3. *LEVELING*

3.1. Introduction:

Leveling *is an operation in surveying performed to determine the difference in levels of two points.*

- By this operation the height of a point from a *datum, known as elevation, is determined.*
- The most commonly used datum is mean sea level (MSL)

Definitions of terms

1. Datum:- A datum is any reference surface to which the elevation (vertical distance) of a points are referred. The most commonly used datum is that of mean sea level.

2. A vertical line: - is a line parallel to the direction of gravity. It is best represented by a plump bob, which is suspended freely at a point.

3. A Level line: -is a curved line in a level surface where all points in a line have equal elevation. Every element of a line is perpendicular to gravity.

4. Horizontal line: - a straight-line tangent to a level line at a given point.

5. Level surface: - is a surface of constant elevation that is perpendicular to a plumb line at every point.

6. Horizontal surface (plane): - is a plane tangent to a level plane or it is a plane perpendicular to the direction of gravity.

7. Difference in elevation: -is the vertical distance between level surface passing through a point.

8. Bench mark (BM): - is a permanent or semi-permanent point of known elevation that provides beginning point for determining the elevation of other points.

Methods of Leveling

There are three general methods of leveling spirit, trigonometric, and barometric.

1. Spirit leveling (direct leveling):- is the usual method of leveling where vertical distances are measured in relation to horizontal line and these measurements are used to compute the differences of elevations between various points. The spirit level is used to fix the line of sight of the telescope.

***2. Trigonometric leveling*:-**in this type of leveling, horizontal distances and vertical angles are measured and used to compute elevation differences. This method is widely applied for points, which are not accessible **e.g.** Mountain peaks.

3. Barometric leveling: -involves the determination of elevations by measuring changes in air pressure. There is an inverse relationship between earth's atmospheric pressure and elevation.

Leveling Instrument:

A level consists of a high- powered telescope with a spirit level attached to it in such a manner that when its bubble is centered, the line of sight is horizontal. The purposes of the telescope are to fix the direction of the line of sight and to magnify the apparent sizes of objects observed.

The telescope has three main parts: the objective lens, the eyepiece, and the reticule (cross-hairs).

Temporary adjustment of leveling

Three steps that are followed before a reading is taken at a station:-

1. Setting up instrument over a station
2. Leveling the instrument
3. Focusing to avoid parallax

1. Setting up instrument over a station:

- Set up the tripod on firm and solid ground. The tripod head should be approximately horizontal.

- On soft & smooth round use supports for the tripod legs such as stakes or a platform.
- Never touch the tripod legs after adjustment.
- **Plumb bob**:- used to center the instrument exactly on the station mark
- **Centering**:- used to place the vertical axis exactly over the station mark
- **Foot screw**:-used to adjust the leveling by screwing in or out ward.

2. Leveling the instrument:

Leveling:- used to make the vertical axis truly vertical

In three- foot screw instrument

a) Turn the telescope until the bubble tube is parallel to two of the screws.

- The bubble is centered by turning these two screws in opposite directions.

b) The telescope is turned so that the bubble tube is perpendicular to a line through screws 1 and 2. The bubble is centered by turning screw 3.

These steps are repeated until the bubble stays centered when the telescope is turned back and forth.

3. Focusing of telescope:

There is an apparent movement of the image of the object on the cross hairs called parallax. The surveyor should carefully focus the objective lens until the image and the cross hair appear to be exactly in the same place.

Care of equipment:

The level: Before the level is removed from its box, the tripod should be set up in a firm position in such a way that it is horizontal. After the instrument is taken from its box, it should be handled by its bas when it is not on the tripod, and it should be carefully screwed on the tripod.

- If possible, levels should not be set up on smooth hard surfaces, such as building floors, unless the tripod points can be either set in indentations in the floor or firmly held in place by some other means, perhaps by triangular frames made for that purpose.

- If the objective lens or the eyepiece lens becomes so dusty that it interferes with vision, it may be cleaned with a camel's hair brush or with lens paper.

***Leveling screws*:-** If the instrument is in proper condition, these screws should turn easily and it should never be necessary to use more than the finger tips for turning them.

