KIITPOLYTECHNIC

LECTURE NOTES

ON

LAND SURVEY-II

Compiled by

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CONTENT

CHAPTER- 1

General

Tachometry is the branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means as opposed to the ordinary slower process of measurements by tape or chain. The method is very rapid and convenient. Although the accuracy of Tachometry in general compares un-favourably with that of chaining, it is best adapted in obstacles such as steep and broken ground, deep ravines, stretches of water or swamp and so on, which make chaining difficult or impossible.

The primary object of tachometry is the preparation of contoured maps or plans requiring both horizontal as well as vertical control. Also, on surveys of higher accuracy, it provides a check on distances measured with the tape.

Tacheometer:

1. A tacheometer is nothing more than a theodolite fitted with stadia hair.
2. The stadia hairs are kept in the same vertical plane as the horizontal and vertical cross hair.
3. For short distance up to 100 m, ordinary leveling stadia may used.
4. According to measurement process system, it is classified under two categories

   i.e. 1. Stadia hair system

   2. Tangential system

5. The stadia hair system again divided into two categories

   i.e. 1. Fixed hair method

   2. Movable hair method

Fixed hair method:

In this method, the distance between the upper hair and lower hair, i.e. stadia interval *i*, on the diaphragm of the lens system is fixed. The staff intercept *s*, therefore, changes according to the distance *D* and vertical angle θ.

Movable hair method:

In this method, the stadia interval '*i*' can be changed. The stadia hairs can be moved vertically up and down by using micrometer screws. The staff intercept *s*, in this case, is kept fixed. Two vanes (targets) are fixed on the staff at a fixed interval of 2 m or 3 m.

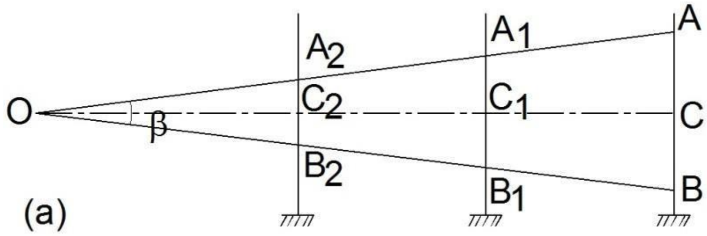
The fixed hair method is the one which is commonly used and, unless otherwise mentioned, stadia method means fixed hair method. Movable hair method is not in common use due to difficulties in determining the value of *i* accurately.

Principle of Stadia Method

The stadia method is based on the principle that the ratio of the perpendicular to the base is constant in similar isosceles triangles. In figure (a), let two rays *OA* and *OB* be equally inclined to the central ray *OC*. Let A_2B_2, A_1B_1 and *AB* be the staff intercepts.

Evidently,

$$\frac{OC_2}{A_2B_2} = \frac{OC_1}{A_1B_1} = \frac{OC}{AB} = \text{constant } k = \frac{1}{2}\cot\frac{\beta}{2}$$



We will derive distance and elevation formulae for fixed hair method assuming line of sight as horizontal and considering an external focusing type telescope. In Figure below, *O* is the optical centre of the object glass. The three stadia hairs are *a*, *b* and *c* and the corresponding readings on staff are *A*, *B* and *C*. Length of image of *AB* is *ab*. The other terms used in this figure are

f = focal length of the object glass,

i = stadia hair interval = *ab*,

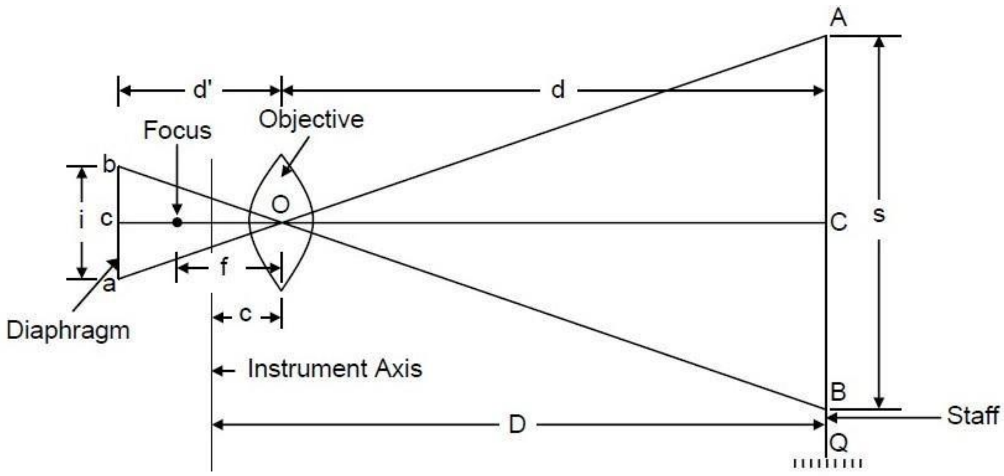
s = staff intercept = *AB*,

c = distance from *O* to the vertical axis of the instrument,

d = distance from *O* to the staff,

d′ = distance from *O* to the plane of the diaphragm, and

D = horizontal distance from the vertical axis to the staff.



Principle of Stadia Method

From similar Δ^s, *AOB* and *aOb*, we get

$$\frac{d}{d'} = \frac{s}{i}$$

And from lens formula,

$$\frac{1}{f} = \frac{1}{d'} + \frac{1}{d}$$

Combining the two equations, we get

$$d = \frac{fs}{i} + f$$

Adding *c* to both the sides

$$D = \frac{fs}{i} + (f + c)$$

Or D = Ks + C

where the constant *K* is equal to (*f* /*i*). It is called **multiplying constant** of the tacheometer and is generally kept as 100. The constant *C* is equal to (*f* + *c*). It is called **additive constant** whose value ranges from 30 cm to 50 cm for external focusing telescopes and 10 cm to 20 cm for internal focusing telescopes. For telescopes fitted with anallactic lens, *C* equals zero.

Anallactic Lens

The basic formula for determination of horizontal distance in stadia tacheometry is

$$D = \frac{fs}{i} + (f + c)$$

Or D = Ks + C

Due to the presence of the additive constant *C*, *D* is not directly proportional to *s*. This is accomplished by the introduction of an additional convex lens in the telescope, called an *anallactic lens*, placed between the eyepiece and object glass, and at a fixed distance from the latter.

The anallactic lens is provided in external focusing telescope. Its use simplifies the reduction of observations since the additive constant ($f + c$) is made zero and the multiplying constant k is made 100. However, there is objection to its use also as it increases the absorption of light in the telescope thereby causing reduction in brilliancy of the image. Anallactic lens is not fitted in internal focusing telescopes.

Determination of Tacheometric Constants

The stadia interval factor (K) and the stadia constant (C) are known as tacheometric constants. Before using a tacheometer for surveying work, it is required to determine these constants. These can be computed from field observation by adopting following procedure.

Step 1 : Set up the tacheometer at any station say P on a flat ground.

Step 2 : Select another point say Q about 200 m away. Measure the distance between P and Q accurately with a precise tape. Then, drive pegs at a uniform interval, say 50 m, along PQ. Mark the peg points as 1, 2, 3 and last peg -4 at station Q.

Step 3 : Keep the staff on the peg-1, and obtain the staff intercept say s_1 .

Step 4 : Likewise, obtain the staff intercepts say s_2, when the staff is kept at the peg-2,

Step 5 : Form the simultaneous equations,

$D_1 = K. s_1 + C$------------- (i)

and $D_2 = K. s_2 + C$ ------------ (ii)

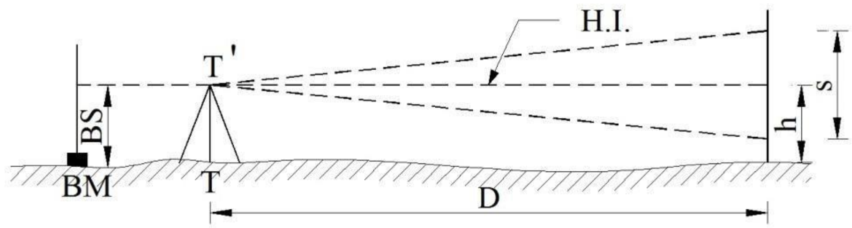
Solving Equations (i) and (ii), determine the values of K and C say K_1 and C_1 .

Step 6 : Form another set of observations to the pegs 3 & 4, Simultaneous equations can be obtained from the staff intercepts s_3 and s_4 at the peg-3 and point Q respectively. Solving those equations, determine the values of K and C again say K_2 and C_2.

Step 7 : The average of the values obtained in steps (5) and (6), provide the tacheometric constants K and C of the instrument.

Stadia tacheometry

Case 1 When staff held vertical and with line of collimation horizontal



When the line of sight is horizontal , the general tacheometric equation for distance is given by

$$D = \frac{f s}{i} + (f + c)$$

The multiplying constant $\left(\frac{f}{i}\right)$ is 100, and additive constant $(f + c)$ is generally zero.

RL of staff station P = HI – h

Where HI = RL of BM + BS

h = central hair reading

BS = Back sight

HI = height of instrument

Case 2 When staff held vertical and with line of collimation inclined

(a) Considering Angle of elevation

Let

T = Instrument station

T_1 = axis of instrument

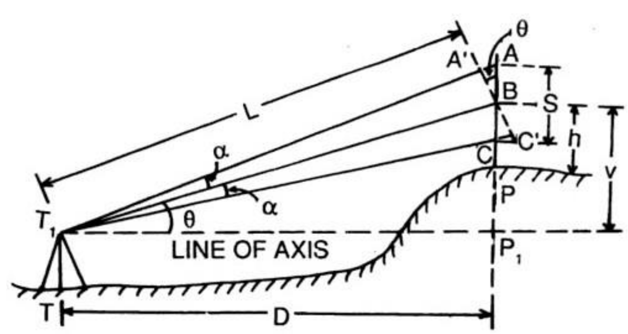
P = staff station

A, B, C = position of staff cut by hairs

$S = AC$ = staff intercept

h = central hair reading

V = vertical distance instrument axis and



central hair

D = horizontal distance between instrument and staff

L = inclined distance between instrument axis and B

θ =angle of elevation

α =angle made by outer and inner rays with central ray

$A'C'$ is drawn perpendicular to the central ray T_1B

Now , internal distance, $L = \frac{f}{i}(A'C') + (f + c)$

Horizontal distance , $D = L \cos\theta$

$$= \frac{f}{i}(A'C') \cos\theta + (f + c) \cos\theta \qquad (1)$$

Now $A'C'$ is to be expressed in terms of AC (i. e. S)

In Δs ABA' and CBC'

$< ABA' =< CBC' = \theta$

$< AA'B = 90^0 + \alpha$

$< BC'C = 90^0 - \alpha$

The angle α is very small

$< AA'B$ and $< BC'C$ may be taken equal to 90^0

So $A'C' = AC \cos\theta = S \cos\theta$

From equation *(1)*

$$D = \frac{f}{i}(S \cos\theta) \cos\theta + (f + c) \cos\theta$$

$$D = \frac{f}{i} \times S \cos^2\theta + (f + c) \cos\theta$$

Again $V = L \sin\theta$

$$= \{\frac{f}{i} \times S \cos\theta + (f + c)\} \sin\theta$$

$$= \frac{f}{i} \times S \cos\theta \sin\theta + (f + c) \sin\theta$$

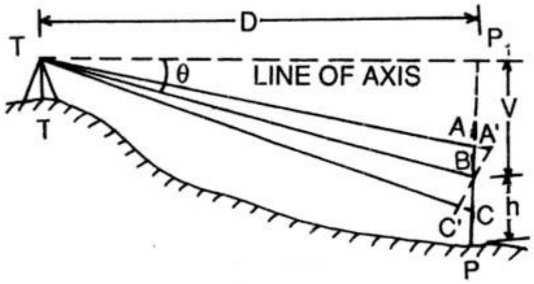
$$V = \frac{f}{i} \times \frac{S \times \sin 2\theta}{2} + (f + c) \sin\theta$$

