approximate head.

(ix) To prevent downstream erosion by the falling stream, proper protection should be given to the downstream channel.

(x) Weirs are not useful for measurement of water carrying silt which gets deposited and affects the accuracy.

(xi) The upstream edge should be sharp so that the over falling water touches the crest at only one point.

Lecture 20

Discharge calculation of rectangular and triangular weirs, advantages of parshall flume over the weirs.

Example1:

A rectangular weir of crest length 30 cm is installed at the centre of a rectangular channel of 50 cm width. The height of water above the weir crest is 10 cm. Calculate the discharge.

Solution:

Data given: H = 10 cm;   L = 30 cm

Number of contractions, n = 2

$Q = 0.0184\ (L - 0.1\ nH)\ H^{3/2}$

$Q = 0.0184 \times (30 - 0.1 \times 2 \times 10) \times 10^{3/2}$

$= 0.0184 \times 28 \times 31.62 =$ **16.29 lps**

Example 2:

A cipoletti weir of 50 cm crest length is installed in a straight channel and the head over the crest of the weir is 15 cm. Calculate the discharge.

Solution:

Data given

L = 50 cm; H = 15 cm

The formula for calculating discharge over a Cipoletti weir is

$Q = 0.0186\ LH^{3/2}$

Q = $0.0186 \times 50 \times 15^{3/2}$

= 54.03 lps

Example 3:

A circular orifice has a diameter of 10 cm and the depth of water on the upstream side is 17 cm above the bottom of the orifice. If the coefficient of discharge is 0.61, calculate the discharge for free flow condition.

Solution:

Data given

H = Head above the centre of the orifice = 17 -5 = 12 cm

$a = \frac{\pi}{4} \times (10)^2 = 78.54$ cm²

The discharge through an orifice can be calculated by the following formula:

$Q = C_d \times 10^3 \times a\sqrt{2gh}$

Q = $0.61 \times 10^{-3} \times 78.54 \times \sqrt{(2 \times 980.6 \times 12)} = 7.35$ lps

20.0 Advantages of parshall flume over the weirs

There are several disadvantages for measurement of flow by weirs and orifices because they require considerable head loss, get silted up easily and the accuracy of the measurement is affected. There are several other limiting conditions for installation, most of these disadvantages of weirs and orifices are largely overcome by use of parshall flumes.

20.1 Advantages of parshall flume

(i) The parshall flume does not require any substantial drop in the channel bed for its installation.

(ii) It does not require a pond above the flume as the velocity of approach has no effect on its performance.

(iii) The flume does not get clogged due to suspended silt or floating debris.

(iv) The parshall flume can be constructed in various sizes to measure a wide range of discharges.

(v) Partly submerged flumes also allow accurate measurement of discharge.

20.2 Disadvantages of parshall flume

i) The parshall flume cannot be combined with a turnout from a canal or storage pond.

ii) It is more expensive.

iii) The construction is difficult.

iv) Only the small size made of sheet metal is portable.

v) Correct selection of the size and proper setting for precise measurements require some expertise.

Lecture 21

Water conveyance systems - open channel, definitions of wetted perimeter, hydraulic radius, hydraulic slope, area of cross section and free board. Manning's formula for estimating mean velocity, side slopes of channels for different soils.

21.0 Open channel

The most common type of water conveyance system is the open channel. In the open channel, water flows with a free water surface. All irrigation canals, drainage channels, natural streams can be termed as open channel. If a pipe flows partially full, it also behaves as an open channel. Channels can be either (i) unlined channel or (ii) lined channel. Unlined channels are simply excavated in the natural soil and no lining is provided. These channels are cheap and easy to construct. But huge quantity or water especially in light textured soil is lost due to seepage. There may be growth of weeds and velocity of flow reduces. As a result larger cross-sections are required to carry the discharge. The lined channels require larger initial investment. But many times the benefit accrued is more than the capital recovery factor due to the additional investment. Open channel flow is divided into (i) uniform flow and (ii) varied flow.

Uniform flow: The flow is said to be uniform if the velocity and depth of flow are constant throughout the length of the channel considered. The water surface remains parallel to the channel bottom. This is possible only in case of a prismatic channel i.e. a channel with uniform cross section throughout.

Varied flow: When the velocity or depth changes along the channel length it is known as varied flow or non-uniform flow. In a non-prismatic channel varied flow occurs.

Steady flow: If the velocity and depth of flow remain constant at a cross-section with time, the flow is said to be steady. Steady flow can be steady uniform flow or steady varied flow.

Unsteady flow: If the velocity and depth of flow change with time at a cross-section, the flow is called unsteady. Unsteady flow cannot be uniform. Therefore unsteady flow refers to unsteady varied flow only.

21.1 Geometric elements of an Open channel: Fig. 43 shows the elements of an open channel.

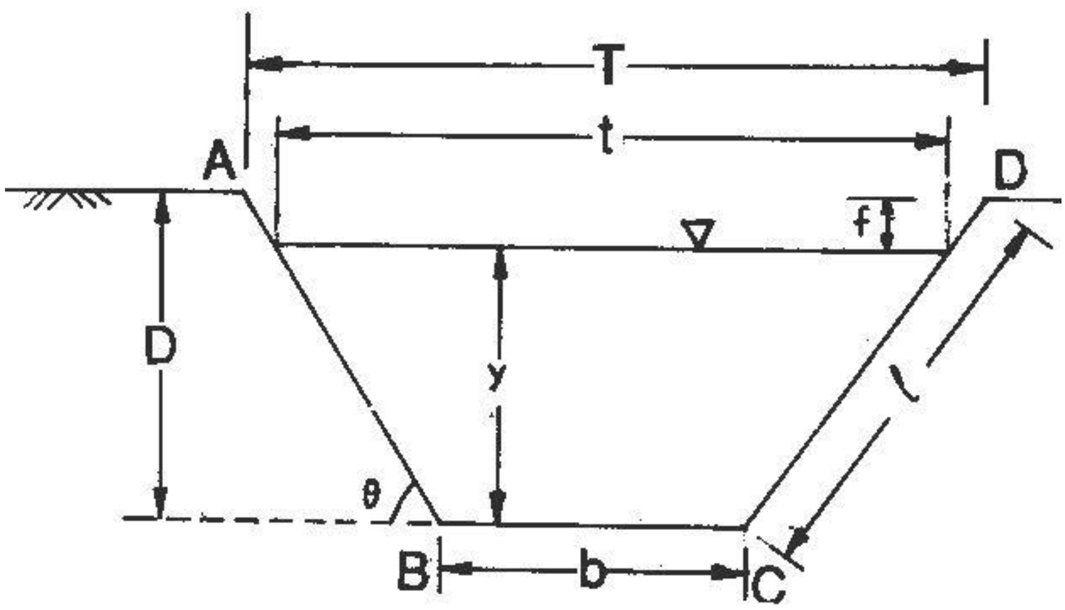


Fig. 43. Elements of open channel

b = bottom width of channel

T = top width of channel

t = top width of water surface

D = total depth of channel

y = depth of water

l = wetted side of the channel

Ø = angle between the slopping side and the horizontal

f = free board

Then the following geometric elements are defined:

Area of cross-section: It refers to the area of the wetted section of the channel in case of a trapezoidal section.

$$A = \left(\frac{b+t}{2}\right)\times y$$

Wetted perimeter: It is the sum of the lengths of sides and bottom that are in contact with water.

$$P = b + 2l$$

Hydraulic radius: It is the ratio between the cross-sectional area of flow and the wetted perimeter.

$$R = \frac{A}{P}$$

Hydraulic slope: Hydraulic slope or friction slope S_f is defined as the ratio of the drop of head (h) between two channel sectors located at a distance "x"

$$S_f = \frac{h}{x}$$

Freeboard: It is the vertical distance between the top of the channel wall and maximum possible water level in the channel. The freeboard (f) is required as a safety measure against overtopping due to wave action or other unforeseen reasons.

21.2 Computation of Discharge through Open Channels

The discharge through an open channel is given by:

$$Q = A\,V$$

Where, Q = discharge m^3/s

A = cross sectional area of flow m^2

V = average velocity of flow m/s

The velocity is calculated by using different formulae.

Chezy's formula: $V = C\sqrt{RS_f}$

Where, V = velocity of flow, m/s

C = Chezy's roughness coefficient

R = hydraulic radius, and

S_f = friction slope.

Manning's formula: $V = \frac{1}{n} R^{2/3} S_f^{\ 1/2}$

Where, n = Manning's roughness coefficient.

Side slopes of channels should be designed to suit the soil conditions. The slopes should not be steeper than the angle of repose of the type of material through which the channel is constructed. Permanent irrigation channels should not usually have side slopes steeper than **1 ½ to 1**. In **stiff clay**, steep slopes up to **½ to 1** are permissible. **Loose sand** should have flat slopes of about **2 to 1**. The natural slope of the land is usually the deciding factor in determining the channel bed slope. The steeper the channel, more will be the velocity and more will be the discharge for the same cross section. But excessive gradients produce very high velocities, which cause erosion.

Normally, a channel should have slope about 0.1%. Silting may takes place in the channel if the slope is less than 0.05%. Where earth channels are to be used on steep slopes, it is necessary to control the gradients and thus the velocity by using drop structures or by building up the channel bed.

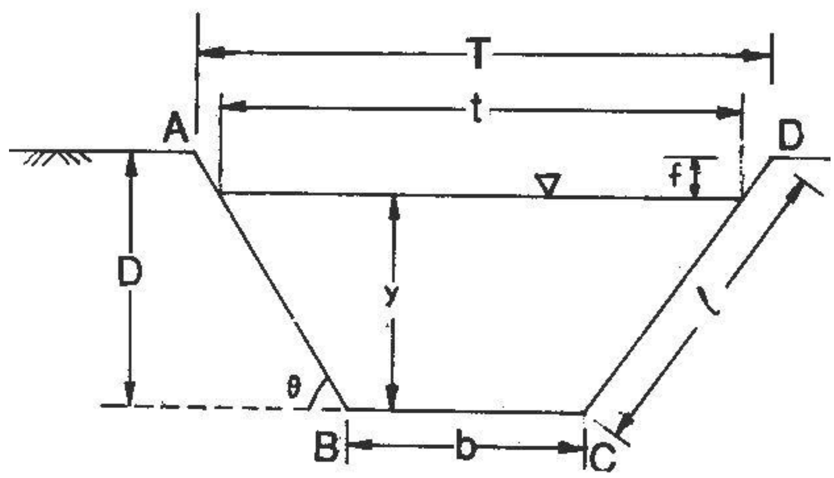
Lecture 22

Capacity calculations of open channels

22.0 Capacity calculations of open channels

Problem 1: Assume an earthen channel on a grade of 0.1%, depth of water 1.2 m, bottom width 60 cm and side slope is 1:1. Calculate the velocity of flow and the carrying capacity of channel. The value of Manning's coefficient (n) is 0.04.

Solution:



y = depth of water = 1.2 m

l = wetted side of the channel = $\sqrt{(1.2)^2 + (1.2)^2}$ = 1.7 m

b = bottom width of channel = 60 cm = 0.6 m

t = top width of water surface = 1.2 + 0.6 + 1.2 = 3.0 m

Wetter perimeter (P) **=** 1.7 + 0.6 + 1.7 **= 4.0 m**

Area (A) = $\left(\frac{0.6+3}{2}\right)\times 1.2$ **= 2.16 m²**

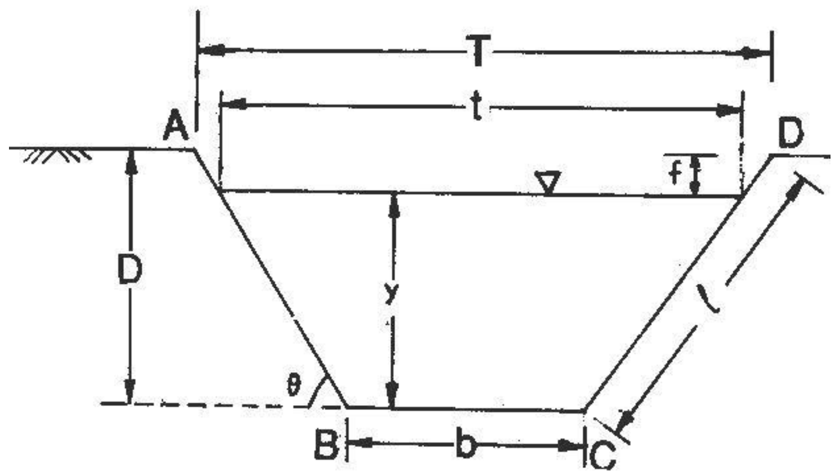
Hydraulic radius (R) = $\frac{2.16}{4}$ **= 0.54 m**

Velocity (V) = $\frac{(0.54)^{2/3}\times(\frac{0.1}{100})^{1/2}}{0.04}$ **= 0.524 m/s**

$\therefore$ Carrying capacity (Q) **=** 2.16 ×0.524 **= 1.132 m³/s**

Problem 2: A Trapezoidal earthen channel is constructed with a bed slope of 1 in 3500. The depth of water flow is 80 cm, bottom width is 2 m and side slope is 2:1. Calculate the velocity of flow and the discharge by using Manning's formula. The value of Manning's coefficient (n) is 0.04.