- When the level is taken indoors for storing or outdoors for use, its screws and clamps should be loosened because severe temperature changes may cause severe damage.

***Level rod*: -** The level rod should never be dragged on the ground and its metal base should never be allowed to strike rocks, pavement, or other hard objects, such use will gradually wear away the metal base and will thereby cause leveling errors due to the change in the length of the rod itself.

Equipments used in leveling

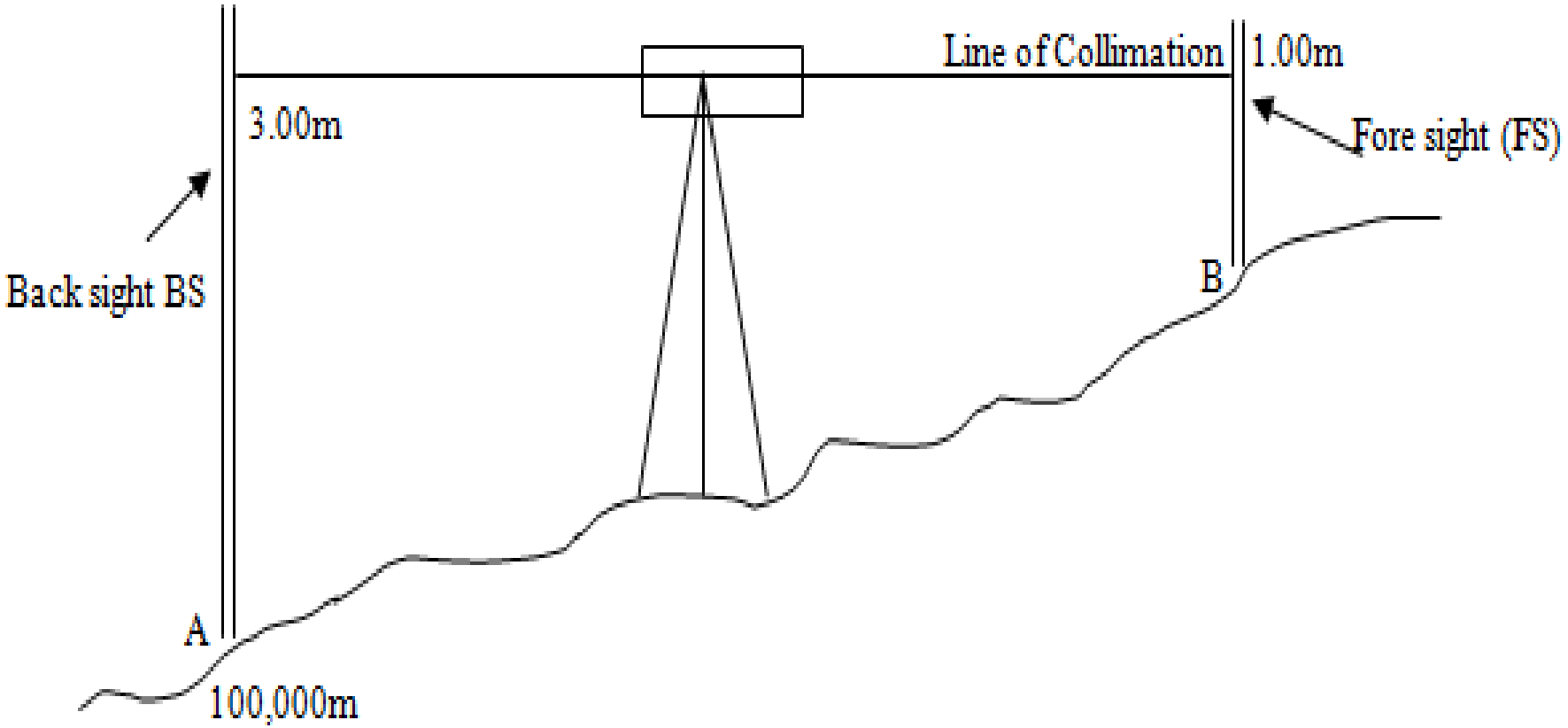
- Basically three equipments are needed.
  - Level – to give the true horizontal line
  - Staff – to read vertical height
  - Tape – to measure height of instruments