Also $\quad V = D \tan\theta$

RL of staff station P = RL of axis of instrument + $V - h$

(b) *Considering Angle of depression*

In this case also the expressions for D and V are same. That is



$$D = \frac{f}{i} \times S\cos^2\theta + (f + c)\cos\theta$$

$$V = \frac{f}{i} \times \frac{S \times \sin 2\theta}{2} + (f + c)\sin\theta$$

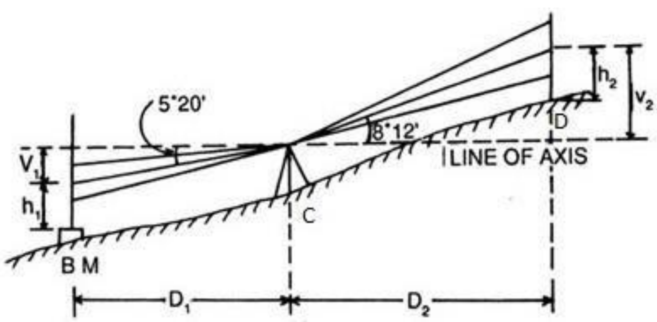
RL of staff station P = RL of axis of instrument − V − h

Problem

A tacheometer was set up at a station C and the following readings were obtained on a staff vertically held.

Inst. station	Staff station	Vertical angle	Hair readings	Remarks
C	BM	$-5^0\,20'$	1.500 , 1.800, 2.450	RL of BM =
C	D	$+8^0\,12'$	0.750, 1.500, 2.250	750.50 m

Calculate the horizontal distance CD and RL of D, when the constants of instrument are 100 and 0.15 .



Solution

When the staff is held vertically, the horizontal and vertical distances are given by the relations

$$D = \frac{f}{i} \times S\cos^2\theta + (f + c)\cos\theta$$

$$V = \frac{f}{i} \times \frac{S \times \sin 2\theta}{2} + (f + c)\sin\theta$$

Here $\frac{f}{i} = 100$ and $(f + c) = 0.15$

In the first observation, $S_1 = 2.450 - 1.150 = 1.300$ m

$\theta_1 = 5^0\ 20'$ (depression)

$$V_1 = 100 \times 1.300 \times \frac{\sin 10^0\ 40'}{2} + 0.15 \times \sin 5^0\ 20' = 12.045 \text{ m}$$

In the second observation, $S_2 = 2.250 - 0.750 = 1.500$ m

$\theta_2 = 8^0\ 12'$ (elevation)

$$V_2 = 100 \times 1.500 \times \frac{\sin 16^0\ 24'}{2} + 0.15 \times \sin 8^0\ 12' = 21.197 \text{ m}$$

$D_2 = 100 \times 1.50 \times \cos^2 8^0\ 12' + 0.15 \times \cos 8^0\ 12' = 147.097$ m

RL of axis of instrument = RL of BM + h_1 + V_1

= 750.500 + 1.800 + 12.045 = 764.345 m

RL of D = RL of axis of instrument + $V_2 - h_2$

= 764.345 + 21197 − 1.500 = 784.042 m

So, the distance CD = 147.097 m and RL of D = 784.042 m

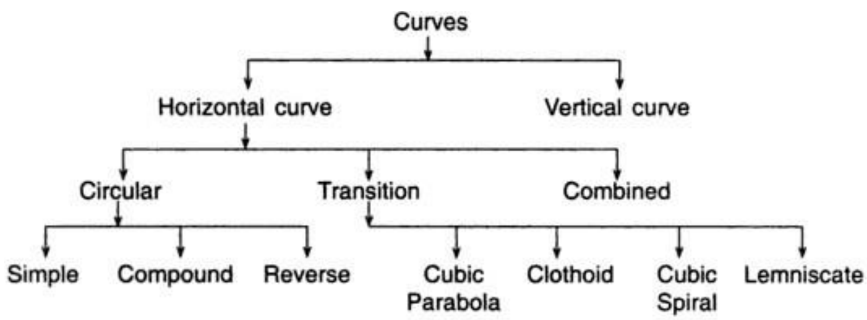
CHAPTER-2

Introduction:

Curves are required to be introduced where it is necessary to change the direction of motion from one straight section of a highway or a railway to another. These are provided due to the nature of terrain or other avoidable reasons to enable smooth passage of vehicles.

CLASSIFICATION OF CURVES

For survey purposes, curves are classified as horizontal or vertical, depending on whether they are introduced in the horizontal or vertical plane.



Horizontal Curves

Horizontal curves can be circular or non-circular (transitional) curves. Different types of horizontal curve are shown in figure below.

Simple Circular Curve

When a curve consists of a single arc with a constant radius connecting the two straights or tangents, it is said to be a circular curve.

Compound Curve

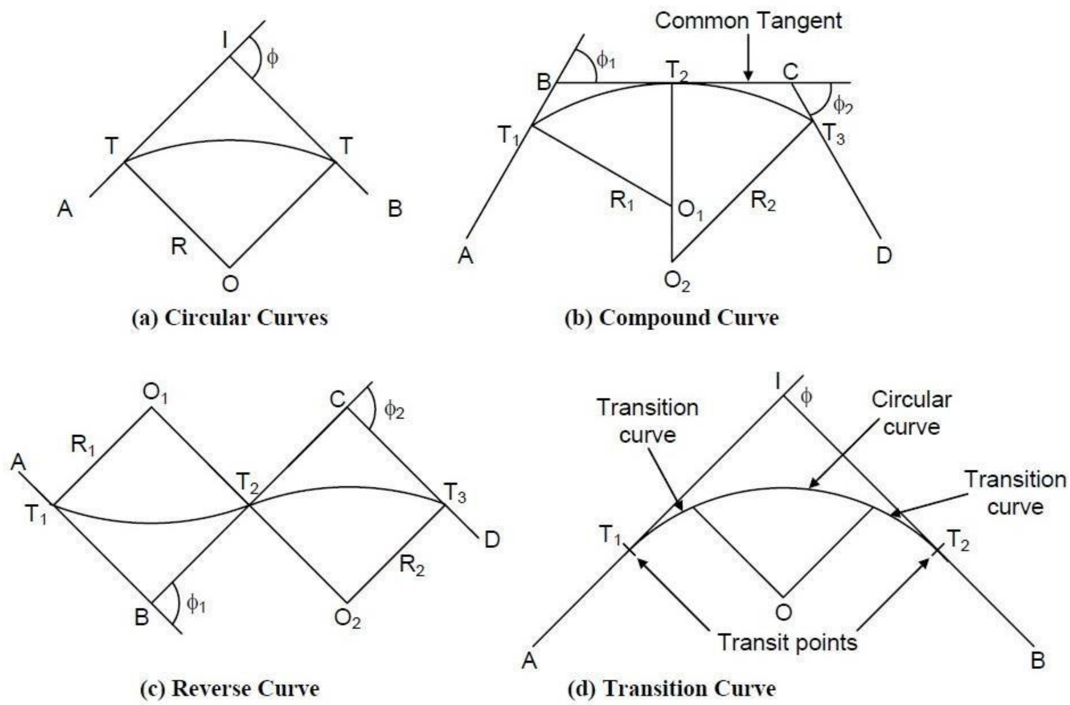
When a curve consists of two or more arcs with different radii, it is called a compound curve. Such a curve lies on the same side of a common tangent and the centres of the different arcs lie on the same side of their respective tangents.

Reverse Curve

A reverse curve consists of two arc bending in opposite directions. Their centres lie on opposite sides of the curve. Their radii may be either equal or different, and they have one common tangent.

Transition Curve

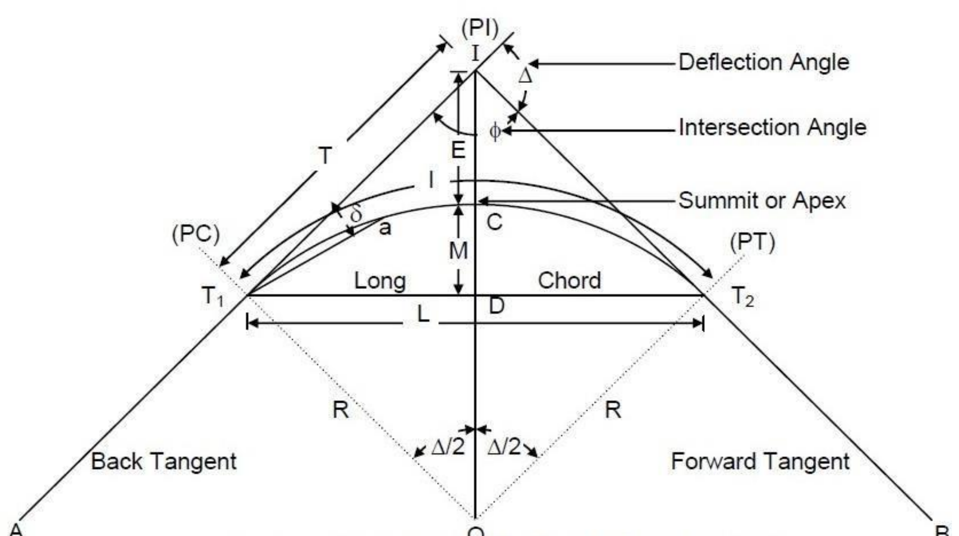
A curve of variable radius is known as a transition curve. It is also called a easement curve. Such a curve is provided between a straight and a circular curve, or between branches of a compound or reverse curve to avoid an abrupt change in direction when the alignment changes. In railways, such curve is used on both sides of a circular curve to minimize superelevation.



Type of Horizontal Curves

SIMPLE CIRCULAR CURVE

Figure shows a simple circular curve with two straight lines *AI* and *IB* intersect at the point *I*. The curve $T_1C\,T_2$ of radius *R* is inserted to make a smooth change of direction from *AI* to *IB*. A simple circular curve has various components whose definitions are given below.



Components of a Simple Circular Curve

Definition of Various Components

Back Tangent

The tangent (AT_1) previous to the curve is called the back tangent or first tangent.

Forward Tangent

The tangent ($T_2 B$) following the curve is called the forward tangent or second tangent.

Point of Intersection

If the two tangents AT_1 and BT_2 are produced, they will meet in a point I called the point of intersection (PI) or vertex.

Point of Curve (PC)

It is the beginning of the curve (T_1) where the alignment changes from a tangent to a curve.

Point of Tangency (PT)

It is the end of the curve (T_2) where the alignment changes from a curve to tangent.

Intersection Angle

The angle between the tangent AT_1 and BT_2 is called the intersection angle (ϕ).

Deflection Angle

The angle Δ through which the forward tangent deflects is called the deflection angle of the curve. It may be either to the left or the right.

Deflection Angle to any Point

The deflection angle δ to any point a on the curve is the angle at PC between the back tangent and the chord $T_1 a$ from PC to point on the curve.

Tangent Distance (*T*)

It is the distance between PC to PI (also the distance from PI to PT).