Solution:



y = depth of water = 80 cm = 0.8 m

l = wetted side of the channel = $\sqrt{(0.8)^2 + (1.6)^2}$ = 1.7 m

b = bottom width of channel = 2.0 m

T = top width of water surface = 1.6 + 2.0 + 1.6 = 5.2 m

Wetter perimeter (P) = 1.7 + 2.0 + 1.7 **= 5.4 m**

Area (A) = $\left(\frac{2.0+5.2}{2}\right)\times 0.8$ **= 2.88 m²**

Hydraulic radius (R) = $\frac{2.88}{5.4}$ **= 0.53 m**

Velocity (V) = $\frac{(0.53)^{2/3}\times(\frac{1}{3500})^{1/2}}{0.04}$ **= 0.277 m/s**

$\therefore$ Carrying capacity (Q) = 2.88 ×0.277 = **0.798 m³/s**

Lecture 23

Underground pipeline, advantages of earthen channels, disadvantages, type of pipes recommended for underground pipeline.

23.0 Lined and unlined channels

Channels without artificial lining of bed or sides are called earth channels.

The advantages of earth channels are:

(i) They are understood and accepted by the farmers

(ii) They can be built and maintained by unskilled persons

(iii) They require no special equipment or materials

The **low initial cost** constitutes the major advantage of earth channels.

The disadvantages of earth channels are:

(a) Excessive seepage losses

(b) Low velocities due to retardance of flow by rough surfaces

(c) Susceptibility to erosion and therefore, relatively large cross-sectional areas are required

(d) Danger of breaks due to erosion and burrowing animals

(e) Growth of aquatic weeds which reduce velocity

(f) High labour requirements for maintenance.

Earth channels should be built with stable side slopes and with banks strong enough to carry the required flow of water safely. Excessive velocity of water in earth channels causes erosion. Very few natural materials will stand velocities in excess of 1.5 m per second. Permissible velocities in earth channels are given below:

Type of soil	Maximum velocity, cm/s
Loamy sand	45
Sandy loam	60
Loam, silt loam and silt	75
Clay loam	90
Gravel soil and clay	100

The major disadvantage of earth channel is excessive seepage losses, is often a problem in irrigated areas. Extreme cases, in sandy soils and fields infested with rodents and burrowing animals, it is very difficult to convey water even through a short distance. Central Water and Power Commission made a study and concluded that, as much as 71% of the irrigation water may be lost in a completely unlined channel. Hence, it is highly essential to provide lining to the irrigation channels to serve the following purposes:

a) Reduces or eliminates water loss due to seepage
b) Prevents weed growth and increases the carrying capacity of water
c) Provides safety against breaks
d) Prevents scouring of the channel
e) Reduces labour requirement for maintenance of the channel
f) Discharge increases due to reduction of roughness coefficient,
g) Reduced drainage problem
h) Being non-erodible, best hydraulic section can be designed.

If the cost of water production is not high and seepage loss is not excessive in a location, the farmer may not go for lining. Before going for lining, the following two important factors should be taken into consideration: (i) annual cost for lining and (ii) annual cost of water saved.

23.1 Materials for channel lining

The most common materials for channel lining include concrete, stone or brick masonry, rock masonry, clay tiles, pre-cast RCC sections, asphalt membrane, synthetic rubber membrane, agri-film etc. The choice of the material depends upon the initial cost, life of the material, discharge and size of the canal, economical considerations, value of the crop and fund & manpower availability for lining. Well mixed and well made cement concrete lining and also single layer bricks or stones laid in cement or lime mortar provide virtually water-proof channel lining.Earth materials can be used for lining with varying degrees of efficiency, especially when a lower initial cost is desirable and when suitable materials are available.

Cement Concrete lining

Cement concrete lining is widely used for lining of canals than any other material in India and other countries. They give long service without trouble and much maintenance costs if properly constructed. But the initial investment is very high and cracks may develop due to poor construction. Cement concrete lining may be placed in forms or may be applied as a plaster to the sides and bottom of the channel. Steep side slopes of 1:1 or 3:4 can be lined with concrete without much difficulty. The most common method of lining irrigation channels with concrete is to apply the material as plaster on the sides and bottom of the channel. Before applying the lining, the sides and bottom of the excavated channel is compacted at suitable moisture content. When new embankments are made, they should be compacted in approximately 15 cm layer. The top width of the embankment should be about 40 to 45 cm or more. A freeboard of at least 5 cm should be allowed. The side slopes can be steeper than in earth channels. They should not normally exceed 1 to 1. The thickness of concrete lining commonly used is 4-5 cm. The concrete mixture recommended for channel lining is 1:3:4 (cement: sand: gravel). Intervals between joints should not be greater than 2 m. Proper curing is necessary to obtain the maximum strength and durability of the concrete. Curing also prevents rapid drying of the concrete, thereby reducing the possibility of shrinkage cracks.

Pre-cast concrete channels

Pre-cast concrete is a term applied to concrete units that are fabricated at a central place and transported to the site of use. This is a very easy method of channel lining. Their low cost, easy to join and operating advantages make them particularly suitable for handling comparatively low discharge. One disadvantage is that if the place of use is very far away from the place of manufacture, then the transportation cost increases and there is likelihood of damage during handling. These pre-cast sections can be extensively used for lining of field channels in command areas. Pre-cast concrete channels may be constructed with concrete “half pipes” made especially for irrigation use by commercial manufacturers. Once the embankment is built and the channel excavated, the construction is rapid, as the 1 meter or larger sections are merely laid in place and the joints cemented. Low cost concrete channel sections can be made in a U- shaped wooden form by tamping in a concrete mixture made of 1: 3: 4 (cement: sand: gravel) with a bare minimum of water. The wooden form can be made by a local carpenter. Hard wood boards 2.5 cm thick are used to make the form. Removable pins at corners permit removal of forms without disturbing the newly cast section. The size of the form will depend on the size of the irrigation stream to be conveyed.

Brick or stone masonary lining

Single layer brick or tile or rubble stone may be used to obtain satisfactory lining of field irrigation channels. The bricks, tile or stones are laid flat on the compacted sides and bottom of the channel and the joints are filled with cement mortar. The mortar should have a cement sand ratio of 1:3**.** The choice between brick, flat clay tile or stones depends mainly on their availability and relative costs. Such linings are recommended for lining water courses from channels where the discharge is more than 30 lts/s**.**

23.2 Underground pipeline water distribution system

An efficient means of conveying and distributing farm irrigation water is through underground pipes. This method practically eliminates conveyance and evaporation losses. Land is not wasted as the land above the pipe line is also put under crop. Their placement below ground level prevents damage. The efficient modern agricultural implements and machinery can be used for various agricultural operations because the fields are not cut into short runs by channels. Open channels often take 2 to 4% of the land area out of cultivation. Since the pipes operate under pressure, they can be laid uphill or downhill, thus permitting delivery of irrigation water to areas not accessible by open channels. The pipes are not clogged by vegetation and wind-blown materials. Water pumped from a well may be delivered directly into the pipeline system. Pipelines are essentially leak-proof.

Underground pipeline irrigation distribution systems have a higher initial cost as compared to lined open channels. They may, however, be more economical under many field situations, including fields being located in benches at different elevations and when the cost of land saved for cultivation are considered. Generally, underground pipelines are not suitable under canal irrigation system because of insufficient head and silt laden water. Therefore, open channels are generally used to distribute canal water supplies. Underground pipelines are usually constructed with factory made reinforced concrete pipes and PVC pipes. In case of small farms, when high pressures are not involved, they may be constructed with non-reinforced concrete pipes.

Lecture 24

Components of underground pipe line, installation procedure, discharge calculation of underground pipe line.

24.0 Structures for pipelines

Underground pipelines require certain structures at specified positions for proper flow and control of discharge and to protect the pipe line from damage due to build up of any excessive pressure. The structures include pump stand, gate stand, outlet structure with valves, air vent, hydrants etc.

24.1 Pump stand: The pump stand is used (i) to convey the flow of the pump into the pipe by maintaining, the required head, (ii) to ensure full flow in the pipeline, (iii) to prevent damage of the pipes, specially the concrete pipes from excessive pressure and (iv) to serve functions of other stands. A vertical pipe installed on the ground to the required height serves as the pump stand (Fig.44). Its diameter is larger than the diameter of the delivery pipe of the pump and the underground pipeline. The pump delivers water into the top of the stand and the underground pipeline is connected at the bottom of the stand. The height of the pump stand is calculated by knowing the height of the final outlet and calculating the head losses occurring in the pipeline, joints, bends, valves etc. Height of stand = R.L. of the highest outlet – R.L. of the bottom of pump stand + head losses + some extra allowance. The extra allowances or freeboard of about 50 cm is provided so that the water does not overflow. Sufficient diameter should be provided to allow access for working and repair from inside.

24.2 Gate stands: Gate stands are used at junctions when the branch lines take off from the main line in different directions. Slide gates are generally provided to control the flow of water in different branches. (Fig. 45). In case the branches are sloping downwards, gate valves are useful at the junctions to provide the pressure for discharge through the valves located upstream.

24.3 Air vents: Air vents are small diameter pipes installed at specific locations to release any entrapped air in the pipeline and also prevent the formation of vacuum inside. They should be of sufficient height so that water does not overflow through them. Removal of the air from the pipeline causes an even removal even flow and eliminates the danger of water hammer. Air vents should be located at the following points.

a) At the high spots in the line.

b) About one metre downstream from the pump stand.

c) At any sharp change in grade downstream or direction of pipeline, and

d) At the end of the pipeline.