Note: There are three types of level

- Tilting
- automatic
- Digital

Principle of leveling

The instruments are set up and correctly leveling in order to make the line of sight through the telescope



- With the instruments set up approximately midway between ground points A & B. If the reduced level (RL) of points A is known and equals to 100,000m above a certain reference datum then the reading at 300m on vertically herd staff at A gives the reduced level of horizontal line of sights as 103,000m.
- This sights on to A is termed as back sights (BS) and reduced level of the line of sights is called height of plane at collimations (HPC/HI)

The reading of 1,000m on to staff at B is called foresight (FS) and shows the ground point B to be 1,000 below HPC/HI therefore its RL = (103,000 – 1,000) = 102,000m

Then this is the basic concept of leveling which is then developed in to following leveling.

Thus, RL = (103,000 – 1,000)

= 102,000m

RLA + BS = HPC

Booking and Reducing the Levels

Before discussing the booking and methods of reducing levels, the following terms associated with differential leveling must be understood.

Station: A station is the point where the leveling staff is held. (Points A, a, b, B, c, and C in Fig. 3.1).

Height of instrument (H.I.) or height of collimation: For any set up of the level, the elevation of the line of sight is the height of instrument.

Back sight (B.S.): It is the first reading taken on the staff after setting up the level usually to determine the height of instrument. It is usually made to some form of a bench mark (B.M.) or to the points whose elevations have already been determined. When the instrument position has to be changed, the first sight taken in the next section is also a back sight. (Staff readings S1and S5 in Fig. 3.1).