External Distance (*E*)

It is distance from the mid-point of the curve to PI. It is also known as the apex distance.

Length of the Curve (*l*)

L is the total length of the curve from PC to PT.

Long Chord (*L*)

It is the chord joining PC to PT.

Mid Ordinate (*M*)

It is the ordinate from the mid-point of the long chord to the mid-point of the curve. It is also called the versine of the curve.

Normal Chord (*C*)

A chord between two successive regular stations on a curve is called a normal chord.

Sub-Chord (*c*)

Sub-chord is any chord shorter than the normal chord. These generally occur at the beginning or at the end of the curve.

Right-hand Curve

If the curve deflects to the right of the direction of the progress of survey, it is called the right-hand curve.

Left-hand Curve

If the curve deflects to the left of the direction of the progress of survey, it is called the left-hand curve.

Elements of Simple Circular Curve

Length of the Curve (*l*)

Length $l = T_1 CT_2 = R\,\Delta$, where Δ is in radians

$= (\pi R)\,\Delta/180^{o}$, where Δ is in degrees.

Tangent Length (*T*)

Tangent length, $T = T_1 I = IT_2$

$= OT_1 \tan \Delta/2 = R \tan \Delta/2$

Length of the Long Chord (*L*)

$L = T_1 T_2 = 2\, OT_1 \sin \Delta/2$

$= 2\, R \sin \Delta/2$

Apex Distance or External Distance (*E*)

$E = CI = IO – CO$

$= R \sec \Delta/2 – R$

$= R (\sec \Delta/2 – l)$

$= R\ \text{exsec}\ \Delta/2$

Mid-ordinate (*M*)

$M = CD = CO – DO$

$= R – R \cos \Delta/2$

$= R (1 – \cos \Delta/2) = R\ \text{versin}\ \Delta/2$

Problem :

Two tangents intersect at a chainage of 1250.50 m having deflection angle of 60^o. If the radius of the curve to be laid out is 375 m, calculate the Length of the curve, Tangent distance, Length of the long chord, Apex distance, Mid-ordinate, Degree of curve and Chainage of P.C. and P.T.

Solution :

Length of the curve, $l = (\pi R)\Delta/180^o$, where Δ is in degrees.

$= \pi \text{ X } 375 \times 60^o/180^o$

$= 392.69$ m

Tangent Length, $T = R \tan \Delta/2$

$= 375 \times \tan 60^o/2$

$= 216.50$ m

Length of the long chord, $L = 2R \sin \Delta/2$

$= 2 \times 375 \times \sin 60^o/2$

$= 375.00$ m

Apex distance, $E = R(\sec \Delta/2 - 1)$

$= 375 \times (\sec 60^o/2 - 1)$

$= 58.01$ m

Mid-ordinate, $M = R(1 - \cos \Delta/2)$

$= 375 \times (1 - \cos 60^o/2)$

$= 50.24$ m

Degree of Arc, $D_a^o = 1718.9/R$

$= 1718.9/375$

$= 4^o.58$

Chainage of PC = Chainage of $I - T$

$= 1250.50 - 216.50$

$= 1034.00$ m

Chainage of PT = Chainage of $I + l$

$= 1250.50 + 392.69$

$= 1634.19$ m

Designation of Curve

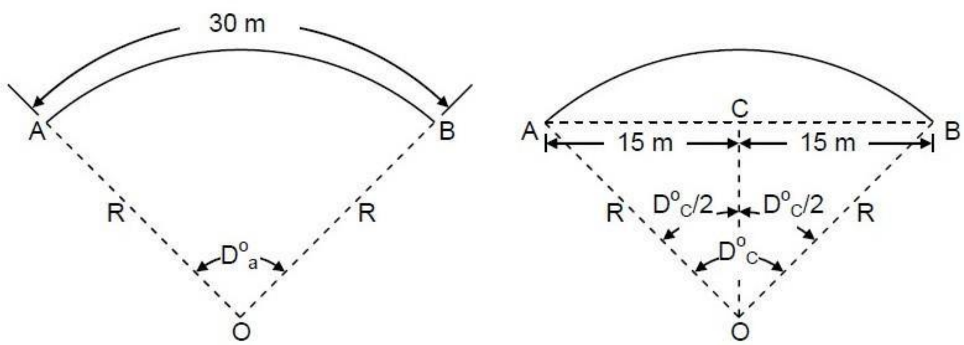
The *sharpness* of the curve is designated either by its *radius* or by its *degree of curvature*. The degree of curvature has several slightly different definitions. According to the *arc definition* generally used in highway practice, the degree of the curve (D_a^o) is defined as the central angle of the curve that is subtended by an arc *AB* of 30 m length .

If the degree of curve (D_a^o) is taken in degrees, for a curve of radius *R* meter, then

$$D_a^o : 30 = 360^o : 2\pi R$$

or $$D_a^o = 10800/2\pi R$$

$$= 1718.9/R \text{ (approximate)}$$



(a) Arc Definition (b) Chord Definition

Degree of Curve

According to the *chord definition* generally used in railway practice, the degree of the curve (D_c^o) is defined as the central angle of the curve that is subtended by its chord *AB* of 30 m length.

$$\sin(D_c^o/2) = AC/AO$$

$$= 15/R$$

$$R = 15/\sin(D_c^o/2)$$

Radius of curvature varies inversely as the degree of curve. A sharp curve has a larger degree of curve whereas a flat curve has a smaller degree of curve.

SETTING OUT SIMPLE CIRCULAR CURVE

A circular curve can be set out in the field by linear method and angular method. These are described below.

(a) Linear method is also called chain and tape method. In this method, only tape and chains are used and no angular measurement is carried out.

(b) In angular method or Instrumental method, a theodolite, tacheometer or a total station instrument is used for angular measurement.

Linear Method

Listed below are some of the linear methods of setting out simple circular curve followed by their description :

(a) Offsets from the long chord

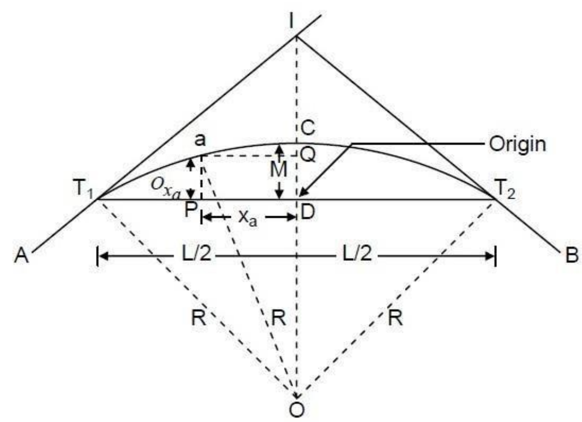
(b) Successive bisection of chord

(c) Offsets from the tangents

(d) Offsets from the chords produced

Offsets from the Long Chord

The method is suitable for setting out circular curves of small radius, such as those at road intersections in a city or in boundary walls. In Figure below, the offset O_{xa} to the point *a* on the curve is the perpendicular distance of point *a* from the long chord T_1T_2, at a distance x_a from *D* along the long chord. Considering the origin at *D*, O_{xa} is the *y*-coordinate of point *a*.



Offsets from the Long Chord

From Δ OT_1D,

$$(DO)^2 = (T_1O)^2 - (T_1D)^2$$

Or $$(OC - DC)^2 = (T_1O)^2 - (T_1D)^2$$

Or $$(R - M)^2 = R^2 - \left(\frac{L}{2}\right)^2$$

Or $$M = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

Draw a line Qa parallel to DT_1 cutting DC at Q

From Δ O a Q

$$OQ = \sqrt{(Oa)^2 - (Qa)^2} = \sqrt{R^2 - x_a^2}$$ OQ =

OD + DQ = OD + O_{x_a}

$$OQ = OD + O_{x_a} = \sqrt{R^2 - x_a^2}$$

$$O_{x_a} = \sqrt{R^2 - x_a^2} - OD$$

$$O_{x_a} = \sqrt{R^2 - x_a^2} - (R - M)$$

$$O_{x_a} = \sqrt{R^2 - x_a^2} - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

In general $O_x = \sqrt{R^2 - x^2} - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$

The long chord is divided into equal parts of suitable length. The offset O_{x_a} corresponding to the distances x_a from *D* are calculated for different points on the long chord. These offsets are measured perpendicular to the long chord with the help of an optical square and points are located. Joining these points will produce the desired curve. The points on the right side of *CD* are set out by symmetry.

Successive Bisection of Chords

The method being approximate is suitable for small curves. It involves the location of points on the curve by bisecting the chords and erecting perpendiculars at the midpoint of the chords.

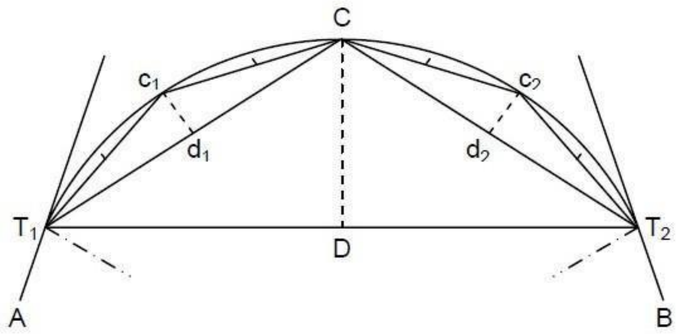
In Figure , T_1T_2 is the long chord and *D* is its midpoint. *C* is the point of intersection of the perpendicular line at *D*, with the curve. *Dc* is the mid-ordinate, which is equal to

$$M = R\left(1 - \cos\left(\frac{\Delta}{2}\right)\right) = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

At *D*, a perpendicular offset equal to *M* is erected and the position *C* is located. Now consider the chords T_1C and T_2C, locate their midpoints d_1 and d_2 respectively. Erect two perpendiculars at d_1 and d_2 and measure the offsets equal to d_1c_1 and d_2c_2, respectively. The offsets d_1c_1 and d_2c_2 are computed from the following formula :

$$d_1c_1 = d_2c_2 = R\left(1 - \cos\left(\frac{\Delta}{2}\right)\right)$$

Now, by the successive bisection of these chords, more points can be located in a similar manner.



Successive Bisection of Chords

After locating T_1 and T_2, the midpoint D of T_1T_2 is obtained, by measuring T_1T_2. The perpendicular offset DC is set out at D with an optical square and point C is located. Measure T_1C, and T_2C, and locate their midpoints d_1 and d_2. The perpendicular offsets d_1c_1 and d_2c_2 are set out at d_1 and d_2, and the points c_1 and c_2 are established on the curve. The process is continued till sufficient numbers of points on the curve are fixed.

Offsets from the Tangents

This method is used when the deflection angle and the radius of curvature both are comparatively small. In this method, the curve is set out by measuring offsets from the tangent. The offsets from the tangent can be either perpendicular or radial to the tangent.

Perpendicular Offsets Method

Let the point *a* be on the curve and the perpendicular offset from the tangent $T1$ to it at P be O_{x_a}. Let the distance of P from $T1$ be x_a. Draw a line Qa perpendicular to $T1O$, intersecting $OT1$ at Q.