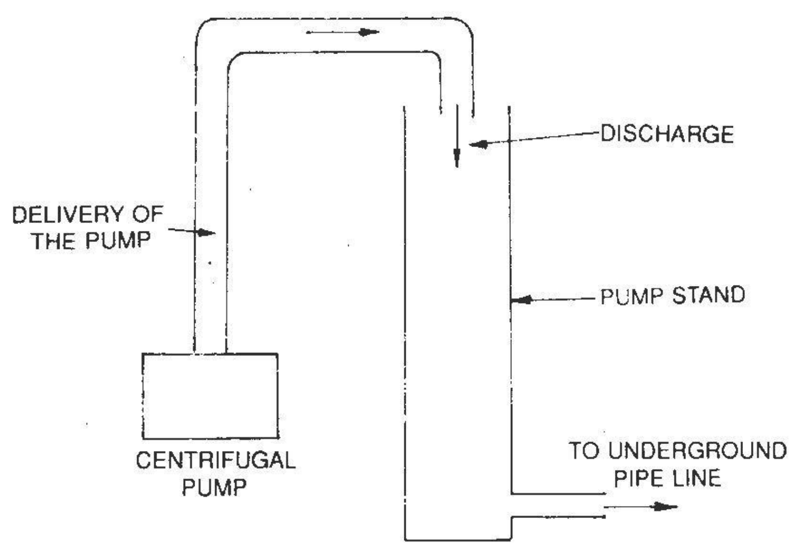


Fig. 44. Pump stand

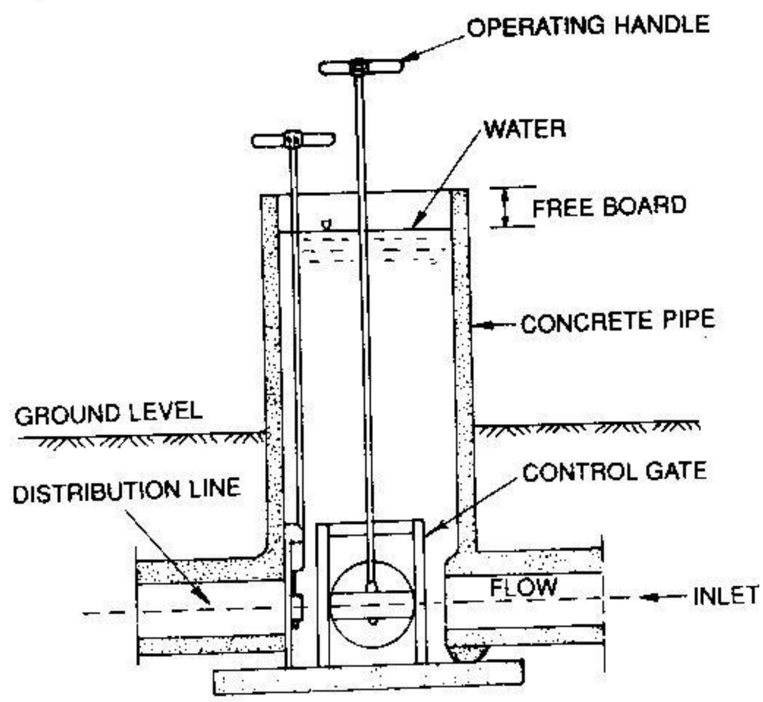


Fig. 45. Gate stand

24.4 Outlets: Some outlet structures or hydrants are needed at regular intervals to deliver water to the land or to the field channel. Either alfalfa valves or orchard valves are used as outlets. An alfalfa valve consists of a handle and cap plate attached to a threaded rod called spindle that moves up and down as the handle is turned. As the valve is closed, the cap plate fits in the circular edge of the valve case a make it water tight (Fig. 46). When the plate is lifted by turning the spindle, water flows from all sides of the valve. For connecting the valve with the pipeline, a tee-joint is provided in the pipeline at the required location. The diameter of the vertical pipe of the tee-joint is same as the main pipeline. At the end of the vertical pipe the valve is joined by grouting. The spindle is usually made of brass to make it rust proof. But now a-days cheap type cast iron spindles are being widely used.

If lower flow rate is required, orchard valves are used instead of alfalfa valves. They can be installed either at the top of the vertical pipe, at the bottom or at any convenient point between them. As the flow rate from orchard valve is less, scouring of the soil around the valve does not takes place.

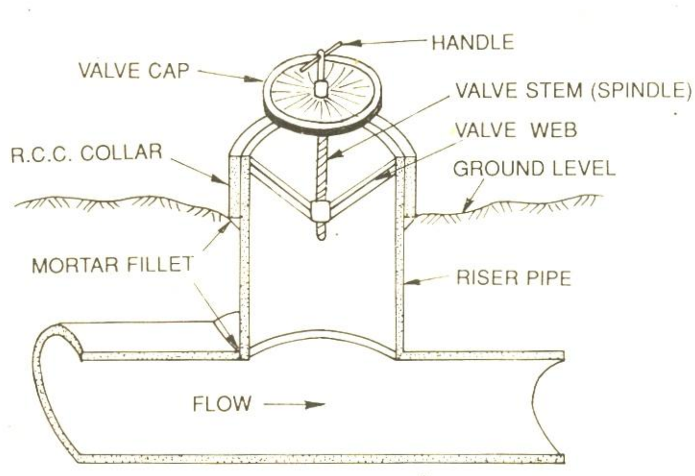


Fig. 46. Outlet valve

24.5 Hydrants and Gated pipes: Hydrants and gated pipes are used to irrigate a particular portion of the command area at a time directly from the flow through the pipe without the use of any field channel. (Fig. 47) Hydrants are the devices connected to the outlet valves so that the gated pipes can be connected to them to convey the water directly to the border, check basin or furrow. Both the hydrants and the gated pipes are portable so that one set serves the purpose at many locations. This helps to eliminate seepage loss in field channels with maximum of extra investment. The hydrants also serve some extra purpose. The suction line of the pump can be connected to the hydrant and water pumped from the pipeline at high pressure to serve some special requirements. For example, in case of municipal water supply line, the high pressure water can be used for extinguishing fire or in case of irrigation pipeline; the water can be supplied to the sprinkler system. If it is desired to take the water in one gated pipe only, a single outlet is provided in the hydrant. Otherwise, two outlets can be provided on two sides to convey the water in two gated pipes simultaneously. Aluminum, right PVC, rubber or steel pipes may be used as gated pipes.

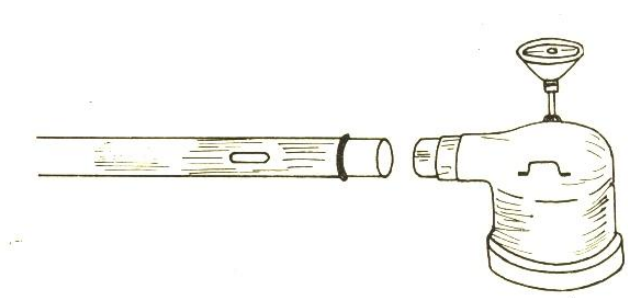


Fig. 47. Portable hydrant

24.6 End plug: An end plug is provided at the end of each pipe line to close the end of the line and to absorb the pressure developed in the pipeline. Incase of concrete pipes, the end plug is made of concrete and is supported by a masonry wall. However, the metallic pipes have threaded metallic caps which fit at the threaded ends of the pipes.

24.7 Discharge capacity of pipelines

The discharge through a pipeline can be determined by applying the Darcy equation:

$$V = \sqrt{\frac{Hdg}{2fl}}$$

Where v = Velocity of flow of water through the pipe, cm/sec

H = Available head causing flow (difference in elevation between the water level in the pump stand and the outlet point), cm

d = Diameter of pipe, cm

g = acceleration due to gravity, cm/s^2

l = Length of pipe, cm

f = Darcy's roughness coefficient

Example : Determine the discharge capacity of an underground concrete pipe line of 16 cm diameter pipes. The length of the pipeline is 210 m. The difference in elevation between the water levels at the pump stand and the discharge point is 2.5 m.

Solution: The value of 'f' is assumed to be 0.009 (Table , with an assumed velocity of flow of 90 cm/s.)

Data given: d = 16 cm

l = 21000 cm

H = 2.5 m = 2500 cm

g = 981 cm/s^2

$$V = \sqrt{\frac{Hdg}{2fl}}$$

$$V = \sqrt{\frac{250 \times 16 \times 981}{2 \times 0.009 \times 21000}} = 101.88 \cong 102 \text{ cm} = 1.02 \text{ m}$$

Area of cross section of pipe, $a = \frac{\pi d^2}{4}$

$$= \frac{\pi \times 16 \times 16}{4} = 0.02 \text{ m}^2$$

Discharge capacity, q = av

$$= 0.02 \times 1.02 = 0.0204 \text{ m}^3\text{/s} = 20.4 \text{ lt/s}$$

Lecture 25

Irrigation methods - sprinkler irrigation, scope, functional components of sprinkler system and their working.

The manner in which irrigation **is** applied to land is called method of irrigation. Irrigation water may be applied to crops by flooding it on the field surface, by applying it beneath the ground surface, by spraying it under pressure or applying it in drops. The quantity and quality of water available, the topography of the land, the crop to be irrigated, the cost of the water application system and the availability of labour determine the method of irrigation which is most desirable. Efficient irrigation results in increased crop yields, with soil fertility maintained and water utilized economically. Over-irrigation however, results in leaching of fertilizers, water logging and salt accumulation. Whatever is the method of water application; it is essential that the system is designed to apply the right amount of water at the right time and apply it uniformly to raise the level of soil moisture in the crop root zone to its field capacity.

Water application method may be broadly classified into two groups: (i) surface irrigation methods and (ii) pressurized irrigation methods. Surface irrigation, also called, gravity irrigation, comprises of the methods of water application in which water is distributed by means of open surface flow. Water is applied to the land surface from a field channel located at the upper reach of the field and water flows into the field under gravity. The common methods of surface irrigation are border strip, check basin and furrow irrigation. In pressurized irrigation systems, water is conveyed through pipes under pressure and applied to the crops by sprinkling it over the land surface or plant canopy or applied on the soil surface as a point source, usually in the form of drops. Pressurized irrigation (or micro irrigation) systems comprise of sprinkler and drip method of water application.

25.0 Sprinkler irrigation

In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the spray of water under pressure through small orifice or nozzle.

25.1 Adaptability of sprinkler irrigation

It can be used for almost all crops (except rice and jute) and on most soils. It is, however, not usually suitable in very fine textured soils (heavy clay soils) where the infiltration rates are less than about 4 mm per hour. The sprinkler irrigation method is particularly suited to sandy soils that have a high infiltration rate. The flexibility of the sprinkler equipment and its efficient control of water application make this method adaptable to most topographic conditions without excessive land preparation. It is especially suitable for steep slopes or irregular topography. Land leveling is not essential for irrigation with sprinklers. Soluble fertilizers, herbicides and fungicides can be applied in the irrigation water economically and with little extra equipment. Sprinkler irrigation can be used to protect crops against frost and high temperatures that reduce the quantity and quality of harvest. Field supply channels and bunds or ridges are not required.

25.2 Advantages of sprinkler irrigation are: (i) elimination of the channels for conveyance, hence no conveyance losses, (ii) suitable to all types of soils except heavy clay, (iii) suitable for irrigated crops where the plant population for unit area is very high, (iv) water saving, (v) higher water application efficiency, (vi) increase in yield, (vii) mobility of system, (viii) saves labour cost, as no bunds are required, (ix) areas located at a higher elevation than the source can be irrigated, (x) possibility of using soluble fertilizers and chemicals.

25.3 Components of sprinkler irrigation system

The components of portable sprinkler system are shown through fig.48. A sprinkler system usually consists of the following components: debris screen, desilting basin, pumping unit, booster pump, mains, water meter, pressure gauge, submains, end plug, laterals, sprinkler head, couplers, flanges, couplings, nipples and fertilizer applicator.

1. Debris screen: Debris screens are usually needed when the surface water is used as source of irrigation. The main function of screens are to keep the system free of thrash that might plug the sprinkler nozzles.

Screens should be fine enough to catch weed seeds and other small particles.

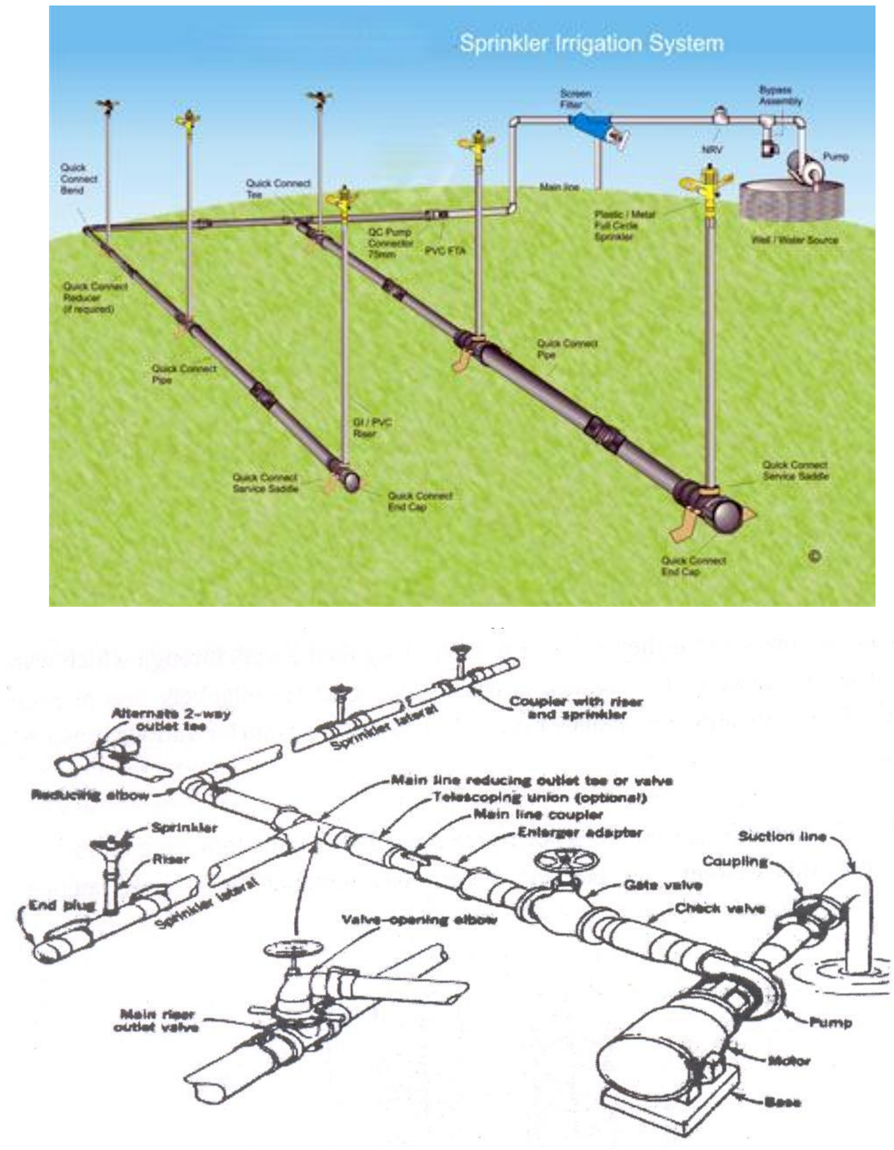


Fig. 48. Sprinkler irrigation system

2. Desilting basin: These are required to trap sand or suspended silt when the water comes from the streams, open ditches and well water having silt. Sometimes, desilting basin and debris screens are built as a combination structure.