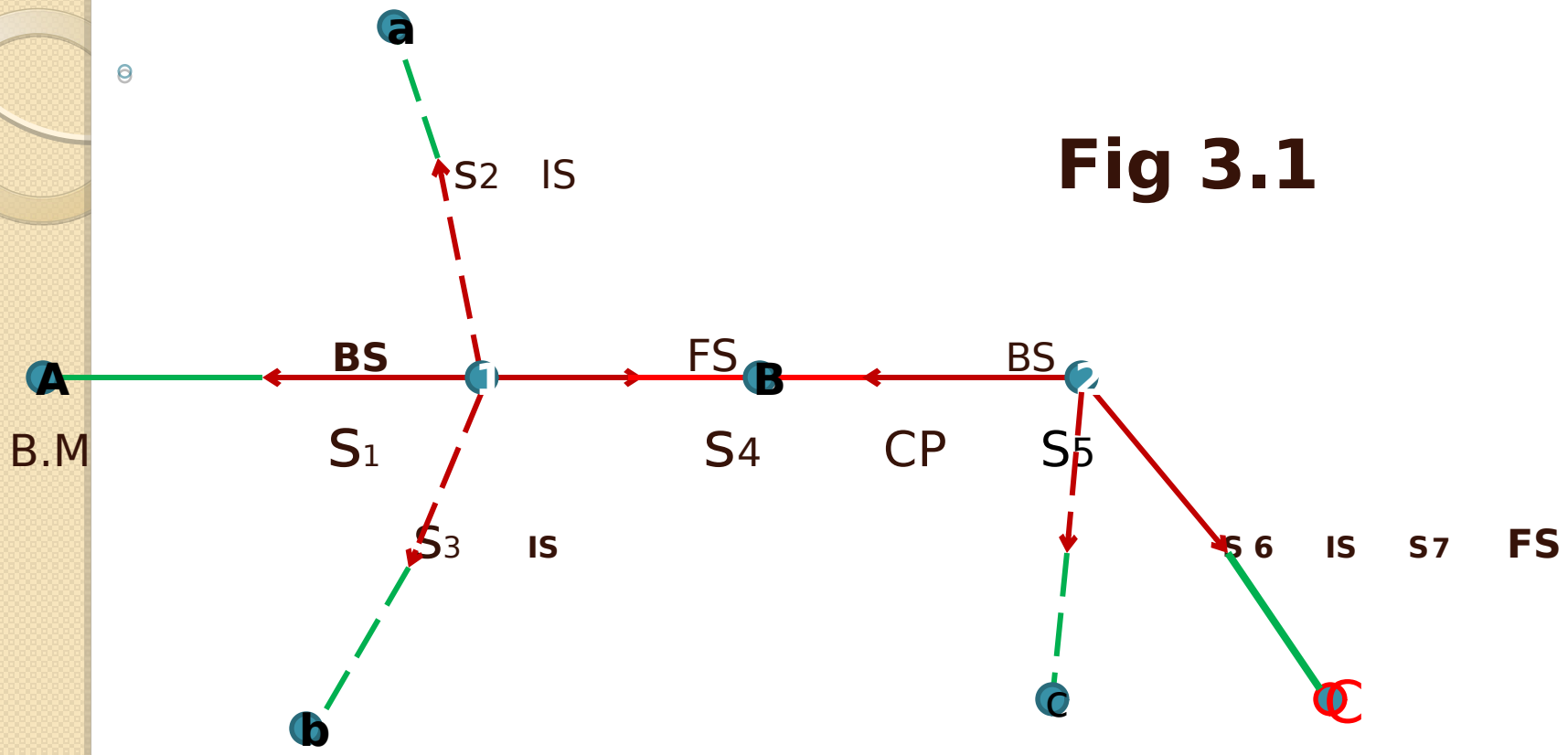


Fig 3.1

Where :- A is B.M,

B , a, b ,c & C are staff position/station

Fore sight (F.S.): It is the last reading from an instrument position on to a staff held at a point.

It is thus the last reading taken within a section of levels before shifting the instrument to the next section, and also the last reading taken over the whole series of levels. (Staff readings S4 and S7

in Fig. 3.1).

Change point (C.P.) or turning point: is the point where both the fore sight and back sight are made on a staff held at that point.

A change point is required before moving the level from one section to another section. By taking the fore sight the elevation of the change point is determined and by taking the back sight the height of instrument is determined.

The change points relate the various sections by making fore sight and back sight at the same point. (Point B in Fig. 3.1).

Intermediate sight (I.S.): The term ‘intermediate sight’ covers all sightings and consequent staff readings made between back sight and fore sight within each section.

Thus, intermediate sight station is neither the change point nor the last point. (Points a, b, and c in Fig. 3.1).

Balancing of sights: When the distances of the stations where back sight and fore sight are taken from the instrument station, are kept approximately equal, it is known as balancing of sights.

Balancing of sights minimizes the effect of instrumental and other errors.

Reduced level (R.L.): Reduced level of a point is its height or depth above or below the assumed datum. It is the elevation of the point.

Rise and fall: The difference of level between two consecutive points indicates a rise or a fall between the two points. In Fig. 3.1, if (SA– SB) is positive, it is a rise and if negative, it is a fall. Rise and fall are determined for the points lying within a section.

Section: A section comprises of one back sight, one fore sight and all the intermediate sights taken from one instrument set up within that section. Thus the number of section is equal to the number of set ups of the instrument. (From A to B for instrument position 1 is section-1 and from B to C for instrument position 2 is section-2 in Fig. 3.1).

For booking and reducing the levels of points, there are two systems, namely the height of instrument or height of collimation method and rise and fall method. The columns for booking the readings in a level book are same for both methods but for reducing the levels; the number of additional columns depends upon the method of reducing the levels. Note that except for the change point, each staff reading is written on a separate line so that each staff position has its unique reduced level.

This remains true at the change point since the staff does not move and the back sight from a forward instrument station is taken at the same staff position where the fore sight has been taken from the backward instrument station. To explain the booking and reducing levels, the leveling operation from stations A to C shown in Fig. 3.1, has been presented in Tables 3.1 and 3.2 for both the methods. These tables may have additional columns for showing chain age, embankment, cutting, etc., if required.