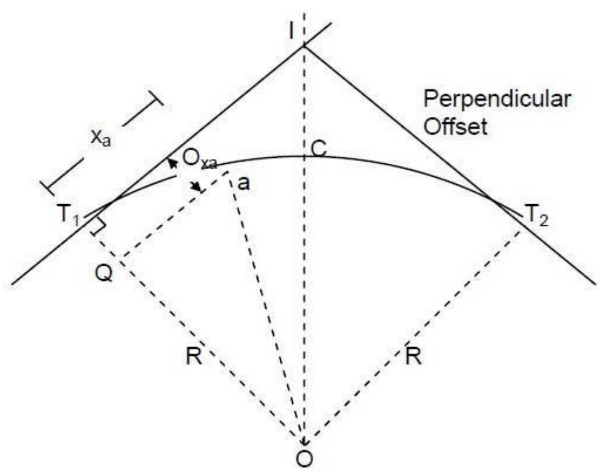
From $\Delta\ QaO$

$$OQ = \sqrt{(Oa)^2 - (Qa)^2}$$

$$R - O_{x_a} = \sqrt{R^2 - x_a^2}$$

$$R - O_{x_a} = R - \sqrt{R^2 - x_a^2}$$

In general $O_x = R - \sqrt{R^2 - x^2}$



Perpendicular Offsets

Before setting out a curve, a table of offsets for different values of x (e.g., 10 m, 20 m, 30 m, etc.) is made. Then from T_1 the distances x_1, x_2, x_3 etc., are measured along the tangent and the corresponding offsets are measured on the perpendiculars to the tangent with the help of an optical square.

Since the offsets of points equidistant from T_1 and T_2, are equal, the same table is used for offsets from both the tangents.

Radial Offsets Method

Let the radial offset to the point a on the curve be O_{x_a} from the point P at a distance of x_a from T_1.

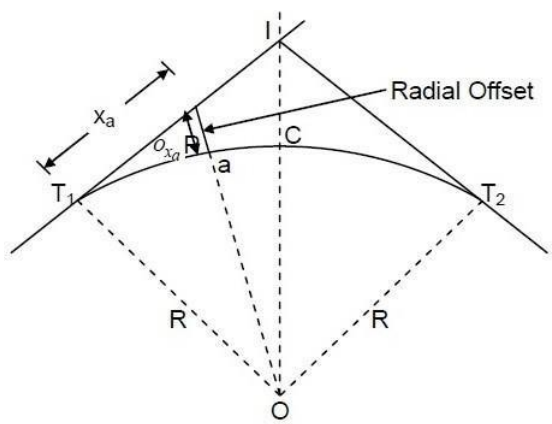
From $\Delta\ OPT_1$

$$OP = \sqrt{(OT_1)^2 + (T_1P)^2}$$

$$R + O_{x_a} = \sqrt{R^2 + x_a^2}$$

$$O_{x_a} = \sqrt{R^2 + x_a^2} - R$$

In general $O_x = \sqrt{R^2 + x^2} - R$



Radial Offsets

Offsets from the Chord Produced

The method has the advantage that not all the land between the tangents points T_1 and T_2 need be accessible. However to have reasonable accuracy the length of the chord chosen should not exceed R/20. The method has a drawback that error in locating is carried forward to other points. This method is based on the premise that for small chords, the chord length is small and approximately equal to the arc length.

For setting out the curve, it is divided into a number of chords normally 20 to 30 m in length. For the continuous chainage required along the curve, the two sub-chords are taken, one at the beginning and the other at the end of the curve. The first sub-chord length is such that a full number of chainage is obtained on the curve near T_1 and the second sub-chord length near T_2.

From the property of a circle, if the angle $\angle FT_1a = \delta_1$

The angle at the centre $\angle T_1Oa = 2\delta_1$

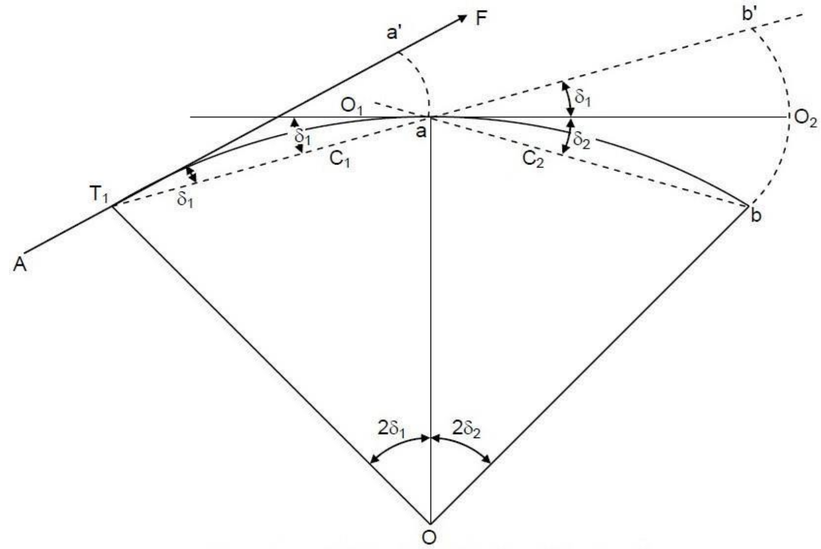
$C_1 = chord\,T_1a \approx arc\,T_1a$

$= 2\delta_1 R$

Or $\delta_1 = \frac{C_1}{2R}$

The first offset $O_1 = C_1\delta_1$

$$O_1 = C_1\frac{C_1}{2R} = \frac{C_1^2}{2R}$$



Offsets from the Chord Produced

The first chord C is called the sub-chord. The length of the sub-chord is so adjusted that the chord length when added to the chainage of T_1 makes the chainage of point a as full chain. Subsequent chord lengths C_2, C_3, C_4...................... are full chains. T_1a is then produced to b' such that a full chain $ab' = C_2$, a full chain.

The second offset

$O_2 = C_2(\delta_1 + \delta_2)$

$$= C_2\left(\frac{C_1}{2R} + \frac{C_2}{2R}\right)$$

$$= \frac{C_2}{2R}(C_1 + C_2)$$

Similarly $O_3 = \frac{C_3}{2R}(C_2 + C_3)$

The last offset $O_n = \frac{C_n}{2R}(C_{n-1} + C_n)$

where C_{n-1} is a full chain and C_n is the last sub-chord which is normally less than one chain length.

`

Angular Method

Following are some of the angular method used to set out a simple circular curve :

(a) Tape and theodolite method

(b) Two theodolite method

(c) Tachometric method

(d) Total station Method

Tape and Theodolite Method

In this method, a tape is used for making linear measurements and a theodolite is used for making angular measurements. The curve can be set out by the following procedures :

Rankine's Method

The method is known as Rankine's method of tangential angle or the deflection angle method. The method is accurate and is used in railways and highways.

Let T_1ab be a part of a circular curve with T_1, the initial tangent point. Thus, T_1a is the first sub-chord which is normally less than one chain length.

From the property of a circle

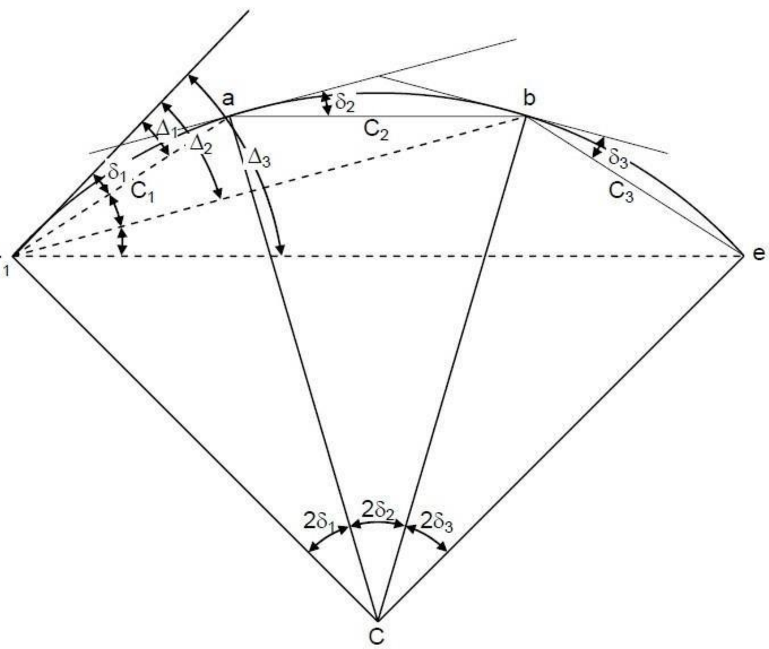
$C_1 = 2\delta_1 R$

$$\delta_1 = \frac{C_1}{2R} \text{ radian}$$

$$= \frac{C_1}{2R}\frac{180^0}{\pi}$$

$$= \frac{C_1}{2R}\frac{180 \times 60}{\pi} \text{ minutes}$$

$$= 1718.87 \frac{C_1}{R} \text{ minutes}$$



Rankine's Method

Therefore to locate the point a with the help of a theodolite and tape, the instrument is set at T_1 and the line of sight is put at an angle of $\delta_1 = \Delta_1$ as computed above. Then with the help of a tape and ranging rod, the tape is put along the line of sight and distance C_1 is then measured to locate point a along the line of sight.

Similarly,

$$\delta_2 = 1718.87 \frac{C_2}{R} \text{ minutes}$$

Since the theodolite remains at T_1, b is sighted from T_1 by measuring $\square_1 + \square_2 = \Delta_2$ from the tangent line. The point b is located with the help of a tape and ranging rod. The tape with the ranging rod is so adjusted that the tape measures $ab = C_2$ and the ranging rod lies along the line of sight $T_1 b$

Similarly,

$\Delta_3 = \square_1 + \square_2 + \square_3 = \Delta_2 + \square_3$

$\Delta_n = \square_1 + \square_2 + \square_3 + \ldots\ldots\ldots + \square_n = \Delta_{n-1} + \square_n$

In practice, C_1 is the first sub-chord and C_n the last sub-chord.

$C_2 = C_3 = \cdots = C_{n-1}$ are full chain lengths. As a check the deflection angle Δ_n for the last point T_2 is equal to $\frac{\Delta}{2}$ where Δ is the angle of intersection.

Field Problems in Setting Out the Circular Curves

The following are some of the field problems in setting out the circular curves.

(a) Point of curve inaccessible.

(b) Point of tangency inaccessible.

(c) Point of intersection inaccessible.

(d) Curve tangential to three lines.

(e) Both point of commencement and point of intersection inaccessible

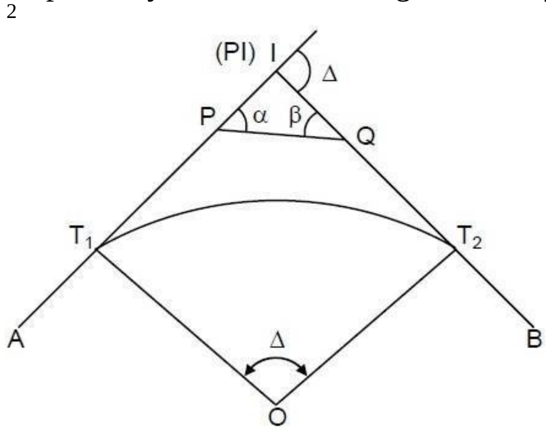
Point of intersection inaccessible

If the point of intersection P.I. is inaccessible then to set out a curve, the following procedure is followed : First locate points P and Q on IT_1 and IT_2 respectively, then measure angles α and β with the theodolite and length PQ with a tape .