3. Pumping unit: Sprinkler irrigation systems distribute water by spraying it over the fields. The water is pumped under pressure to the fields. The pressure forces the water through sprinklers or through perforations or nozzles in pipelines and then forms a spray. A high speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the source of water is an open well or when the distance from the pumping inlet to the water surface is less than eight meters. If it is more than eight meters or for pumping water from deep wells, a turbine pump is suggested. The driving unit may be either an electric motor or an internal combustion engine.

4. Booster pump: Booster pumps should be used when the existing pumping system is insufficient to force the water through sprinklers.

5. Mains: Main lines conveys water from the source and distributes it to the submains.

6. Pressure guage: It is necessary to know whether the sprinkler system is working with desired pressure to ensure uniformity in application.

7. Water meter: It is used to measure the volume of water delivered. This is necessary to operate the system to give the required quantity of water.

8. Sub mains: Submains convey water from the mains and distributes it to the laterals.

9. Laterals: Laterals convey the water from the sub mains and distributes to the sprinklers.

10. **Take-off valves**: These are generally needed to control pressures in the lateral lines.

11. **Couplers**: These are required for connecting or disconnecting two pipes quickly and easily.

12. **Pipe fittings and accessories**: These are required for proper connection to the pump, suction an delivery line.

13. **Sprinkler head:** Sprinkler head (Fig.49) distribute water uniformly over the field without runoff off or excessive loss due to deep percolation. Different types of sprinklers are available. They are either rotating fixed type. The rotating type can be adopted for a wide range of application rates and spacing. Most agricultural sprinklers are of the slow rotation type and operate at high pressures. Fixed head sprinklers and ‘Pop-up’ sprinkler heads are commonly used to irrigate small lawns and gardens. Perforated lateral lines are sometimes used as sprinklers. They require less pressure than rotating sprinklers. They release more water per unit area than rotating sprinklers. Most commonly used sprinkler heads have two nozzles, one to apply water at a considerable distance from the sprinkler and the other to cover the area near the sprinkler centre.

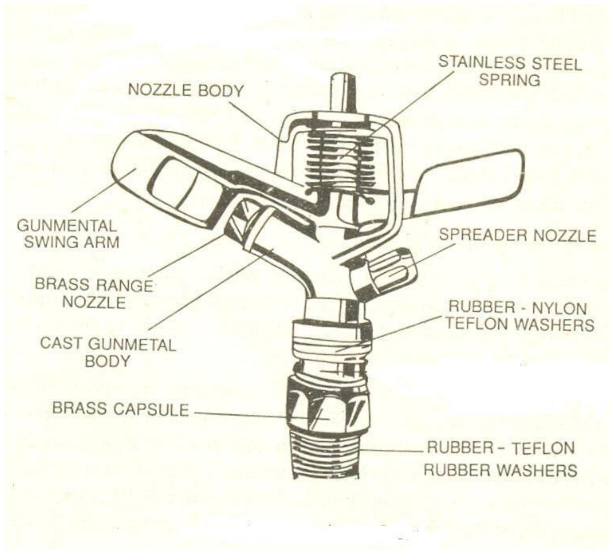


Fig. 49. Sprinkler head

14. End plugs: These are generally placed at the end of sub mains. These are caps that prevent the water flow from sub mains and makes water enter in to risers.

15. Fertilizer applicator: Soluble chemical fertilizers can be injected into the sprinkler system and applied to the crop. The equipment for fertilizer application is relatively cheap and simple. It can be fabricated locally. The fertilizer applicator consists of a sealed fertilizer tank with necessary tubing and connection. A venturi injector can be arranged in the main line, which creates the differential pressure suction and allows the fertilizer solution to flow in the main water line.

25.4 Working of sprinkler irrigation system

In sprinkler irrigation system, water is drawn through desilting basin or debris screen from the shallow well by means of centrifugal pump or from deep tube wells by means of deep well turbine pumps and filtered. When the pressure exerted by the existing pump is not sufficient to drive the water, a booster pump is installed in addition to pumping unit. The filtered water enters into the mains. The water pressure is regulated with take-off valves by monitoring a pressure gauge. The quantity of water flowing in the system is regulated by water meter. The water then enters into sub mains. Coupler are provided at each junction i.e., at the place of joining of two pipes. End plugs are provided at the end of sub mains. Water from sub mains enters into the laterals which in turn enter into sprinkler head, through which water is sprayed in the entire field resembling rainfall.

Lecture 26

Types of sprinkler irrigation, operation and maintenance of the system, cost economics.

26.0 General classification of different types of sprinkler systems

Sprinkler systems are classified into the following two major types on the basis of the arrangement for spraying irrigation water.

(1) Rotating head or revolving sprinkler system.

(2) Perforated pipe system.

Rotating head: Small sizes nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe. The lateral pipes are usually laid on the ground surface. They may also be mounted on posts above the crop height and rotated through 90^o, to irrigate a rectangular strip. In rotating type sprinklers, the most common device to rotate the sprinkler head is small hammer activated by a thrust of water striking against a vane connected to it.

Perforated pipe system: This method consists of drilled holes or nozzles along their length through which water is sprayed under pressure. This system is usually designed for relatively low pressure (1 kg/cm^2). The application rate ranges from 1.25 to 5 cm per hr based on pressure and spacing.

Based on the portability, sprinklers are classified in following types:

(a) **Portable system**: A portable system has portable mainlines, laterals and pumping plant. It is designed to be moved from field to field or to different pump sites in the same field. The portable system may be designed to be moved manually or by mechanical power.

(b) **Semi-portable system**: A semi-portable system is similar to a fully portable system except that the location of the water source and pumping plant is fixed. Such a system may be used on more than one field.

(c) **Semi-permanent system**: It has portable lateral lines, permanent main lines and sub-mains and a stationary water source and pumping plant. The main lines and submarines are usually buried, with risers for nozzles located at suitable intervals.

(d) **Permanent system**: A fully permanent system consists of permanently laid mains, sub main and laterals and a stationary water source and pumping plant. Sprinkler installations in orchards are usually of the permanent type.

26.1 Constraints in application of sprinkler irrigation system

1) Wind distorts sprinkler pattern and causes uneven distribution of water.

2) Ripening soft fruit must be protected from the spray.

3) A stable water supply is needed for the most economical use of the equipment.

4) The water must be clean and free of sand, debris and large amount of dissolved salts.

5) Evaporation loss when operation under high temperatures.

6) Highly impermeable soils are not available.

7) Initial cost is high.

8) Proper design.

9) Lack of package of practices.

10) Lack of awareness.

11) Power requirements are usually high as high water pressure required to operate sprinkler system (>2.5 kg/cm^2).

12) Fine textured soils that have a slow infiltration rate cannot be irrigated efficiently in hot windy areas.

26.2 Trouble shooting methods

The following are the general guidelines to identify and remove the troubles in the sprinkler systems:

1. Pump does not prime or develop pressure:

a) Check that the suction lift is within the limits. If not, get the pump closer to the water.

b) Check the suction pipeline and all connections for air leaks. All connections and flanges should be air tight.

c) Check that the strainer on the foot valve is not blocked.

d) Check that the flap in the foot valve is free to open fully.

e) Check the pump gland(s) for air leaks. If air leaks are suspected, tighten the gland(s) gently. If necessary, repack the gland(s) using thick grease to seal the gland satisfactorily.

f) Check that the gate valve on the delivery pipe is fully closed during priming and opens fully, when the pump is running.

2. Sprinklers do not turn:

a) Check pressure.

b) Check that the nozzle is not blocked. Preferably unscrew the nozzle or use a small soft piece of wood to clear the blockage. Do not use a piece of wire or metal as this may damage the nozzle.

c) Check the condition of washers at the bottom of the bearing and replace them if worn or damaged.

d) Check that the swing arm moves freely and that the spoon which moves into the water stream is not bent by comparing it with a sprinkler which is operating correctly.

e) Adjust the swing arm spring tension – Usually it should not be necessary to pull up the spring by more than about 6 mm.

3. Leakage from coupler or fittings:

The sealing rings in the couplers and fittings are usually designed to drain the water from the pipes when the pressure is turned off. This ensures that the pipes are automatically emptied and ready to be moved. At high pressures, the coupler and fittings should be leak proof. If, however, there is a leakage, check the following.

a) There is no accumulation of dirt or sand in the groove of the coupler in which sealing ring fits. Clean out any dirt or sand and refit the sealing ring.

b) The end of the pipe going inside the coupler is smooth, clean and not distorted.

c) In the case of fittings such as bends, tees and reducers ensure that the fitting has been properly connected into the coupler.

26.3 Unit cost of sprinkler system

Different components required for a sprinkler irrigation system to irrigate 1 ha to 4 ha area and their cost has been estimated and are given in Table 1.

Table 1: Components required for a sprinkler irrigation system to irrigate 1 ha to 4 ha area and their approximate cost.

Sprinkler system components	1.0 ha (50 mm dia)		3.0 ha (63 mm dia)		3.0 ha (75 mm dia)		4.0 ha (75 mm dia)	
	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount
HDPE Pipes with quick action coupler (20.5 kg/cm^2) of 6m long	25	7770.00	30	10448.70	37	13378.09	45	16270.65
Sprinkler coupler with foot baton assembly	5	921.60	7	1411.20	11	2382.30	14	3032.00
Sprinkler nozziles (1.7 to 2.8 kg/cm^2)	5	1188.00	7	1662.20	11	2613.60	14	3326.40
Riser pipe 20mm diameter × 75cm long	5	264.00	7	369.60	11	580.80	14	739.20
Connecting nipple	1	115.20	1	129.00	1	167.00	1	167.00
Bend with coupler 90^o	1	108.00	1	126.00	1	168.00	1	168.00
Tee with coupler	1	138.00	1	152.40	1	180.00	1	180.00
End plug	2	96.00	2	108.00	2	132.00	2	132.00
Basic system cost per hectare (Rs)		10600.80		14407.10		19601.79		24015.25

26.4 Operation and maintenance of sprinkler system

It should be ensured that, the prime mower and the pump are in alignment. While laying the main and lateral pipes, always begin laying at the pump. This necessarily gives the correct connection of all quick coupling pipes. While joining couplings, it is ensured that both the couplings and the rubber seal rings are clean. In starting the sprinkler system, the motor or engine is started with the valves closed. The pump must attain the pressure stated on type-plate or otherwise there is a fault in the suction line. After the pump reaches the regulation pressure, the delivery valve is opened slowly. Similarly, the delivery valve is closed after stopping the power unit. The pipes and sprinkler lines are shifted as required after stopping. Dismantling of the system takes place in the reverse order to the assembly.