Table 3.1 Height of instrument method

Station	B.S.	I.S.	F.S.	H.I.	R.L	Remarks
A	S1			H.I.A=hA+S1	hA	B.M. = ha
a		S2			ha= H.I.A – S2	
b		S3			hb= H.I.A– S3	
B	S5		S4	H.I.B=hB+S5	hB= H.I.A– S4	C.P.
c		S6			hc= H.I.B– S6	
C			S7		HC= H.I.B– S7	
	ΣB.S.		ΣF.S			

Check: ΣB.S. – ΣF.S. = Last R.L. – First R.L

- In reducing the levels for various points by the height of instrument method, the height of instrument (H.I.) for each section highlighted by different shades, & is determined by adding the elevation of the point to the back sight reading taken at that point. The H.I. remains unchanged for all the staff readings taken within that section and therefore, the levels of all the points lying in that section are reduced by subtracting the corresponding staff readings, i.e., I.S. or F.S., from the H.I. of that section.

- **In the rise and fall method**, the rises and the falls are find out for the points lying within each section. Adding or subtracting the rise or fall to or from the reduced level of the backward station obtains the level for a forward station. In the ffg Table 3.2, r and f indicate the rise and fall, respectively, assumed between the consecutive points.

Table 3.2 Rise and fall method

Station	BS	IS	FS	Rise	Fall	RL	Remark
A	S1					hA	B.M. = ha
a		S2		r1 =S1– S2		ha= hA+ r1	
b		S3			f1 =S2– S3	hb= ha– f1	
B	S5		S4		f2 =S3– S4	hB= hb– f2	C.P
c		S6			f3 =S5– S6	hc= hB– f3	
C			S7	r2 =S6 S7		hC= hc+ r2	
	ΣB.S		ΣF.S .	ΣRise	ΣFall		

Check: ΣB.S. −ΣF.S. = ΣRise − ΣFall = Last R.L. −First R.L

The arithmetic involved in reduction of the levels is used as check on the computations. The following rules are used in the two methods of reduction of levels.

(a) For the height of instrument method

(i) ΣB.S. – ΣF.S. = Last R.L. – First R.L.

(ii) Σ[H.I. × (No. of I.S.'s + 1)] – ΣI.S. – ΣF.S. = ΣR.L. – First R.L.

(b) For the rise and fall method

ΣB.S. – ΣF.S. = Σ Rise – Σ Fall = Last R.L. – First R.L.