Then $\frac{IP}{\sin\beta} = \frac{PQ}{\sin\Delta}$

Or $IP = \frac{PQ\sin\beta}{\sin\Delta}$

Similarly



Point of Intersection Inaccessible

$$IQ = \frac{PQ\sin\alpha}{\sin\Delta}$$

Calculate $PT_1 = IT_1 - IP$ QT_2

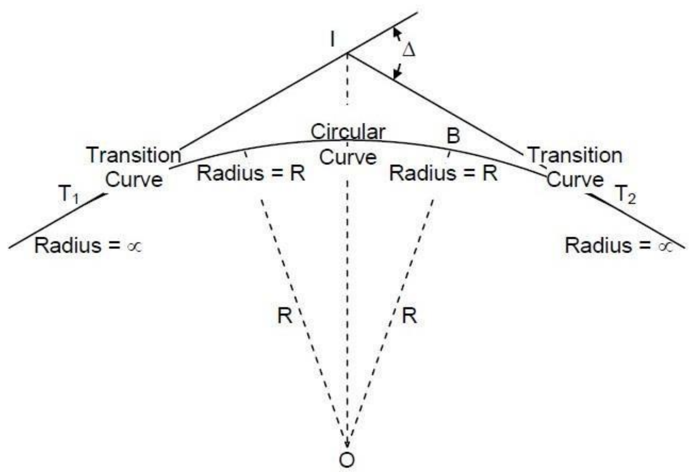
$= IT_2 - IQ$

Thus, T_1 and T_2 can be located from P and Q respectively and the curve can be plotted from T_1.

TRANSITION CURVE

A transition or easement curve is a curve of a varying radius introduced between a straight and a circular curve, or between branches of a compound curve or reverse curve. The introduction of a transition curve between the straight and the circular arc, as indicated in Figure below, permits the gradual elevation of the outer edge or gradual introduction of *cant or super-elevation* (raising the outer edge over the inner). At the same time, it also permits gradual change of direction from straight to the circular curve and vice-versa.

On a straight track, its two edges are at the same level. On a circular arc the outer edge is elevated depending on the radius of the curve and the speed to the vehicles expected, to avoid over turning of the vehicles due to centrifugal force acting on them while moving on circular path. Also, there is an abrupt change in direction when the alignment changes from straight to circular curve and vice-versa.



Transition Curve

In railways, such a curve is provided on both sides of a circular curve to minimise super-elevation. Excessive super-elevation may cause wear and tear of the rail section and discomfort to passengers.

Advantages of a Transition Curve

The introduction of a transition curve between a straight and a circular curve has the following advantages :

(a) The chances of overturning of the vehicles and the derailment of trains are reduced considerably.

(b) It provides comfort to the passengers on vehicles while negotiating a curve.

(c) The super-elevation is introduced gradually in proportion to the rate of change of curvature.

(d) It permits higher speeds at curves.

(e) It reduces the wear on the running gears

Characteristics of a Transition Curve

(a) It should be tangential to the straight.

(b) It should meet the circular curve tangentially.

(c) Its curvature should be zero at the origin on tangent.

(d) Its curvature should be equal to that of the circular curve at the junction with the circular curve.

(e) The rate of change of curvature from zero to the radius of the circular curve should be the same as that of increase of cant or super-elevation.

(f) The length of the transition curve should be such that full cant or super-elevation is attained at the junction with the circular curve.

CHAPTER-3

Scale is a fundamental concept of geography and is as essential for understanding Earth and its environments as it is for implementing public policy. Its precise definition is often debated by geographers, in part, because various subfields of geography use scale in different ways. Generally, scale is a form of size.

Map or Cartographic Scale

Map or cartographic scale is the ratio of a distance on Earth compared to the same distance on a map. There are three types of scales commonly used on maps: written or verbal scale, a graphic scale, or a fractional scale. A written or verbal scale uses words to describe the relationship between the map and the landscape it depicts such as one inch represents one mile. A map reader would use a ruler to measure the distances between places. A graphic scale is a bar marked off like a ruler with labels outlining the distances the segments represent. Just as you would with a written or verbal scale to measure distance with this type of scale you would use a ruler. Finally, a fractional scale, typically represented as a ratio (1/50,000 or 1:50,000), indicates that one unit (inch, centimeter, football field or pitch, etc.) on the map represents the second number of that same unit on Earth. So if the ratio was 1:50,000 one centimeter on the map would represent 50,000 centimeters (500 meters) in real life. The whole map, at this ratio, would encompass a typical county in the United States.

Somewhat counterintuitively we describe detailed maps of smaller areas as large scale maps and global maps as small scale. This is best illustrated with the fractional scale system. A large-scale map has a smaller ratio (1:10,000 or 1:25,000) and would have more details such as streets and building footprints. Whereas a small-scale map has a larger ratio (1:500,000 or 1:1,000,000) and illustrates an entire state, province, or country with just the larger cities or towns and major highways. Maps are not complete without a scale. It is key to making an accurate and understandable map.

Spatial Scale

There are three more general ways to describe scale as well: local, regional, and global. Local-scale is a specific place with unique physical features such as climate, topography, and vegetation.

Regions, however, vary considerably in size. They are generally larger than one place, such as a town or city, and may include several towns or multiple states or provinces. There are three types of regions: formal, functional, and vernacular. The easiest to identify is a formal region as it has recognized boundaries or borders and often governments. An example would be the German state of Bavaria or the Sahara Desert. A functional, or nodal, region is characterized by a common point or trait and is frequently used to describe economic areas such as the metropolitan area around Washington, D.C. in the United States. Finally, a vernacular or perceptual region is one that has characteristics that are perceived to be different from that of the surrounding areas. An example would be the Appalachian Mountains in the United States. Certain economic activities and cultural characteristics are attributed to an area that encompasses nine U.S. states that the mountain range covers.

Global-scale, of course, covers all of Earth. Studying patterns at this scale is critical due to globalization. As the world becomes more interconnected information, goods, and ideas are traded at faster and faster rates changing the way we communicate and live. While most feel globalization has not destroyed the uniqueness of specific places, forces promoting globalization often come into conflict with those focused on preserving local traditions. Additionally, in some cases, globalization has increased the wealth gap between wealthy and poorer nations.

Examining patterns in different scales is critical to understanding the problem and its effects, which often vary by location. In the study of climate change, choices made at the local level, such as burning fossil fuels for power, can have larger impacts at the regional level (e.g., acid rain) or the global level where we see the increase in atmospheric carbon dioxide leading to rising temperatures. The results of the rising levels of carbon dioxide have different impacts on different localities. Coastal regions battle rising sea levels and the ground is shifting below Arctic communities as the permafrost melts. In order to appropriately understand and address complex issues like climate change, we need to examine it and devise solutions at multiple scales.

Chapter-4

Survey of India, The National Survey and Mapping Organization of the country under the Department of Science & Technology, is the OLDEST SCIENTIFIC DEPARTMENT OF THE GOVT. OF INDIA.

It was set up in 1767 and has evolved rich traditions over the years. In its assigned role as the nation's Principal Mapping Agency, Survey of India bears a special responsibility to ensure that the country's domain is explored and mapped suitably, provide base maps for expeditious and integrated development and ensure that all resources contribute with their full measure to the progress, prosperity and security of our country now and for generations to come.

CHAPTER-5

Photogrammetry, digital orthophotography, orthophoto & orthoimage

An orthophoto or orthoimage is an image that is free of distortion (it has been ortho-rectified) and which is characterized by a uniform scale over its entire surface. We can consider by simplifying that it is like if each element shown on the image has been photographed directly from the vertical over it.

In other words, an orthophoto is a kind of scaled photographic map, on which it is perfectly possible to perform measurements as if it were a standard map. It is part of the photogrammetry field and is generally performed by Unmanned Aerial Vehicles (UAV).

The orthoimage can be overlaid with other maps containing other urban or technical elements like a power supply network, a dam, a road, a cable television network, a construction project, etc. Photogrammetry allows to obtain useful maps containing a lot of information helping making decisions.

Orthophotos are much faster and easier to create than establishing of a new area conventional map and they can be reproduced on a regular basis thanks to the cost efficiency and quick operability of drones.

These photographs are shot by air and the ease with which our Unmanned Aircraft Systems (UAS) can perform low altitude slow flight is particularly adapted for their acquisition.
The precision of an orthophoto is directly proportional to the resolution of the image captured by the embedded digital camera on board.

With the automated navigation flight, the Remotely Piloted Aircraft System (RPAS) will fly over the area to explore in a systematized way covering it completely. A percentage of overlap between the pictures will bring out the reliefs, the same way than the human stereoscopic vision does. The flight plan used by the operator will be uploaded on the drone on a case by case basis and will be adjusted to correspond to each specific photogrammetry mission.

Depending on the navigation path, the drone will scan the area on parallel axes and with a shift of a few degrees to precisely reach this stereoscopic human vision effect through the onboard camera.

Once on the ground, the images are analyzed, processed and corrected in order to eliminate distortions including the effect of the relief displacement. It calculates the Digital Elevation Model (DEM which is a topographic representation of an area) in order to correct them and adjust any associated terrain deforming errors.

Used in several fields, such as the urban & land use planning, administrative departments management, communication, agriculture, archeology and others, photogrammetry allows the identification of objects and geometric shapes projecting their measurements on the horizontal plane (Planimetrics).

CHAPTER-6

9.1 Micro-optic Theodolites :-

Micro-optic theodolites can read angles to an accurancy of 10” or even less. The es-sential principle is illustrated in Fig.9.1. The special features of such theodolites are as follows.

(a) Conventional metal circles are replaced by glass circles on which the graduations are etched by photographic methods. The graduations can be made finer and sharper by this technique. Both the horizontal and vertical circles are made of glass and generally graduated to 10.

(b) Light passing through the circle at the point of the reading is taken through a set of prisms to the field of view of the observer. For passing light through glass circles, sunlight is reflected through a reflecting prism and passed through the circle. In case night operation is required, the battery-operated light provided in the instrument can be used.

(c) Both the horizontal and vertical circles are seen at the same in the field of view. This is an advantage, as the readings of both the circles can be taken at the same time. Some manufacturers make a switching arrangement so that the horizontal or vertical circle reading can be seen along with the micrometer reading.

(d) The optical micrometer is used to read fractions of the main scale division. Depending upon the reading system, angles can be read up to 10’ or less.

(e) The circles are generally graduated to 10’ or 20’ of the arc. The micrometer can be read after coinciding the index with the nearest main scale division. The fractions are then read from the micrometer scale, which is also seen in the field of view.

(f) A small, separate reading telescope is provided besided the main telescope. It eliminates the need to move while bisecting an object and taking the reading.

(g) In most instruments, diametrically opposite ends of the circle are brought together in the field of view.

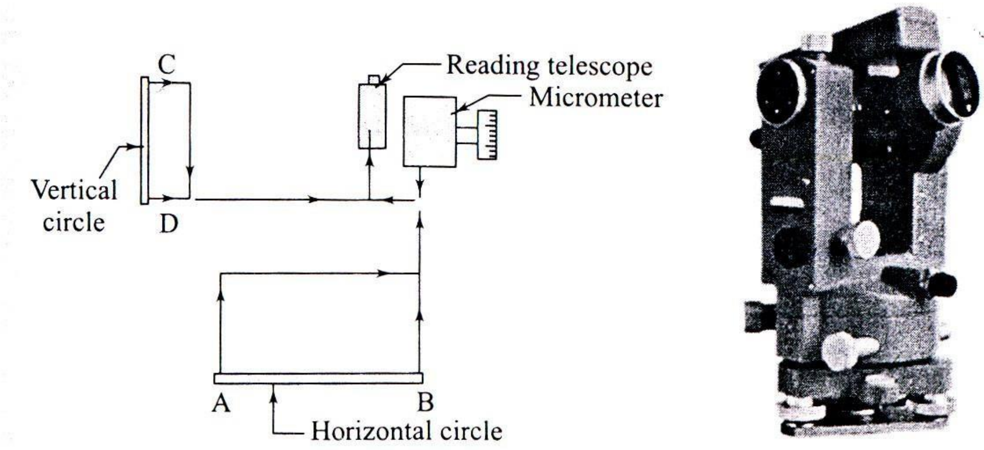


Fig.9.1

Digital theodolites:-

Digital theodolites are very fine instruments for angle and distance measurements. The instruments are light weight and are simplar to electronic theodolites in construction.