Lecture 27

Drip irrigation system - scope, functional components of drip system and their working principles.

27.0 Development of micro irrigation systems

Micro irrigation is frequent application of water directly on or below the soil surface near the root zone of plants. It is based on the fundamental concepts of irrigating only the root zone of the crop rather than the entire land surface and maintaining the water content of the root zone at near optimum levels. It is one of the latest methods of irrigation, which is becoming increasingly popular in areas with water scarcity and salt problems. It delivers required and measured quantity of water in relatively small amounts slowly to the individual or groups of plants. Water is applied as continuous drops, tiny streams or fine spray through emitters placed along a low-pressure delivery system. During the last three decades, micro irrigation systems made major advances in technology development and the uptake of the technology increased from 3 Mha in 2000 to more than 6 Mha in 2009.

27.1 Historical development of drip irrigation

Drip irrigation was used in ancient times by filling buried clay pots with water and allowing the water to gradually seep into the soil. Use of subsurface clay pipes for irrigation in Germany led to doubling of crop yields in 1860 and perhaps that was the beginning of the concept of applying irrigation water directly to the root zone. Nehemiah Clark, in 1873, obtained the first known US patent for a water emitting device as a dripper (a simple hole). In 1913, E.B.House at Colorado State University (USA) succeeded in applying water to the root zone of plants without raising the water table. An important breakthrough was made in Germany in 1920when perforated pipe drip irrigation was introduced.

During the early 1940’s Symcha Blass, an engineer from Israel, observed that a big tree near a leaking tap exhibited more vigorous growth than other trees in the area. This led him to the concept of an irrigation system that would apply water in small quantity literally drop by drop. In India, drip irrigation is practiced through indigenous methods such as perforated earthen ware pipes, perforated bamboo pipes and pitcher/porous cups. In Meghalaya, some of the tribal farmers are using bamboo drip irrigation system for betel, pepper and arecanut crops by diverting hill streams in hill slopes. Earthenware pitchers and porous cups have been used for growing vegetable crops in Rajasthan and Haryana. In India, drip irrigation was introduced in the early 70's at agricultural universities and other research institutions. The growth of drip irrigation has really gained momentum in the last one decade. These developments have taken place mainly in areas of acute water scarcity and in commercial/ horticultural crops, such as coconut, grapes, banana, fruit trees, sugar cane and plantation crops in the states of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Gujarat. In India, the area under drip irrigation had grown from a negligible level in 1975 to around 18.97 lakhs ha in 2009-2010.In India, Maharashtra, Tamil Nadu and Karnataka are some of the states which have taken a lion's share in drip irrigated area constituting 39.7%, 28% and 24.3% respectively of total area under micro irrigation.

27.3 Advantages of micro irrigation

i) Water saving.

ii) Enhanced plant growth and yield.

iii) Uniform and better quality of produce.

iv) Efficient and economic use of fertilizers.

v) Less weed growth.

vi) Suitable to waste lands.

vii) Possibility of using saline water.

viii) No soil erosion.

ix) Flexibility in operation.

x) Easy installation.

xi) Labour saving.

xii) Suitable to all types of land terrain.

xiii) Save the land as no bunds etc, are required.

xiv) Minimum diseases and pest infestation.

27.4 Disadvantages of drip irrigation system

i) High initial cost of investment.

ii) Skilled persons are required to operate the machine.

iii) The water must be relatively clear.

iv) Poor water distribution efficiency when a low pressure system is installed on steep slopes or uneven lands.

Drip irrigation is a method of watering plants frequently and with a volume of water approaching the consumptive use of the plants, thereby minimizing conventional losses like deep percolation, runoff and soil water evaporation. In this method, irrigation is accomplished by using small diameter plastic lateral lines with devices called "emitters" or "drippers" at selected spacing to deliver water to the soil surface near the base of the plants. The system applies water slowly to keep the soil moisture within the desired range for plant growth.

27.5 Drip irrigation components

The components of micro irrigation system can be grouped into two major groups (Fig.50):

i) Head control unit and

ii) Distribution network.

Head control unit:

The head control unit consists of micro irrigation system includes the following components.

1. Pump/overhead tank: It is required to provide sufficient pressure in the system. Centrifugal pumps are generally used for low pressure trickle systems. Overhead tanks can be used for small areas or orchard crops with comparatively lesser water requirements.

2. Fertilizer applicator: Application of fertilizer into pressurized irrigation system is done by either a by-pass pressure tank or by venture injector or direct injection system.

3. Filters: The hazard of blocking or clogging necessitates the use of filters for efficient and trouble free operation of the micro irrigation system. The different types of filters used in micro irrigation system are described below.

a) Gravel or media filter: Media filters consists of fine gravel or coarse quartz sand, of selected sizes (usually 1.5 to 4 mm in diameter), free of calcium carbonate placed in a cylindrical tank. These filters are effective in removing light suspended materials such as algae and other organic materials, fine sand and silt particles. This type of filtration is essential for primary filtration of irrigation water from open water reservoirs, canals or reservoirs in which algae may develop. Water is introduced at the top, while a layer of coarse gravel is put near the outlet bottom. Reversing the direction of flow and opening the water drainage valve cleans the filters. Pressure gauges are placed at the inlet and at the outlet ends of the filter to measure the head loss across the filter. If the head loss exceeds more than 30 kPa filter needs back washing.

b) **Screen filters**: Screen filters are always installed for final filtration as an additional safeguard against clogging. While majority of impurities are filtered by sand filter, minute sand particles and other small impurities pass through it. The screen filter, containing screen strainer, which filters physical impurities allows only clean water to enter into the micro irrigation system. The screens are usually cylindrical and made of non-corrosive metal or plastic material. These are available in a wide variety of types and flow rate capacities with screen sizes ranging from 20 mesh to 200 mesh. The aperture size of the screen opening should be between $1/7^{th}$ and $1/10^{th}$ of the orifice size of emission device.

4. Pressure relief valves, regulators or bye pass arrangement: These valves may be installed at any point where possibility exists for excessively high pressures, either static or surge pressures to occur. A bye pass arrangement is simplest and cost effective means to avoid problems of high pressures instead of using costly pressure relief valves.

5. Check valves or non return valves: These valves are used to prevent unwanted flow reversal. They are used to prevent damaging back flow from the system to avoid return flow of chemicals and fertilizers from the system into the water source itself to avoid contamination of water source.

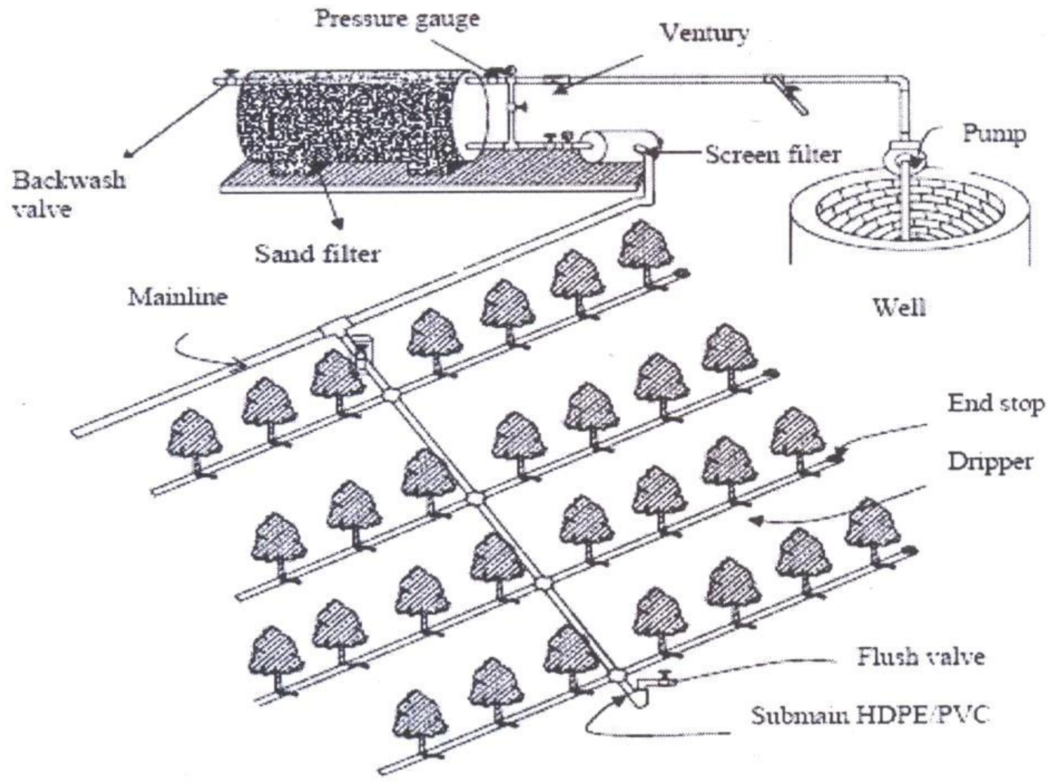


Fig. 50. Drip irrigation system

Distribution network: It mainly constitutes main line, sub mains, line and laterals with drippers and other accessories (Fig.50).

1. Main line: The main line transports water within the field and distribute to sub mains. Main line is made of rigid PVC and high density polyethylene (HDPE). Pipe lines of 65 mm diameter and above with a pressure rating of 4 to 6 kg/cm^2 are used as main pipes.

2. Sub mains: Sub mains distribute water evenly to a number of lateral pipes. For sub main pipes, rigid PVC, HDPE or LDPE (Low density polyethylene) of diameter ranging from 32 mm to 75 mm having pressure rating of 2.5 kg/cm^2 are used.

3. Laterals: Laterals distribute the water uniformly along their length by means of drippers or emitters. These are normally manufactured from LDPE. Generally pipes having 10, 12 and 16 mm internal diameter with wall thickness varying from 1 to 3 mm are used as lateral.

4. Drippers: They function as energy dissipaters, reducing the inlet pressure head (0.5 to 1.5 atmospheres) to zero atmospheres at the outlet.

The commonly used drippers are online pressure compensating or online non-pressure compensating, in-time dripper, adjustable discharge type drippers and micro tubing of 1 to 4 mm diameter. These are manufactured from poly-propylene or LDPE.

a) Online pressure compensating drippers: A pressure compensating type dripper supplies water uniformly on long rows and on uneven slopes. These are most suitable on slopes and difficult topographic terrains.

b) Online non-pressure compensating drippers: In such type of drippers, discharge tends to vary with operating pressure. These are cheap and available in affordable price.

c) In line drippers or In line tubes: These are fixed along with the line i.e., the pipe is cut and dripper is fixed in between the cut ends, such that it makes a continuous row after fixing the dripper. These types of drippers are suitable for row crops.

Lecture 28

Operation and maintenance of the drip system, cost economics.

28.0 Operation and maintenance of drip irrigation system

Periodic preventive maintenance is required for successful operation of Micro-irrigation system (Fig. 51).

28.1 General maintenance

a) Check emitter functioning, wetting pattern, leakages of pipes, valves, fittings etc.

b) Check the placement of drippers.

c) If the placement is disturbed, put the dripper in proper location.

d) Check leakage through filter gaskets in the lids, flushing valves, fittings etc.

28.2 Filter cleaning:

Filter is the heart of a drip system and its failure will lead to clogging of the entire system. Pressure differential across the filter is the correct indication of the timing of cleaning of the filter.

A) **Sand Filter**:

a) Backwash the filter daily for five minutes to remove the silt and other dirt accumulated during the previous day's irrigation.

b) Do not allow pressure difference across the sand filter more than 0.3 kg/cm^2

c) Once in a week, while backwashing, allow the backwash water to pass through the lid instead of the backwash valves.

d) Stir the sand in the filter bed up to the filter candles without damaging them. Whatever dirt is accumulated deep inside the sand bed will get free and goes out with the water through the lid.

B) **Screen filter**

1) Clean screen filter everyday.

2) Open the flushing valve on the filter lid so that the dirt and silt will be flushed out.

3) Open the filter and take out the filter element and clean them from both sides. Care should be taken while replacing the rubber seals, otherwise they may get damaged.

4) Do not allow pressure difference across the screen filter more than 0.2 kg/cm^2

5) Never use hard brush to rub screen surface.