- Generally in *Height of instrument (HI) method*

The desired elevation of a point is found by:-

1st adding BS in to given benchmark to find height of instrument:- HI=BM+BS

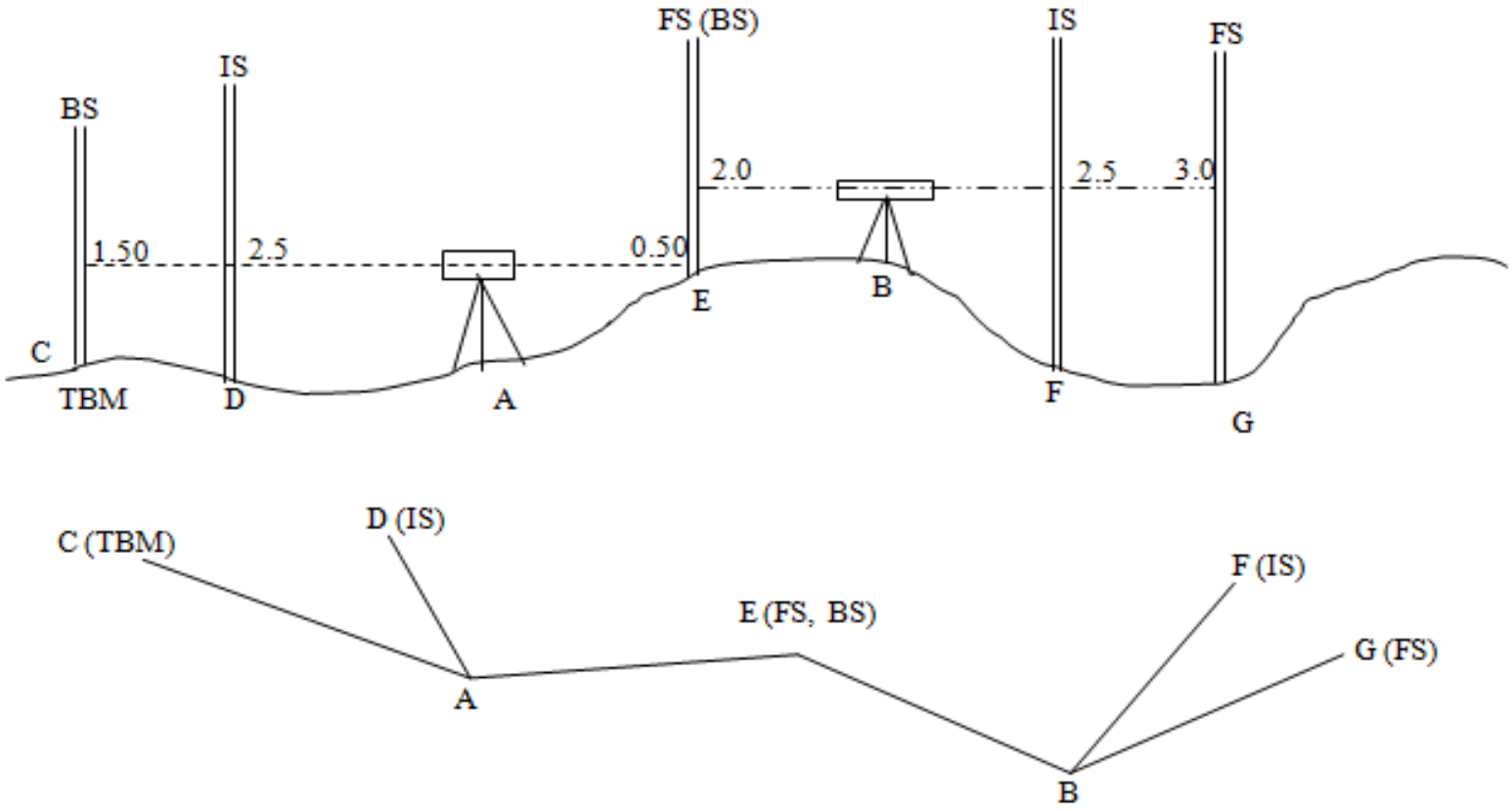
2nd subtracting IS or FS from height of instrument to find RL. RL=HI-IS/FS

Example:-

Station	BS	IFS	FS	Remark
A	2.20			BM(RL=100 m)
B	1.50		2.30	TP
C	1.75		1.80	TP
D	1.30		1.50	TP
E		1.90		
F			1.80	Closing point

Station	BS	IFS	FS	HI	RL	Remark
A	2.20			102.20	100.0	BM
B	1.50		2.30	101.40	99.90	TP
C	1.75		1.80	101.35	99.60	TP
D	1.30		1.50	101.15	99.85	TP
E		1.90		>>	99.25	
F			1.80	>>	99.35	Closing pt.

Cont..


BS
IS
FS (BS)
IS
FS
1.50
2.5
0.50
2.0
2.5
3.0
C
TBM
D
A
E
B
F
G
C (TBM)
D (IS)
E (FS, BS)
F (IS)
G (FS)
A
B

Let RL be reduced level

R = Staff reading.

Then

RLC = TBM

RLD = RLC + (RC – RD)

RLE = RLC + (RC – RE)

RLF = RLE + (RE – RF)

RLG = RLE + (RE – RG)

Rise and fall

The basic concept of rise and fall is illustrated by the above fig. Let RLC = TBM = 100, 000m above BM

The line of sight from the instruments at A is truly horizontal. It can be seen that the higher reading of D i.e. 2.50 indicates that it is lower than C (TBM).

This can be written

1.5 – 2.50 = -1.0 indicated fall from C to D

Similarly from C to E

1.5 – 0.5 = +1.0 indicating the rise from C to E.

If the reduced level of TBM = RLC then

RLD = RLC + (RC – RD) but RC – RD = fall

= 100.00 – 1 = 99.00

RLD = RLC + fall

RLE = RLC + (RC – RE)

But RC – RE = Rise

= 100 + 1 = 101

RLE = RLC + rise

* This method of reducing staff reading gives system of booking known as rise and fall method.