The instrument is set up over a station as in the case of normal theodolites. They will have extendable tripod legs which can be adjusted for comfortable viewing. The centering and leveling operations are done with a circular vial for coarse setting one has to press only a measure button to get the readings of angles and distances. Some models also have a laser pointer for easy alignment in critical cases and for staking out operations. With the arrival of total stations, these theodolites have less demand though they are cheaper compared to a total station.

The following are typical features in a digital theodolite:

- Angle measurement – by absolute encoding glass circle; Diameter – 71 mm
- Horizontal angle- 2 sides; vertical angle – one side; Minimum reading – 1"/5"
- Telescope – Magnification – 30x; Length – 152 mm; objective lens – 45 mm

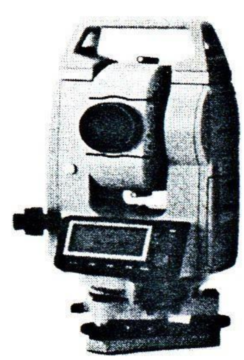


Fig.9.2

- Field of view - $1^0$30’ Minimum focus distance – 1m
- Stadia values: Multiplying constant – 100; additive constant-0
- Laser pointer – coaxial with telescope; 633 nm class II laser; Method – focusing for alignment and stake out operations.
- Display on both sides; 7-segment LCD unit
- Display and reticle illuminated
- Compensator- tilt sensor; vertical tilt sensitivity + 3’
- Optical plummet – magnification – 3x; field of view - 3^0; focusing from 0.5 m ti infinity
- Level sensitivity – Plate vial – 40”/2mm; circular vial – 10’/2mm
- Power supply – 4 AA size batteries; Operating times – Theodolite only – 140 hours
- Laser only – 80 hours; Theodolite + laser – 45 hours
- Weight – 4.2 kg.

(i) Electronic Distance Meter (EDM):

EDM equipment can be classified based upon the type of wave used, into M (microwave) DM and EO (electro-optical) DM equipment. The first type uses low-frequency short radio waves while the second type uses high-frequency light waves. They cal also be classified based upon the range as follows.

(a) Short-range equipment such as teleprompters and mekenometers with a range of up to 3 km.

(b) Medium-range equipment such as geodimeters with a range of up to 25 km. The range is about 5 km during the day and can go upto 25 km at night.

(c) High – range equipment with a range of up to 150 km. Tellurometers and distomats come under this category.

The accuracy varies with the range. Short-range equipment has an accuracy of ± (0.2 mm) + 1 mm/km. Medium-range equipment has an accuracy of ± (5 mm + 1 mm/km) while high-range equipment ha san accuracy of ± (10 m + 3 mm/km). Distomats have replaced other forms of equipment due to their compact design, ease of operation, and precision.

All types of equipment using electromagnetic waves perform the following functions.

(a) Generation of two waveforms for carrier and measurement functions.

(b) Modulation and demodulation of waves.

(c) Measurement of phase difference.

(d) Computation and display of distance or the results of measurement.

8.2 Total Stations

One of the recent developments in surveying equipment is the integration of distance- and angle-measuring components in one piece of equipment. A total station is the integration of an electronic theodolite with the EDM equipment. Many companies market total stations. Though the technology details used by different manufacturers may be different, they all have common features, which will be discussed below.

A digital theodolite is combined with one of the many forms of EDM equipment to obtain a very versatile instrument that can perform the required functions very easily.

Digital Theodolite:

The electronic or digital theodolite was discussed in Chapter 4. We will just recapitulate some salient points. These instruments have glass circles, which are encoded in the incremental or absolute mode. These are read by an optical scanning system and the reading is converted into angles and displayed or stored by the instrument. All the instruments are provided with an optical plummet for centering and a compensator system (single-axis or dual-axis) to take care of the tilt of the and the displayed angles and distances are previously corrected for such minor errors. The user can choose the required accuracy of angular measurement. These theodolites are normally operated by a rechargeable battery pack. The charged batteries can work for 40-80 hours. Some instruments need a prisms. Even reflecting tapes are used. A digital theodolite comes with the following facilities.

(a) Zero-setting

(b) Bidirectional measurement

(c) Precision setting

(d) Horizontal and vertical angles

(e) Slant distance and horizontal distance

(f) Difference in elevations

(g) Entry and display of data

(h) Display and storage of result

(i) Data management system and data transfer facility

A total station has all the above facilities and in addition measures horizontal distance using a built-in EDM module. Total stations come with a lot more facilities of data storage and manipulation. The following are the salient features of a total station.

Angle measurement:- Horizontal and vertical angles are measured to an accuracy of 1”-5”. The angles are displayed on the display unit of the console. Many instruments have console units on both sides of the instrument.

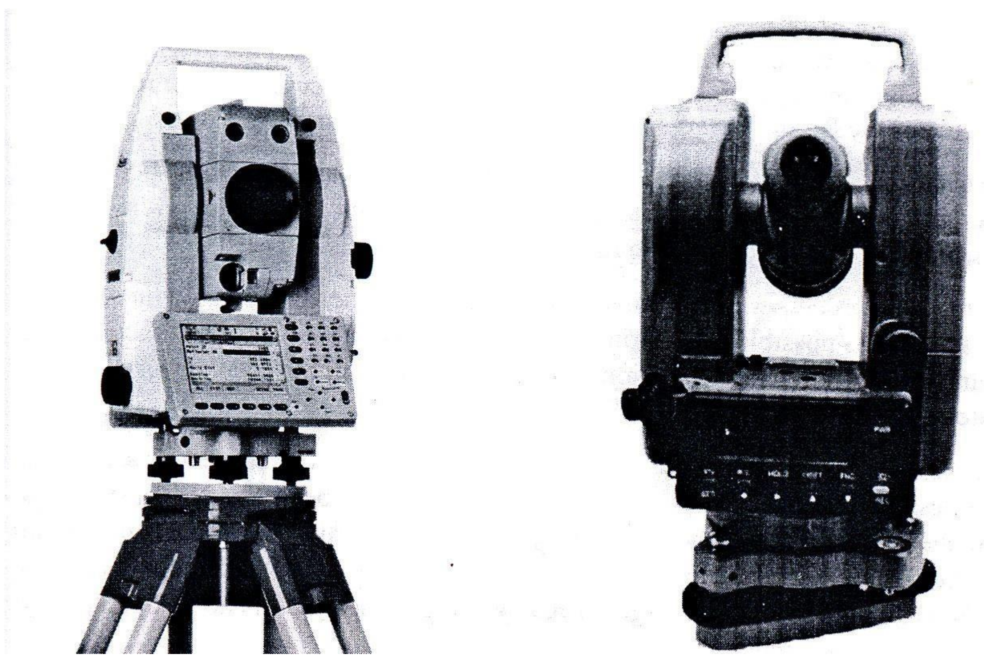


Fig.9.3

Distance measurement:- This is done with an EDM module functioning coaxially with the telescope tube. The distance measured is the slant distance if the stations are at different elevations. Reflecting multiple prisms are commonly used as targets, even though reflectorless distance measurement has also been made possible. The instrument uses the vertical angle measured by the theodolite and calculates the horizontal distance measurement can be done in different modes such as standard or coarse mode, precision mode, and fast mode, and fast mode. The precision and time taken vary depending upon the mode.

Microprocessor and software:- The onboard software in total stations can per form many functions. The processor is per-programmed, and in some cases can be programmed by the user to perform many useful functions with the measured data. The details may very with the manufacturers but some of the common features are as follows.

Automatic target recognition:- Most of the modern total stations have the facility of automatic target recognition (ART). In ATR, the telescope has to be roughly pointed towards the target while the measurement key is pressed. The instrument automatically points to the target before measurement. The instruments have motorized endless drives to facilitate ATR.

Reflectorless distance measurement:-Until recently, total stations had to be used with special multiple prisms as targets for EDM. The new versions of total stations can measure distances without a prism target. This means that distances to points where a target cannot be erected can now be measured easily without any extra survey effort. This has been made possible by a red laser, which can direct to a point on any surface.

Computation of reduced levels:- The reduced levels are measured from slope distance and vertical angle. Data input enables the user to input the height of instrument, height of target prism, and the RL of the station occupid. The instrument calculates the RL of the target station and displays the same.

Orientation:- The instrument automatically orients to any direction specified by the user. If the coordinates of two points are input, the horizontal circle will be oriented to measure the bearing of the line automatically.

Automated processes:- Automatic computation of coordinates of points, areas, offsets, etc. is possible with a total station. More and more on-board functions are being incorporated in total stations. Setting out points on the ground using coordinates or directions is possible.

Wireless keyboard and remote unit:- Many new total stations some with a separate wireless keyboard. The input of data to the station becomes very easy with a handheld keyboard. Another development is the availability of a remote unit so that the person at the prism can operate the total station for almost all the functions. As there is no need to bisect a target or read the angle, the system can be operated by one person positioned near the target.

Data management system:- Total stations have a very efficient data management system. Data transfer to data recorders, computers, or flash cards is possible. The in-built memory can store up to 10,000 blocks of data.

Graphic display:- Many new instrument have extremely powerful graphic display programmes. With large display panels, the data can be plotted and displayed.

Working with total station:-

Total stations are manufactured by many leading manufacturers of Survey equipment. Leica geosolutions, Topcon, Pentax, Nikon tripod data systems, Stonex are some of the major manufacturers of total stations. While specific details may vary with the manufacturers, some features are common to all of them.

A total station, as mentioned earlier, is a versatile equipment for surveying operations. The equipment details and operations can be understood by referring to the user manual provided with the equipment.

8.3 Aerial Surveying

The procedure for aerial surveying includes reconnaissance of the area, establishing ground controls, flight planning, photography, and then paperwork including computation and plotting.

Reconnaissance is undertaken to study the important features of the ground for reference purposes. Ground control is required in order to obtain a set of points known position based on which other points are located and plotted. The number of ground control points depends upon the extent of area covered, scale of the map to be prepared, flight plan, and the process of preparing the maps. A minimum of three control points must appear in each photograph. These points are established by triangulation or precise traversing.

Flight control is achieved by flight planning, which takes into account the extent of the area, type of camera and its focal length, scale of the photographs, altitude speed of aircraft, and the overlaps of the photograph. The area covered by each photograph. Time interval between exposures and the number of photographs quired are decided based upon such flight planning.

Stereoscopes:-

There are many types of stereoscopes- mirror stereoscope, lens stereoscopes, scanning mirror and zoom stereoscopes. Lens and mirror stereoscopes are handy and commonly used.

Mirror stereoscope :-The schematic diagram of the mirror stereoscope is shown in fig.9.4 (a). The mirror stereoscope consists of two viewing eyepieces. A stereoscopic pair of photographs is placed at a distance from the stereoscope. The photographs are adjusted so that one photograph is seen through one eyepiece. The instrument has four mirrors, two mirrors attached to each eyepiece. As the viewer looks through the stereoscope, he/she sees the image of the same object (the overlapping part) on the two photographs and this gives a stereoscopic view by fusion. The terrain is seen in relief due to this.