28.3 Sub-main and lateral /bi-wall flushing

Sometimes silt escapes through the filters and settles in sub mains and laterals. Also some algae and bacteria lead to the formation of slimes/pastes in the pipe and laterals. To remove them, the sub mains should be flushed by opening the flush valves. The lateral lines are flushed by removing the end caps. By flushing, even the traces of accumulated salts will also be removed.

28.4 Chemical treatment

Clogging or plugging of emitters/orifices of bi-wall will be due to precipitation and accumulation of certain dissolved salts like carbonates, bi-carbonates, iron, calcium and manganese salts. The clogging is also due to the presence of microorganisms and the related iron and sulphur slimes due to algae and bacteria. The clogging or plugging is usually avoided / cleared by chemical treatment of water. Chemical treatment commonly used in micro-irrigation systems includes addition of chloride and/or acid to the water supply. The frequency of chemical treatment depends on degree of problem at the site. As a general rule, acid treatment should be performed once in ten days and chlorine treatment once in fifteen days.

28.4.1 Acid treatment: Hydrochloric acid is injected into drip system at the rates suggested in the water analysis report. The acid treatment is performed till a pH of 4 is observed at the end of lateral length. After achieving a pH of 4, the system is shut off for 24h. Next day, the system is flushed by opening the flush valve and lateral end caps.

28.4.2 Chlorine treatment: Chlorine treatment in the form of beaching powder is performed to inhibit the growth of microorganism like algae and bacteria. The bleaching powder is dissolved in water and this solution is injected into the system for about 30 minutes. Then the system is hut off for 24 hours. After that the lateral end caps and flush valves are opened to flush out the water with impurities. The bleaching powder can directly be injected through venture at the rate of 2 mg/L.

The trouble shooting methods of drip irrigation system is presented in Table2.

Table.2. Drip irrigation system trouble shooting

S. No.	Problems	Causes	Remedies
1	Leakage of water at the joint between sub main and lateral	Damaged joints	Correct damages
2	Leakages in the poly tube	Damage of poly rube by rat	Block the holes. Use poly jointers at cuts
3	Water and flowing up to lateral end	Holes in laterals. Cuts in laterals. Bents in laterals.	Close the holes and cuts. Remove the bends.
4	Out coming of white mixture on removing the end plug	More salinity in water. Uncleaned lateral	Remove the end stop. Clean the laterals fortnightly
5	Under flow or over flow from laterals	Clogging of drippers. Unclosed end plug	Clean the sand and screen filters. Close the end cap
6	Oily gum material comes out on opening the lateral end	More algae or ferrous material in water	Clean the laterals with water or give chemical treatment
8	More pressure drop in filters	Accumulation of dirt in filters	Clean filters every week. Back wash the filters for every 5 minutes daily.
9	Pressure gauge not working	Rain water entry inside, corrosion in gauge pointer damage	Provide plastic cover and fix pointer properly.
10	Drop in pressure	Leakage in main opened outlet. Low water level in well	Arrest the leakage and close outlet. Lower the pump with reference to well water level
11	More pressure at the entry of sand filter	No bypass in the pipeline/by pass not opened. Displacement of filter element, less quantity of sand in filters	Provide bypass before filter and regulate pressure. Place filter element properly. Fill required quantity of sand
12	Accumulation of sand and debris in screen filter	Displacement of filter element. Less quantity of sand in filters	Place filter element properly. Fill required quantity of sand
13	Venturi not working during chemical treatment and fertigation	Excess pressure on filters. Improper fitting of ventury assembly	Bypass extra water to reduce pressure. Repair the ventury assembly
14	Leakage of water from air release valve	Damaged air release valve ring	Replace the damaged ring

28.5 Cost of drip irrigation system

The cost of drip system depends on the types of crop, spacing, water requirement, proximity to water source etc. The cost estimation has been done for installing drip irrigation system for few important crops by considering the cost of components supplied by the manufacturer for the land holdings of one acre (0.4ha). The cost estimation for installation of drip system for Coconut, Aonla, Banana, tomato, Okra and chilli crops are worked out and are as given below. The life of the drip system components usually lasts 5 years for laterals and emission devices and about 10 years for mains and submains. The estimation for different crops (Coconut, Aonla, and Banana) is given in Table 3.

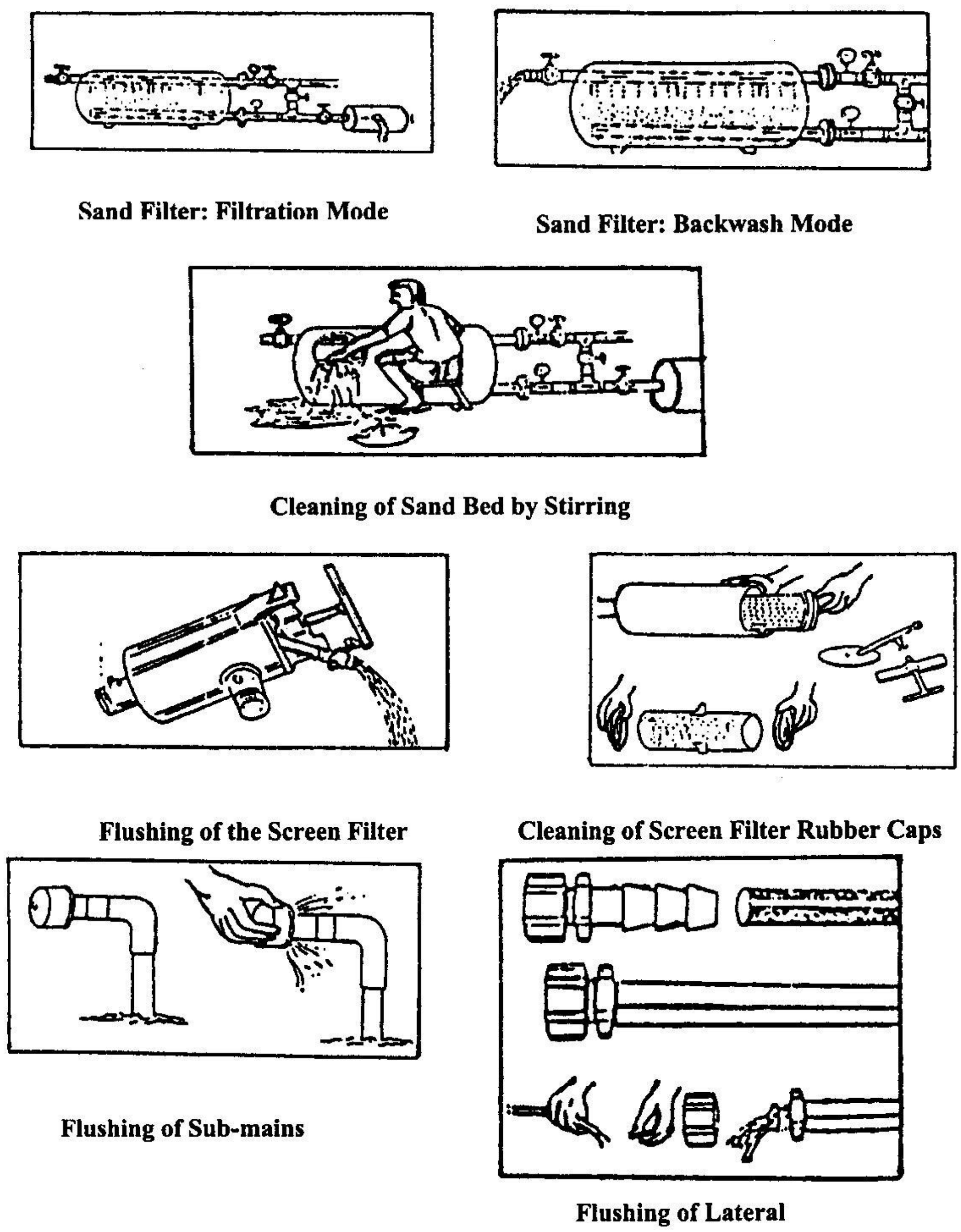


Fig. 51. Maintenance of Drip irrigation system

Table 3. Cost of estimation for coconut, anola and banana

Particulars	**Crops**		
	Coconut	**Anola**	**Banana**
Area	4000 m^2 (100 ×40)	4000 m^2 (100 ×40)	4000 m^2 (100 ×40)
Plant spacing	7 m × 7 m	6 m × 6 m	2 m × 2 m
No. of rows	15	17	50
No. of plants per row	7	8	20
Total number of plants	15 m × 7 m=105	17 m × 8 m=136	50 m × 20m=1000
Water requirement of crop	64 L /day	30 L /day	20 L /day
No. of emitters per plant	4 (4 L per hr capacity)	2 (4 L per hr capacity)	2 (4 L per hr capacity)
No. of hours of operation of pump	4	3.8	2.5
Total number of emitters per acre	105 ×4 = 420	136×2 = 272	1000×2 = 2000
Length of sub-main pipe (50 mm dia)	100 m	100 m	100 m
Length of laterals	630 mm (16 mm dia)	700 mm (12 mm dia)	2000 mm (12 mm dia)
Cost of drip system			
Cost of sub-main pipe	Rs. 3162=00	Rs. 3162=00	Rs. 3162=00
Cost of lateral pipe	Rs.3654=00	Rs.2625=00	Rs.7500=00
Cost of emitters	Rs.1176=00	Rs.762=00	Rs.5600=00
Cost of start, washer, and end cap	Rs.204=00	Rs.204=00	Rs.459=00
Cost of connectors	Rs.45=00	Rs.45=00	Rs.102=00
Cost of ball valves	Rs.360=00	Rs.360=00	Rs.360=00
Cost of dummies	Rs.60=00	Rs.60=00	Rs.150=00
2” venture with accessories	Rs.2000=00	Rs.2000=00	Rs.2000=00
Screen filter (2” size)	Rs.3500=00	Rs.3500=00	Rs.3500=00
Erection charges	Rs.750=00	Rs.750=00	Rs.1000=00
Total cost (excluding cost of pumping system)	**Rs.14,911=00**	**Rs.13,468=00**	**Rs.23,833=00**
Cost of 3 HP motor pump set			**Rs.7500=00**
Total cost with pumping system (Coconut, Anola and Banana)			**Rs.59,712=00**

Lecture 29

Soil and water conservation - definition and scope, soil erosion - definition, types, geological and accelerated soil erosion, causes and ill effects of soil erosion.

29.0 Erosion

One of the principal reasons for low productivity is the progressive deterioration of soil due to erosion. Soil erosion is the detachment and transportation of soil material from one place to another through the action of wind, water in motion or by the beating action of the rain drops.

Simply, soil erosion is the detachment of soil from its original location and transportation to a new location. Mainly water is responsible for this erosion although in many locations wind, glaciers are also the agents causing soil erosion. The main factors responsible for soil erosion in India are excessive deforestation, overgrazing and faulty agricultural practices.

Soil is the upper most layer of the earth's crust and consists of weathered and disintegrated minerals mixed with organic substances. Its depth is variable: in some places there is no soil, in some places the soil layer is many meters deep. However, it is little exaggeration to say that, the top 30 cm of soil supports all human and animal life. This thin layer is largely responsible for both the physical support and nutritional of plant growth. Our existence depends on conserving this vital natural resource.

29.1 History of soil erosion: All over the world, wherever man has cultivated sloping land, there has been soil erosion to some degree. As the water ran down the barren slopes, it carries soil with it. The erosion of the high lands has been accompanied by rapid sedimentation along the lower river courses. With water channels blocked and gradient of drainage ways destroyed by sedimentation. Classic examples of disappearance of human civilization in India due to mismanagement of soil resources are Mohenjodaro and Harappa. Vast tracts of hilly areas of north eastern states have been made barren by shifting cultivation. Siwalik range of the Himalayas suffered a severe soil loss due to overgrazing by cattle. The Kosi river originating from Napal got silted up due to erosion problems in the upper catchment. Many cultivated areas have turned into gullies.