The comparison of line of collimation method and Rise – fall method

Height of collimation

1. It is more rapid & souse time
2. Is use for reduction of level for construction work Such as longitudinal or cross sectional leveling operation.
3. There is no check for reduction of RLs of intermediate site
4. There are only two arithmetic check.
5. Errors if any in IS are got detected

Rise & fall method

1. It is laborious to compute the rise & fall
2. It is well adopted for determining d/c in elevation of two points.
3. There is complete check on reduction of RLs of IS.
4. There arithmetic check.
5. Errors in IS are detected.

Errors in leveling

The errors in leveling might occur due to

- Instrumental error : *Collimation* (when the line of sight is not truly horizontal), *Defect of staff, Tripod defects.*
- Field error: *staff not vertical, Handling the instruments and tripod*
- Effect of Earth curvature and refraction of light

Chap-4

4.Topographic Surveying and Mapping

Topographic survey

- Made to determine the locations of *natural* and *artificial* features on the Earth's surface and to define the configuration (relief) of that surface.
- Then these features can be represented on maps.

Natural:

Vegetation, rivers, lakes, oceans, and so on

Artificial:

Roads, rail roads, buildings, bridges, canals, and so on

Chap-4

Relief:

Hills, valleys, plains, and other surface irregularities

Application of TM for d/t Disciplines

Engineers and planners: suitable site for roads, pipelines...

Geologists: to investigate mineral oil, water

Foresters: fire control routes, observation towers

Architects: housing and landscape design

Methods of showing relief

- Contours: the most commonly used
- Digital Elevation Model (DEM)
- Three Dimesional perspective models

Newer methods

Chap-4

- Hachures
- Shading
- Tinting

Not quantitative enough, generally unsuitable for surveying and engineering work

- **Contour** is a line which connects points of equal elevation.

- Field work in topographic surveying is divided in to two:

1. Control establishment
2. Detail surveying

A. Contol Establishment:

1. Horizontal control establishment steps

   - Identify control points
   - Establsih the baseline/reference b/n two C.Ps

Chap-4

- Set the tripod & instrument
- Take horizontal angle measurments and distance
- Computation and adjustment

2. Vertical control establishment steps

- Identify the traverse/croxining
- Mount/put the level and tripod
- Setting the level and take measurement of backsight and forsight
- Error adjustment and calculation of reduced level

Chap-4

B. Detail surveying

(1) All natural or artificial features that will appear on the map and

(2) Enough ground points and spot elevations to make the drawing of contour lines possible.

Map Drafting

1. Plotting the traverse

1.1 plotting horizontal controls

- ✓ Select Scale
- ✓ Select convenient point from the first station
- ✓ show meridain or Zero angle line through this point.

Chap-4

1.2 Measure the angle to second point

1.3Draw the line through measured angle and measure the distance on that line.

1.4 Second point is found

2. Plotting the details from control points

3. Drawing the topography and special data

4. Finishing the map

Chap-4

Contour Interval

Depends up on

- The nature of the terrain
- The purpose of the survey
- The extent of the survey
- The scale of the map

Horizontal equivalent is the horizontal distance between two points on the consecutive contour lines for a given slope.

Contour characterstics

- Two contour lines of deferent elevations cannot cross to each other

Chap-4

- Contour lines of different elevations can unite to form one line only in the case of vertical cliff/slope.
- Closely spaced contour lines indicate steep slope.
- Widely spaced contour lines indicate gentle slope.
- Equally spaced contour lines indicate uniform slope
- Contour lines cannot begin or end on the plan
- The same contour must appear on both sides of a ridge or valley
- Contours do not have sharp turnings
- A single contour lines cannot lie between two contour lines of higher or lower elevation & etc

Chap-4

Application of contours

- Drawing of sections
- Determination of inter-visibility b/n points
- Tracing of contour gradient and location of route
- Selection of suitable site
- Measurement of catchment area
- Calculation of reservoir capacity & etc

Chap-4

Uses of Digital Elevation Models/DEM

- Determine aspects of terrain
  - ✓ Slope, aspect, spot elevations
  - ✓ Source for contour lines
- Finding terrain features
  - ✓ Watersheds, drainage networks, stream channels
- Modeling of hydrologic functions
- Creation of relief maps
- Engineering and infrastructure design