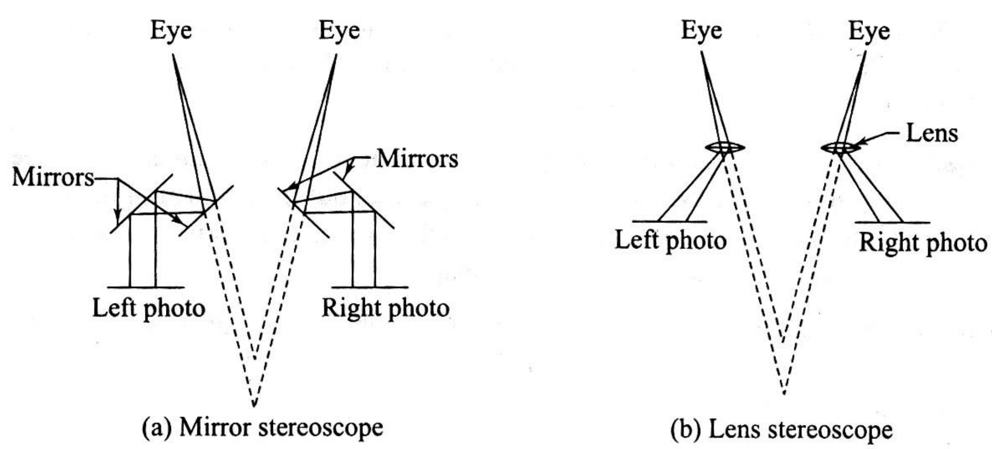


Fig.9.4

Lens stereoscope:- A lens stereoscope has two eyepieces through which the observer sees the photographs, providing the experience of stereoscopic or spatial view. The lenses help to magnify the image as seen by each eye. The distance between the eyepieces is adjustable and can be set by the observer as per requirement. This distance is approximately equal to the distance between human eyes. The lenses tend to magnify the object and its height. Lens stereoscopes are more compact than mirror stereoscopes.

Photo-interpretation:-

Photo-interpretation is the key to effective use of photographs. It refers to the accurate identification of the features seen in photographs. Objects seen in photographs are often not easy to recognize, and it takes some amount of skill on the part of the interpreter to correctly identify the objects and judge their significance. It is more difficult to identify objects in vertical photographs than in tilted photographs owing to the familiarity of view in oblique photographs. Colour photographs are easier to interpret than black and white photographs due to tonal variations. A stereoscopic pair is easier to interpret due to the depth available in the photographs when seen through a stereoscope. Considerable amount of practice and experience is required to correctly interpret photographs.

Interpretation of aerial photographs is required extensively in developmental project design and execution. It has been successfully applied in a variety of fields. The success of project planning depends on the effective and efficient interpretation of photographs by engineers and others and others. A good deal of patience and ingenuity is required to interpret photographs.

General Features of Photographic Images:-

The knowledge of some of the basic characteristics of the image in aerial photographs helps helps one to interpret these images. Photo-interpretation requires large-scale photographs. The success of the interpretation depends upon the experience of the person in addition to the conditions under which the photographs should be studied in the correct orientation with respect to the light conditions at the time of photography. Some of the basic features of photographs that help in identification are discussed here.

Size:- The size of an object in the photograph is sometimes helpful in interpretation. Knowing the photograph scale, it is possible to have an idea about the size knowing the correct size, one may not confuse among objects having similar shapes such as a river, road, canal, or drain.

Shape:- The shape of an object is helpful in identification. Regular shaped objects are generally man-made. Shape relates to the general outline or form of the object. A railway line and a roadway can be distinguished from their form. Objects of the same size can be distinguished from their shape.

Texture:- it is simply the variation in tone of the photograph. It is produced by a combination of factors such as size, shape, tone pattern, and shadow. Vegetation and other ground features can be distinguished by the tonal changes.

Pattern:- It is the spatial arrangement of objects in a particular set. A habit can be easily distinguished by the arrangement of roads, houses, etc. because of the pattern.

Shadow:- The shadow of an object formed during photograph is sometimes helpful in identification, as it shows the outline of the object.

Tone:- It is produced by the amount of light reflected back by the object to the camera. If the particular tones associated with specific objects are known, it is easy to identify them.

Location:- The location of an object in the photographs helps in identifying the object itself. Knowing the objects or areas surrounding the object, one can identify the main object. Refer Chapter 24 for more on visual image processing.

Applications and Advantages of Aerial Surveying:-

As has been discussed in the preceding sections, aerial surveying finds many applications in map preparation and map revision for large areas. Modern plotting machines and mostly automated operations have simplified the process of preparing maps from aerial photographs. Aerial surveying also finds extensive application in urban planning and development, transportation network design and calculations, disaster management, forestry, mining operations, reservoirs, agriculture, etc.

With advancements in technology, aerial photography has given way to aerial image processing. High-resolution digital image (soft image) can be made and processed using software to prepare excellent maps. All forms of rectification and corrections can be done automatically before converting the data into a map. Digital photogrammetric equipment and software have developed sufficiently to facilitate the preparation of very accurate maps.

Aerial Photogrammetry:-

Terrestrial photogrammetry virtually went out of use with the advent of aerial surveying techniques. Aerial photogrammetry makes use of cameras fitted in an aircraft to photograph an area from an overhead position. The principle of stereoscopic vision is used in studying and interpreting aerial photographs. Therefore overlapping photographs are taken in the direction of flight as well as in the lateral direction as the aircraft flies along a parallel path. It must be understood that while a map is an orthographic projection by projecting points perpendicular to the plane a photograph is a perspective projection, as all the light rays for forming the image pass through a point.

Basic Terminology:-

An aerial photograph is a record of the ground features at a point in time. Aircraft fitted with cameras moves along predetermined paths and takes photographs at planned intervals. The following are the basic terminology used to describe aerial photography.

Altitude: - Height of the aircraft above the ground.

Flying height: - Height of the aircraft above a chosen datum.

Exposure station:- Position of the aircraft at the time of exposure of the film. It is essentially the position of the optical centre of the camera lens when film I exposed.

Air base: - Distance between two consecutive exposure stations.

Tilt and tip: - Tilt is inclination of the optical axis of the camera about the line of flight. In ϕ is the tilt. Tip is the inclination of the camera axis about line perpendicular to the line of flight.

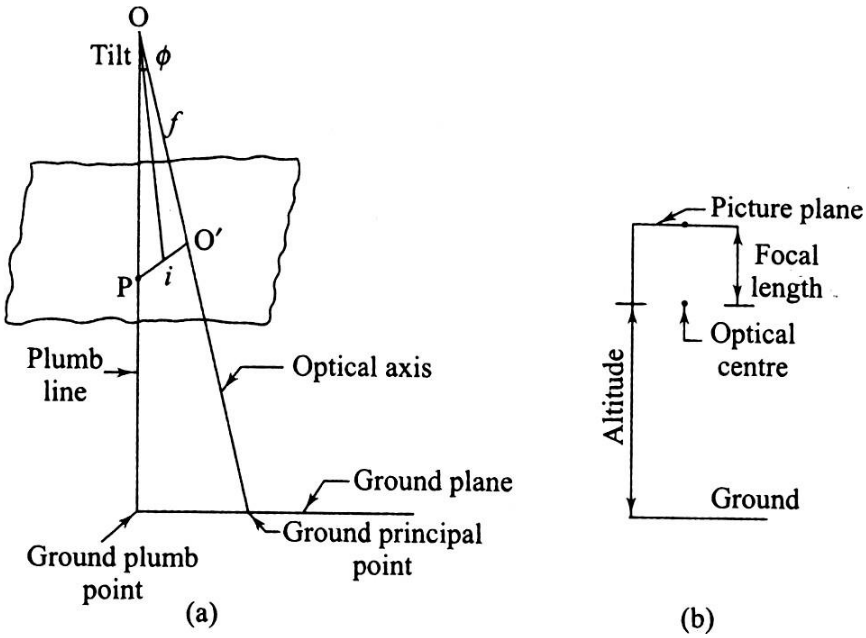


Fig.9.5

Picture plane:- Plane that contains the image at the time of camera exposure.

Ground plane: - Horizontal surface from which heights can be measured and which can be used as a datum surface.

Principal point:- Point of intersection of the optical axis of the camera with the photographic plane. O is the optical centre and O′ is the principal point. When the optical axis is extended downwards, the point of intersection with the surface is known as the *principal ground point.*

Isocentre: - Point on the photograph at which the bisector of the angle of tilt meets the photographic plane. 'i' is the isocentre, at a distance of $f \cos \phi$ along the principal line, where f is the focal length of the camera.

Plumb points: - The points at which the vertical line through the optical centre meets the photographic plane and the ground surface. The plumb point on the ground surface is also known as ground nadir point. The plumb point on the photograph is known as nadir point.

Homologous points: - Points on the ground and their representations in the photo graph in perspective projection.

9.4 Remote Sensing

Remote sensing, as the name implies refers to collecting data from a remote location without being in physical contact with the object. Remote sensing is not as uncommon as we may think. We have many remote sensing activities in day-to-day life. When we see an object and recognize its colour as red, we are using the concept of remote sensing. Similarly, our sense of smell also helps us to use remote sensing. Some of the common methods of remote sensing are described below.

Active and passive system of remote sensing:

In an active system of remote sensing, the sensing equipment emits radiation, which is reflected back from the object. Radar is a typical example of such a system. Radar equipment transmits radiation and the reflected radiation is analysed to determine the distance and presence of any object in the ranging area.

In a passive system of remote sensing, the instrument does not generate and emit radiation. The radiation reflected from an external source is made available to the object. We use the passive system exhaustively in the form of the sun's radiation. Taking a photograph using light from the sun is an example. Photographic cameras, still or motion picture, and television cameras use the passive system of remote sensing.

Applications/Uses of Remote Sensing

Remote sensing has applications in a wide spectrum of areas. Remote sensing can be used for taking sound decision for planning many human development activities. It is also possible to take preventive action as in the case of forest fire and natural disasters, Weather forecasting is another important application. Some of the application areas are given below.

Land use and land cover analysis:- Perhaps one of the prime uses of satellite remote sensing is in the study of land use and cover. Land cover through vegetation and specific crop areas can be studied using remote sensing data. Forest cover is an important aspect, which has been studied: the depletion of forest areas has been identified with the help of remote sensing. It is also possible to study crop diseases over large areas.

Mineral exploration:- It will be possible to use satellite data ana discover the presence of valuable minerals and ores that are vital to economic development. Non-renewable energy resources, such as fossil fuels, can be identified using remote sensing data.

Environmental studies:- Global weather phenomena are a major area for study using remote sensing data. Global warming and ozone layer depletion can be continuously monitored using remote sensing. Similarly, oceanographic studi4es also provide valuable information about the various characteristics of oceans around the world. Assessing water resources, their extent and depletion, snow cover studies, etc have proved to be valuable.

Archaeology:- Archaeological studies can make use of remote sensing data. The underlying old settlements can be recognized from remote sensing data and appropriate action can be taken to excavate and study the various aspects of old civilizations.

Disaster management: - This is another important application area of remote sensing. It has been possible to predict earthquake hazards by detecting unusual movements in the earth's crust. Floods .landslides, forest fires, etc can be detected on time and appropriate action can be taken for preventive action in disaster management.