Out of the total geographical area of 329 million hectares, an area of about 150 million hectares is subjected to either water or wind erosion. A net area of about 140 million hectares is cropped at present. An area of 40 million hectare is considered to be flood prone. Area lost through ravines and gullies is estimated to be about 4 million hectares. As a whole, it is estimated that, about 175 million hectares i.e., 53.3% of the total geographical area of the country is subjected to various soil and land degradation problems like saline- alkali soils, waterlogged areas, ravenous and gullied lands, area under shifting cultivation, and desertification. By the year 2010 A.D, the projected population of the country is expected to be two billion, whereas the food grain production is almost stagnant at 211 million tones in last 5 years. The per capita cropped area is shrinking every day, in the year 1950, it was 0.33 ha/capita, 0.2 ha in 1980 and it was 0.15 ha by the 2000. This clearly shows that the limited land resource has to be managed very carefully by adopting total conservation measures for the very survival of the hug population. The erosion may be broadly classified into two groups:

(1) Geological erosion, referred to as natural or natural erosion

(2) Accelerated erosion , known as abnormal erosion

29.2 Geological erosion: It represents erosion under the cover of vegetation. It takes place as a result of the action of water, wind, gravity and glaciers. It is a very slow process and responsible for soil formation as well as soil loss (means that loss of soil is compensated for by the formation of new soil under natural weathering process). Both together maintain a balance for favourable growth of the plants. As far as its adverse effects on agricultural lands are concerned, geological erosion is not of much consequence.

29.3 Accelerated erosion: When the vegetation is removed and land is put under cultivation, the natural equilibrium between soil building and soil removal is disturbed. The removal of surface soil takes place at much faster rate than it can be built up by the soil forming processes. This is known as accelerated soil erosion or abnormal erosion. It is destructive in nature and caused much land degradation. Only accelerated erosion is matter of concern for the agricultural land and henceforth it will be referred to erosion only. The erosion can be classified as (i) water erosion, (ii) wind erosion, and (iii) coastal erosion.

29.4 Causes and ill effects of soil erosion

Soil erosion is the spectacular result of bad land management. Some of the main damages caused by water erosion are:

1. Loss of productive soil
2. Deposition of sand on productive fields
3. Silting of lakes and reservoirs
4. Silting of drainage and irrigation channels.
5. Lowering of water table
6. Fragmentation of land

Loss of productive soil: The surface soil lost with runoff water consists of rich productive soil and fresh or active organic matter. The eroded material, which is ultimately carried into the ocean and thus lost, consists of colloidal matter, clay, silt, and the finest grades of sand. Only a small fraction of the eroded material, however reaches the ocean. The coarser material is usually deposited on river beds or plains when the velocity of water reduces with the reduction of slope of the river bed. The soil deposited in a river bed or reservoir is not unavailable for agricultural use.

Deposition of sand on productive fields: In the plains, fertile lands have been made unproductive by the deposition of coarser material brought down from the hills y streams and rivers.

Silting of lakes and reservoirs: Soil erosion from the catchment areas of reservoirs results in the deposition of soil, thus reducing their storage capacity and shortening their useful life.

Silting of drainage and irrigation channels: Deposition of silt in drainage ditches and natural streams and rivers reduces their depth and their capacity to handle runoff. At the same time, the demand on these outlets is increased. As a result, overflow and flooding of downstream increases, with damage to crops and disaster to man-made structures. Subsequently, the productivity of such flooded areas may be reduced or eliminated because of impairment of drainage.

Lowering of water table: With the increase in runoff, the quantity of water available for entering the soil is decreased. This reduces the supply of water to recharge the ground water in wells, which results the yield of the well is reduced.

Fragmentation of land: Gullies may divide the farm into many valleys and ridges. Fields thus become smaller and more numerous. Crop rows are shortened, movement from field to field is obstructed, and the farm value is decreased. Roads, bridges, buildings and fences are often damaged by gully development.

Lecture 30

Accelerated soil erosion - water and wind erosion definitions, rain drop (splash) erosion, sheet erosion, rill erosion, gully erosion, stream bank erosion and their stage of occurrence.

30.0 Accelerated erosion

When the vegetation is removed and land is put under cultivation, the natural equilibrium between soil building and soil removal is disturbed. The removal of surface soil takes place at much faster rate than it can be built up by the soil forming processes. This is known as accelerated soil erosion or abnormal erosion. It is destructive in nature and caused much land degradation. Only accelerated erosion is matter of concern for the agricultural land and henceforth it will be referred to erosion only. The erosion can be classified as (i) water erosion, (ii) wind erosion, and (iii) coastal erosion.

30.1 Water Erosion: It is the removal of soil from the land's surface by water in motion. Water erosion is due to the dispersive action and transporting power of water-water as it descends in the rain and leaves the land in the form of runoff. Rainfall is the chief detaching agent in water erosion.

30.2 Wind Erosion: It is the removal of soil from the land's surface by wind in motion. The most serious damage caused by wind erosion is the change in soil texture. The smaller particles of soil are more subjected to movement by wind.

Depending upon the degree of erosion and its location, water erosion is further classified as:

(i) Raindrop erosion
(ii) Sheet erosion
(iii) Rill erosion
(iv) Gully erosion
(v) Stream channel erosion

30.3 Raindrop or splash erosion:

Raindrop erosion is the result of direct impact of raindrops on bare soil or in thin film of water. If the soil surface is covered with good vegetation, much harmful effects do not occur as the drops break into finer sprays and much of it infiltrates into the ground. However, if the raindrop strikes the bare soil, considerable raindrop erosion takes place. It has been observed that, a single rain drop may splash wet soil as much as 60 cm height and move laterally to a distance of 150 cm from the spot. Ellison found that, the relative soil loss for a 30 minute rainfall period varies as the 4.33 power of velocity.

Soil loss $\propto V_t^{4.3}$

V_t = terminal velocity of the rain drop.

The same soil particles are generally splashed more than once. Thus they are detached from the main soil body and easily carried with the runoff water. In a level surface, much serious problem may not occur as the soil is just shifted from one place to another. But in sloping lands, they are easily transported down the slope and may join a reel or a gully from where further downward movement becomes easier. Apart from soil particles, the plant nutrients are also splashed and removed from the productive land.

A part of the rainfall with clay and silt suspension infiltrates into the ground. In this process the fine particles are removed due to staining and sedimentation phenomena. These fine particles block the soil pores and the infiltration capacity of the soil is greatly reduced. As a result, the runoff rate increases and more soil particles are transported. Thus raindrops striking bare soils on sloping ground cause severe damage which intensifies, as the duration increases. Factors the affecting raindrop erosion are (i) vegetative cover and mulches, (ii) rainfall, (iii) wind velocity and direction, (iv)soil texture and structure, (v) topography, particularly degree and length of slope.

Raindrops falling on plants, crop residue or other mulches lose their energy before striking the soil. High wind velocity in the direction of slope causes higher splash. The wind velocity and air resistance also affects the raindrop velocity. The raindrop velocity depends upon the height of fall upto a height of about **10.5 m,** after which it attains the terminal velocity.

Soil loss increases with the increases of this terminal velocity, which may vary from 4.5 to 9 m/s depending upon the drop size. Surface roughness and obstructions reduce the soil loss due to splashing.

30.4 Sheet erosion

Sheet erosion is the removal of a fairly uniform layer of soil from the land surface by the action of rainfall and runoff. The top fertile layer of the soil is slowly skimmed off every year and flows down as muddy water. This type of erosion is so slow and extremely harmful to the land. After sometime, the sub-horizon of the soil and finally the bed rock may be exposed rendering the soil unfit for any crop production. The farmer is not conscious of its existence. Initially the reduction in the crop yield may not be significant. But over the years the yield declines till it reaches a minimum. It is common on lands having a gentle slope. Movement of soil by raindrop splash is the primary cause of sheet erosion. The eroding and transporting power of sheet flow is greatly influenced by the depth and velocity of runoff.

30.5 Rill erosion

Rill erosion is the removal of soil by running water, with the formation of shallow channels that can be smoothed out completely by normal cultivation. Rill erosion is more serious in soils having a loose shallow topsoil. It may be regarded as a transition stage between sheet erosion and gullying.

Rill erosion is called the second of erosion, in which the removal of soil by rain water from small but well demarcated channels or streamlets takes place due to overland flow. Rill erosion is said to have started when channels are large enough to be visible.

30.6 Gully erosion

Gully erosion is the removal of soil by running water, with the formation of channels that cannot be smoothed out completely by normal cultivation. It requires costly structure and practices to control the further advancement of gully. It is an advanced stage of rill erosion. The rill erosion is an advanced stage of sheet erosion. Any concentration of surface runoff is a potential source of gullying.

The advancement of gully depends upon watershed characteristics and size, rainfall, soil characteristics, shape of the gully, slope of the channel and cultivation practices in the watershed.

Following four different processes are involved in the development of the gully:

(i) **Waterfall erosion**: Water falling at the gully head cuts the edge and caving mass of banks takes place. The detached mass of soil is carried away by runoff water. If the subsoil is loose, undermining proceeds at a fast rate. The depth and width of the gully thus increase.

(ii) **Channel erosion**: It is caused by the water flowing through the gully or by raindrop splash on unprotected soil. As much of the water passes through the gully head, lengthening of the gully takes place. Gullies formed by channel erosion usually have sloping heads and sides and are often called V-gullies.

(iii) In cold regions, alternate freezing and melting of snow take place on the exposed banks and causes erosion.

(iv) Due to undercutting, slides or mass movement of the soil takes place and huge quantity of soil is lost at a much faster rate.

Generally, the following four stages are involved in the development of gully:

Stage 1: Formation stage: Channel erosion takes place by downward scour of the topsoil.

Stage 2: Development stage: Upstream movement of the gully head and simultaneous enlargement of width and depth take place.

Stage 3: Healing stage: Vegetation begins to grow in the channel and further erosion ceases.

Stage 4: Stabilization stage: The gully bed and sides reach a stable slope and sufficient vegetation grows to anchor the soil and to trap soil flowing from upstream.

30.7 Stream Channel erosion:

Stream channel erosion is the scouring of material from the water channel and the cutting of banks by running water. The flowing water gradually erodes the river bank or undercut below the water surface. This is a very serious problem as the river gets widened every year. The widening of the river destroys huge cultivated lands, villages, cities, rails, bridges, structures etc. Very costly protection measures are required to prevent this type of erosion. Stream channel erosion consists of two parts namely, bank erosion and scour erosion caused by undercutting, which is more serious, cause huge landslide. The stream bank erosion is caused by removal of vegetation, by overgrazing or by tilling very close to the river bank. The velocity and soil texture influence the scour erosion.

Stream channel erosion differs from gully erosion in the following aspects:

(i) Stream channel erosion occurs at the lower end of head water tributaries, whereas gully erosion occurs near the upper end of head water tributaries.

(ii) Stream channel erosion occurs in streams that have almost continuous flow, where gully erosion occurs in streams with intermittent flow.

Lecture 31

Erosion control measures – engineering measures, contour bunds, graded bunds.

31.0 Field structures and practices to control erosion by water

Soil conservation is the preservation of soil from deterioration and loss by using it within its capabilities, and applying the conservation practices needed for its protection and improvement. Soil conservation planning should generally be done on a watershed basis. The watershed is the total land area above a given point on a waterway that contributes runoff water to the flow at that point. One of the first principles in a watershed programme is to manage the land so as to get as much of the rainfall **to soak in** as possible. The soil conservation programme and practices should start from the topmost portion of this unit and proceed downwards. Measures intended to control surface flow, should aim at preventing the concentration and retarding the movement of free water over the ground. Different agronomical and mechanical or engineering practices are required to be followed to achieve the desired effects.

31.1 Land use capability classification

Soil erosion problem can be tackled by planning suitable cropping system based on erosion hazard and other limitations. The ultimate goal is the improvement of the soil health and its preservation. To develop a scientific programme of management, land is first classified in different groups known as "Land use capability classification", which is shown in Table 4. Land capability is the suitability of land for use without damage. The land is broadly classified in two groups. Land suited for cultivation comes under group 1 and land not suited for cultivation is termed as group 2. Each group is again divided into four classes.