Geomorphology: - Geological studies can provide valuable data on faults, tectonic movements, rock type identification, etc using remote sensing data.

Topography and cartography: - This is another application related directly to surveying. Remote sensing can be used to accurately locate points with reference to ground surveys are difficult or time consuming. This data can be used to prepare maps or revise existing maps.

Other applications: - Remote sensing data is now being used to study troop movements, etc for defense purposes. Other applications include urban planning studies, traffic studies, and assessment of earth's resources for various purposes, and so on.

Image Interpretation:-

Image interpretation is the process of extracting useful information from remote sensing data. Both qualitative and quantitative information can be extracted from maps .Earlier, the data was in analog form which is generally interpreted by humans Today, the data is generally is digital form which can be interpreted by humans of processed by computers. The correct interpretation of remote sensing data is very important if it is to be useful for the various purposes for which it has been obtained.

Visual Image Processing:-

The remote sensing data can come in either of the two forms – raw data or processes after certain corrections. Visual images can be monochromatic or grey scale images or colour composites or colour photographs. The objective of visual interpretation is to obtain qualitative information about objects seen in the image. This includes finding their size, location, and relationship with other objects the way our eye perceives an object is different from the way remote sensing data is obtained. first, the image is taken from an aerial platform- an aircraft or a satellite. The view from above will be quite different from the view seen from the ground. Second, the sensors used for imaging record radiations from many parts of the electromagnetic spectrum including the visible band. This makes the imagery look different from what we see otherwise. Third, resolution obtained and scale of the image may be quite unfamiliar to the eye. Finally, the ground relief feature may not be evident in two-dimensional photograph or image. Stereoscopes are used to view photo pairs having common imagery to get a feeling of depth.

The following three processes are involved in image interpretation:

(1) Image reading is the first step in image interpretation and involves identifying objects in the image by their size, shape, pattern, etc.

(ii) Measurement from images is the extraction of information such as length, width, height, and other parameters like density or temperature from data keys as reference.

(iii) image analysis is the understanding of the information extracted and comparing with ground reality or the status of the features as existing at the time of imaging.

Visual interpretation as it is done using photographs has to be supported by ground investigation for correctness of the interpretation. This becomes very necessary as the image may have many features which are not immediately understandable by the interpreter. Multiple images in multiple scales and multi- spectral images have to be interpreted and verified before reaching any conclusion.

Elements of visual Interpretation:-

Some key elements that assist the interpreter in studying and extracting information about the objects in the image are the following:

Location: - It refers to the information about the objects in the image in terms of any of the coordinate systems used such as latitude, longitude, and elevation. If some points are available in the image with known coordinates, then the coordinates for other points or objects can be obtained by measuring distances from the known points. Actual ground surveys can also be performed using easier methods that use GPS or by traditional methods of surveying that use total station to get coordinates. Computer processing of the image after rectification can also be employed to get information about coordinates.

Size: - The size of an object seen in an image depends upon the scale of the image. Knowing the scale of the image, the length, width, perimeter or area can be used to extract information about the subject. The absolute size of an object along with its relative size is also important in distinguishing between features having the same shape. The size can help distinguish between objects of the same shape such as a building or a football field.

Shape:- The shape of an object is distinguishable in the image and can help the interpreter to identify the object. Objects of regular shapes such as rectangles square, circle or oval are generally man-made structures. Irregular boundaries of an object generally mean that the object is of natural origin such as forest area or a lake. Since the imaging is done from above, it is necessary to know how an object looks from the top.

Shadow:- Shadows are generally not desirable in images as they change the nature of the image that would have been seen otherwise. However, shadows help in finding the heights of tall structures like towers and multi-storey buildings. Shadows are created due to low sun angles. In addition to aiding in ascertaining the height of objects, shadows also provide a profile view of objects which is helpful in identification.

Tone: - It is the relative brightness or colour intensity of the image. A black and white photograph is a grey tone image with brightness ranging from black to white. The remote sensing sensor receives and displays a band of the spectrum of electromagnetic radiation and this is displayed as continuous shades of grey which gives different tones in the image. Tones are useful features of interpretation because different objects give unique tonal qualities due to their reflectance. Tonal differences can occur due to different bands in multi-spectral images. Experience and a clear eye help to distinguish the tonal variation.

Color :- Color images are obtained from colour films. Colour photographs or images hold a lot more information than black and white grey tone images. From the natural colour of the image in the film many features like vegetation can be identified. Colour can change depending upon the type of film and filters used. Colour corrections can be done to images to give true colours of the objects.

Texture:- It can be defined as the characteristic placement and variations in definite patterns for objects in the grey tone image. Textures are classified as smooth or coarse. This is due to the visual impression created by the tonal changes. Coarse textures are due to sudden changes due to abrupt changes in tone in small patches giving a mottled appearance. Smooth texture comes from very little changes in tone. Texture helps to identify objects in an image due to characteristic textures of objectse, especially vegetation and forest trees.

Pattern: - It refers to the randomness or regularity of similar objects in the image. The pattern seen in the image is helpful in identification. Arrangement of trees in a forest is random, while trees in a orchard are placed in an orderly way. Same is true of houses in a neighborhood or buildings in a developed area. Such patterns can be identified and the objects recognized from the pattern.

Elevation: - As mentioned in Chapter 22, stereoscopes are used in association with photo pairs to have a view of the difference in elevation of objects. The overlapping areas of the images in photo pairs are useful in finding the elevations of points and also to have an idea about the relative heights of different objects seen in the image.

Interpretation keys: - These are used to help in visual interpretation of images. The keys are prepared by experienced interpreters who from past experience and ground verification prepare keys based on major elements of identification. Keys can be prepared for specific uses such as forestry, urban studies, network studies, and so on.

Chapter-7 BASIC ON GPS & DGPS AND ETS

The Global Positioning System (GPS) is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel.
GPS was introduced in 1978 with the launch of the first global positioning satellite. It was controlled and used solely by the U.S. government until the 1980s. The full fleet of 24 active satellites controlled by the
U.S. did not come into use until 1994.
Because the GPS satellite system is owned by the U.S. government, and it can selectively deny or limit access to the network, other countries have developed their own GPS satellite networks. These include:

- China's BeiDou Navigation Satellite System
- Russia's Global Navigation Satellite System (GLONASS)
- The European Union's Galileo positioning system
- India's Indian Regional Navigation Satellite System (IRNSS), also known as NAVIC

The GPS project was started by the U.S. Department of Defense in 1973, with the first prototype spacecraft launched in 1978 and the full constellation of 24 satellites operational in 1993.
The satellite system consists of a constellation of 24 satellites in six Earth-centered orbital planes, each with four satellites, orbiting at 13,000 miles (20,000 km) above Earth and traveling at a speed of 14,000 km/h.
GPS works through a technique called trilateration. Used to calculate location, velocity and elevation, trilateration collects signals from satellites to output location information. It is often mistaken for triangulation, which is used to measure angles, not distances.
Satellites orbiting the earth send signals to be read and interpreted by a GPS device, situated on or near the earth's surface. To calculate location, a GPS device must be able to read the signal from at least four satellites.
Each satellite in the network circles the earth twice a day, and each satellite sends a unique signal, orbital parameters and time. At any given moment, a GPS device can read the signals from six or more satellites.

Working of GPS

When a satellite sends a signal, it creates a circle with a radius measured from the GPS device to the satellite.
When we add a second satellite, it creates a second circle, and the location is narrowed down to one of two points where the circles intersect.
With a third satellite, the device's location can finally be determined, as the device is at the intersection of all three circles.
That said, we live in a three-dimensional world, which means that each satellite produces a sphere, not a circle. The intersection of three spheres produces two points of intersection, so the point nearest Earth is chosen.
Here is an illustration of satellite ranging:

ERRORS IN GPS

The major sources of GPS positional error are:

- Atmospheric Interference
- Calculation and rounding errors
- Ephemeris (orbital path) data errors
- Multi-path effects

USES OF GPS

There are five main uses of GPS:

1. Location — Determining a position.

2. Navigation — Getting from one location to another.
3. Tracking — Monitoring object or personal movement.
4. Mapping — Creating maps of the world.

5. Timing — Making it possible to take precise time measurements. Some specific examples of GPS use cases include:

- **Emergency Response:** During an emergency or natural disaster, first responders use GPS for mapping, following and predicting weather, and keeping track of emergency personnel. In the EU and Russia, the eCall regulation relies on GLONASS technology (a GPS alternative) and telematics to send data to emergency services in the case of a vehicle crash, reducing response time. Read more about GPS tracking for first responders.
- **Entertainment:** GPS can be incorporated into games and activities like *Pokémon Go* and Geocaching.
- **Health and fitness:** Smartwatches and wearable technology can track fitness activity (such as running distance) and benchmark it against a similar demographic.
- **Construction, mining and off-road trucking:** From locating equipment, to measuring and improving asset allocation, GPS enables companies to increase return on their assets. Check out our posts on construction vehicle tracking and off-road equipment tracking.
- **Transportation:** Logistics companies implement telematics systems to improve driver productivity and safety. A truck tracker can be used to support route optimization, fuel efficiency, driver safety

and compliance.

CHAPTER-8

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The key word to this technology is **Geography** – this means that some portion of the data is spatial. In other words, data that is in some way referenced to locations on the earth.

Coupled with this data is usually tabular data known as attribute data. Attribute data can be generally defined as additional information about each of the spatial features. An example of this would be schools. The actual location of the schools is the spatial data. Additional data such as the school name, level of education taught, student capacity would make up the attribute data.

It is the partnership of these two data types that enables GIS to be such an effective problem solving tool through spatial analysis.

GIS is more than just software. People and methods are combined with geospatial software and tools, to enable spatial analysis, manage large datasets, and display information in a map/graphica

What can we do with GIS?

GIS can be used as tool in both problem solving and decision making processes, as well as for visualization of data in a spatial environment. Geospatial data can be analyzed to determine (1) the location of features and relationships to other features, (2) where the most and/or least of some feature exists, (3) the density of features in a given space, (4) what is happening inside an area of interest (AOI), (5) what is happening nearby some feature or phenomenon, and (6) and how a specific area has changed over time (and in what way).

1. **Mapping where things are.** We can map the spatial location of real-world features and visualize the spatial relationships among them. Example: below we see a map of frac sand mine locations and

sandstone areas in Wisconsin. We can see visual patterns in the data by determining that frac sand mining activity occurs in a region with a specific type of geology.

2. **Mapping quantities.** People map quantities, such as where the most and least are, to find places that meet their criteria or to see the relationships between places.
Example: below is a map of cemetery locations in Wisconsin. The map shows the cemetery locations as dots (dot density) and each county is color coded to show where the most and least are (lighter blue means fewer cemeteries).

3. **Mapping densities.** Sometimes it is more important to map concentrations, or a quantity normalized by area or total number. Example: Below we have mapped the population density of Manhattan (total population counts normalized by the area in sq. miles of census tracts.)

4. **Finding what is inside.** We can use GIS to determine what is happening or what features are located inside a specific area/region. We can determine the characteristics of "inside" by creating specific criteria to define an area of interest (AOI). Example: below is a map showing a flood event and the tax parcels and buildings in the floodway. We can use tools like CLIP to determine which parcels fall inside the flood event. Further, we can use attributes of the parcels to determine potential costs of property damage.

Reference book:

Surveying vil-I,II,III

By: B. C. Punmia

A text book of surveying and levelling

By: R. Agor

Surveying and Levelling

N. N. Basak