31.2 Mechanical or Engineering practices

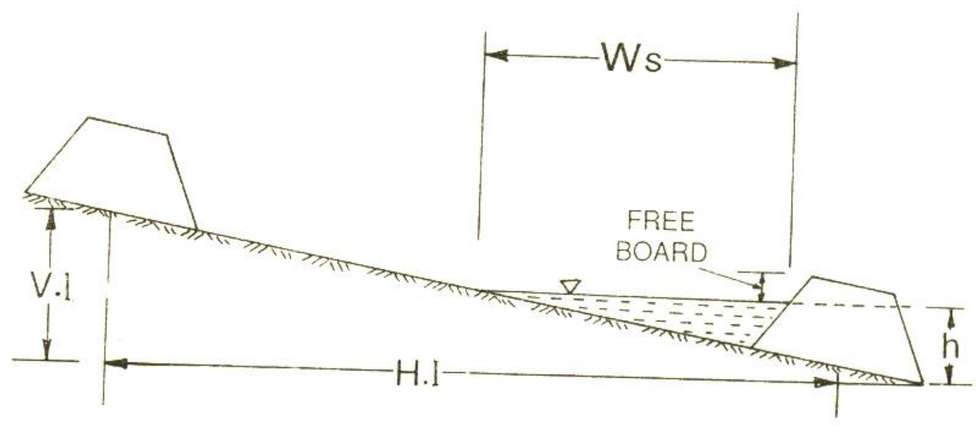
31.2.1 Contour bunding

Bunding or construction of small embankment is carried out to reduce the length of slope, to reduce the velocity of runoff water and to hold the water in the catchment for a longer period (Fig.52). Thus more water infiltrates in to the ground and less runoff and soil erosion takes place. When the bunds are constructed along the contours with some minor deviation to adopt to practical situation, they are known as contour bunds. Side bunds are constructed along the slope at the two sides of the contour bund. Lateral bunds are constructed along the slope in between two side bunds to reduce the length of the contour bund. This reduces the concentration of runoff water along one side. Supplemental bunds are constructed between two contour bunds to limit the horizontal spacing of the contour bunds.

Table 4. Land capability classification

Class of land	Percent slope	Adapted land use and soil conservation measures
Land suited for cultivation		
Class I	0-1	Any crop with proper crop rotation and green manuring to maintain soil fertility.
Class II	1-3	Contour farming, contour strip cropping and cover cropping. Contour bunding or terracing.
Class III	3-5	Intensive agronomical measures such as contour cropping, contour strip cropping and cover cropping. Terracing or contour bunding.
Class IV	5-8	Contour bunds or terraces and intense agronomical measures. Mostly soil building and soil maintaining crops are to be grown.
Land not suitable for cultivation		
Class V	8-12	Permanent pasture with controlled grazing.
Class VI	12-18	Pasture, grasses and forestry. Grazing should be restricted.
Class VII	18-25	Forest with restricted felling. Contour trenching as conservation measure.
Class VIII	Greater than 25	Forests with complete closure to grazing and felling of trees.

In India, contour bunding or simply bunding has been practiced for a long time and the Indian farmers have very good knowledge about it. It was known that bunds could stand well in shallow, medium and medium deep soils. Deep black soils cracked in dry conditions and the bunds failed. In addition to controlling soil erosion and maintaining soil fertility, the construction of bunds helps in better infiltration of water into the soil, ultimately replenishing the underground storage. Under contour bunds, however, an area of about 5% is lost under the bunds and is not available for cultivation. Contour bunds are also not successful in very shallow soils having a depth less than 7.5 cm.



H. I. = Horizontal interval between the bunds.

V.I = Vertical interval

Fig. 52. Contour bund

31.2.2 Graded bunds

In areas of high rainfall (annual rainfall greater than 80 cm) and fine textured soil, the entire runoff cannot easily and economically be stored in the catchment through contour bunding. The excess runoff may not safely be disposed off through surplussing arrangement. Under such situations, graded bunds can be used to dispose off the excess runoff safely. Graded bunds have generally wide and shallow channels and earthen bund laid along a predetermined longitudinal grade. Therefore, contour bunds are mostly used for conservation of moisture in low rainfall areas with permeable soils. Graded bunds are used partly for conservation of moisture and safe disposal of the excess water in high rainfall areas and/or in light soils. The graded bunds, commonly used in India, are comparable to the narrow base terraces. If the bunds are constructed with some slope they are known as graded bunds.

Graded bunds may have uniform grade or variable grade. Uniform graded bunds are suitable where the length of bund is less and the discharge behind the bund is not much. Graded bunds are suitable where the length of bund and the discharge behind the bund are more.

Lecture 32

Broad based terraces and bench terraces.

32.0 Terracing

Terracing is a mechanical method by which land surface is modified through construction of ridges, channels and ridges or change of land slope for control soil erosion and conservation of moisture. A terrace reduces the length of the hill-side slope, thereby reducing sheet and rill erosion and prevents formation of gullies. Terracing is a costly soil conservation measure and should be used only where less expensive biological control measures don’t provide sufficient protection. If terracing is properly designed and constructed, terraces provide excellent measures for soil and water conservation, helps to raise cultivated crops on sloping land on a sustainable basis.

32.1 Classification of terraces

A terrace is an embankment or ridge of earth constructed across a slope to control runoff and minimize soil erosion. There are different criteria for classification of terraces. It is classified based on functional basis and construction or shape.

On functional basis, terraces are classified as:

(i) Level terrace (absorption type)

(ii) Graded terrace (Drainage type)

On the basis of construction or shape, terraces are classified as:

a) Bench terrace

b) Broad base ridge type terrace

c) Channel type

32.1.1 Level Terrace

The terrace is constructed where moisture conservation is important. A ridge of required height and cross section is constructed to retain the run off from the inter terraced area for gradual absorption in to the soil (Fig.53). The ridge follows the contour and can be constructed in areas only where rainfall is low and soil is very permeable.

32.2.2 Graded terrace

It is also known as drainage type terrace (Fig.53) and it is used to convey excess water at a safe velocity in to a vegetated water way. Either a constant or a variable grade may be used. Generally, a wide, shallow channel with flat side and bed slopes is constructed for this purpose.

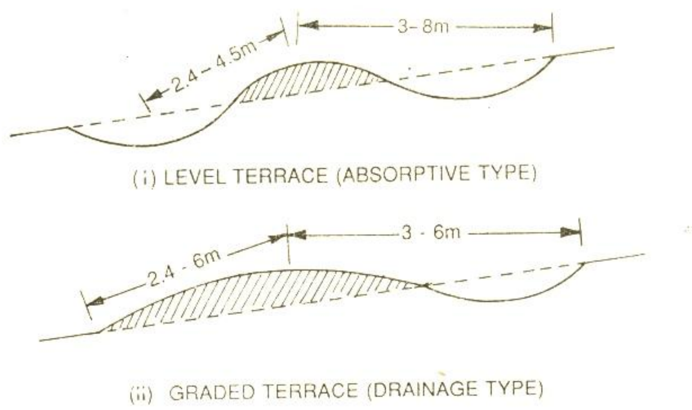


Fig. 53. Level and graded terraces

32.2.3 Channel type terrace

It is similar to drainage type and it is mainly used to convey excess rainfall from the field at non-erosive velocities. If the drainage is not perfect, the channel also intercepts sub surface flow and collects excessive ground water. A wide, relatively shallow channel of gentle side and bed slopes is constructed for this purpose.

32.2.4 Ridge type terrace

It is similar to level type terrace and is used mainly for water conservation through storage. They are suitable for low rainfall areas with high infiltration rates and flat land slopes. Depending upon the base width, ridge type is further classified in to

i) Narrow base

ii) Broad base.

The base width of narrow base terrace varies from 1.2 to 2.4 m and the sides of the terrace can not be cultivated .A broad based terrace has a very wide base width of 4.5 to 9 m and sides of the ridge can be cultivated.

32.3 Bench terrace

Bench terraces are constructed to divide a steeply sloped hilly land into a series of level or nearly level strips or benches running across the slope. The benches are separated by almost vertical risers retained by rocks or thick growth of vegetation. In India, bench terracing although not very scientifically designed, has been very widely used for centuries. In the hilly regions of the north eastern states, Himachal Pradesh, Kerala, Tamil Nadu, Bihar, etc., farmers have been using bench terraces for growing cultivated crops. Bench terraces are constructed on steep slopes greater than 6 to **7%,** although recent recommendations favour their construction on slopes greater than 15%. Therefore, the cost of construction is very high and the construction is justified only when land available for cultivation is very scarce. The depth of soil should be adequate so that even after cut, sufficient depth is available for crop growth.

32.3.1 Components of bench terrace: The bench terrace essentially consists of the four components namely: riser, outlet channel, platform and shoulder bund (Fig.54). The **riser** is vertical wall at the upstream end of the strip of the land converted to bench terrace. The **outlet** can be located either at the upstream or at the downstream end depending upon the rainfall and soil conditions. **Platform** is the level or nearly level strip obtained by terracing and crop is grown in this zone. **Shoulder bund** helps to retain the rainfall in the terraced area.

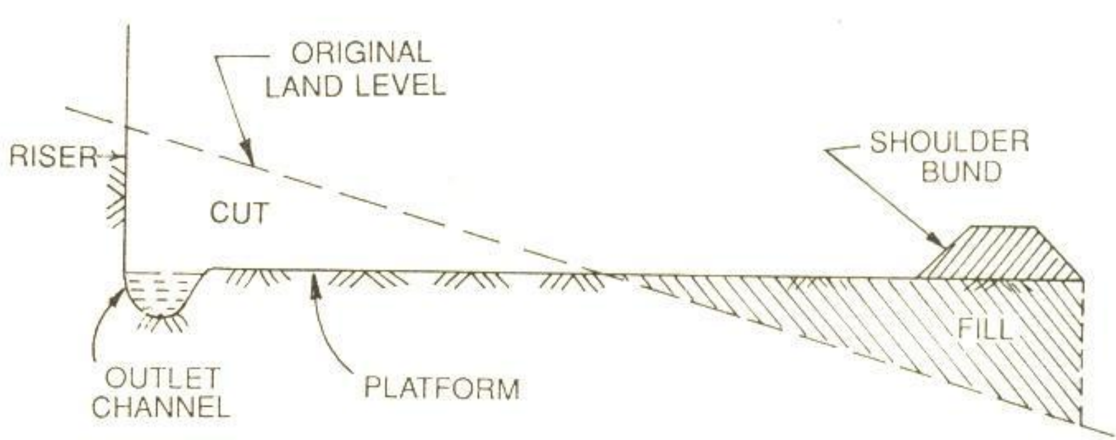


Fig. 54. Components of bench terrace

32.3.2 Types of bench terraces

Depending upon slopes terraces are classified as: level bench terrace, outward sloping bench terrace and inward sloping bench terrace (Fig.55). There are other types such as California type, Tati terrace, conservation bench terrace etc.

Level bench terrace:

They are also known as table top or paddy terraces. They are generally used in paddy cultivation as paddy requires some ponded water. On a land of very mild-slope such as 1% also, level bench terrace is constructed to facilitate paddy cultivation. The level type is suitable in area with medium rainfall and permeable soils.

Outward sloping bench terrace

In areas of low rainfall or shallow soil depth, this type is suitable. The existing steep slope can be reduced to a mild slope to reduce soil erosion, conserve some moisture and grow crops other than transplanted paddy. The surplus runoff water should be safely disposed off through the provision of a graded channel.

Inward sloping bench terrace

In high rainfall areas with steep slopes, this type of terraces may be used. They have a drain on the inner side, which is provided with a suitable grade along the length to convey the excess water to one side. Vegetated waterway is used to dispose off the water from such drains.

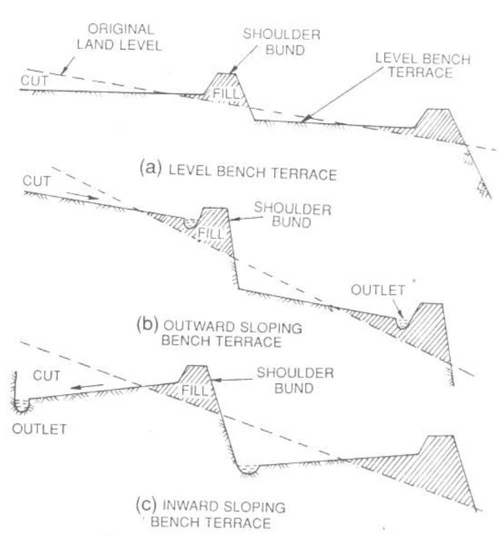


Fig.55. Types of bench terraces

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