Road Construction and Maintenance Level-III

Based on September, 2023 Curriculum Version 2

Module Title: Establish Control Points and Boundaries

Module code: EIS RCM3 01 0923

Nominal duration: 100 Hour

Prepared by: Ministry of Labor and Skill

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Addis Ababa, Ethiopia

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Acronym

DM D	Double Meridian Distance method
DTM	Digital Terrain Model
E.D.M	Electronic Distance Measurement
ERA	Ethiopian Road Authority
GPS /GNSS	Global Positioning System/ Global Navigational Satellite System
GRN	Geodetic Reference Network
OSHA	Occupational Safety and Health Administration
ppm	Parts per million
VPI	Vertical Point of Intersection

Introduction to module

This module aims to give the trainee all the necessary theoretical knowledge to set up, manage and use surveying equipments to establish control points for the construction and monitoring of large or small engineering works. This module is designed to meet the construction industry requirement under control point establishment and area computation to demarcate boundary and route alignment selection particularly for the unit of competency: **Road Construction and Maintenance level III.**

This module covers the units:

- Planning and preparation
- Traversing
- Triangulation
- Intersection and Resection
- Alignment
- Description writing

Learning Objective of the Module

At the end of completing the module the trainee will be able to:

- Plan and prepare
- Perform traversing
- Compute Triangulation
- Establish intersection and re- section
- Set out alignment
- Write description

Module Instruction

For effective use these modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit one: Plan and prepare

This unit is developed to provide the trainee the necessary information regarding the following content coverage and topics:

- Overview
- Work instructions
- Safety and signage requirements
- Tools and equipment
- environmental protection requirements

This unit will also assist the trainee to attain the learning outcomes stated in the cover page. Specifically, upon completion of this unit, the trainee will be able to:

- Prepare work instructions
- Apply safety and signage requirements
- Differentiate tools and equipment
- Identify environmental protection requirements

1.1 Overview

Surveys gather data for use by planners and engineers. The products resulting from surveys are generally topographic maps and/or a digital terrain model (DTM). Both conventional (on the ground) and photogrammetric methods are used to gather data for engineering surveys. Before construction activities are started, thorough planning is carried out in regard to equipment and material, method, task and activities, schedule and cost of project. Planning begins with the pre-job meeting between the Project Surveyor and the Project Manager to discuss about:

- Project Schedule
- Overall project survey needs
- Alternative survey methods
- Safety considerations
- Recommendations for survey methods
- Appointment of Project Surveyor to the Project Development Team
- Surveys that might be eliminated because of existing data
- Accuracy requirements for the survey
- Additional surveys needed (right of way, construction, etc.)

Generally a work plan for engineering surveys is prepared by the Project Surveyor. This work plan should contain:

- A list of the required engineering survey products
- A schedule for the requested project surveys, including critical milestones
- Resource needs (method, personnel, equipment, cash overtime, travel, specification, required accuracy level, expense)

1.2 Work instruction

1.2.1 Office Preparation

The Project Surveyor, in consultation with the field supervisor and party chief, is responsible for the development of the necessary instructions and information (field package) for performing the requested engineering surveys. Surveys office staff, under the direction of the project surveyor, generally prepares the field package using information obtained from the research/reconnaissance, together with other compiled and computed data. The field package should contain all the necessary information and data to efficiently complete the field work required by the survey request.

Typical information/data that may be included are:

- Copy of survey request (always included)
- Special instructions including safety and hazardous waste considerations (always included)
- Control diagram and station listing
- As-built plans
- Monumentation and right of way maps and monument listing
- Maps of record
- Utility maps
- Utility easement descriptions
- Data in digital format
  - Control data: descriptions, coordinates, elevations
  - Monumentation data: descriptions, coordinates

Instructions from the Regional Survey Supervisor, and, in the case of surveys performed by consultant firms, the contract, will define requirements for each separate project.

Because of rapidly changing technology, data transfer methods will not be defined here.

1.2.2 Field Work

Field work should not be initiated without a completed field package, including survey request form and written instructions designating any special survey needs. Planning and preparation stage (identify the activities, method, equipment, duration, human resources, budget, required accuracy) is a prerequisite for field work. If the planning and preparation phase completed carefully, the field work can carry out easily and accurately as per the plan.

Project control (general)

a) Horizontal

All survey projects shall be tied to the Geodetic Reference Network (GRN).

- Ties shall consist of pairs of intervisible monuments along the length of the project. Spacing will depend on the type project, terrain, etc. and will be determined by the Regional Survey Supervisor (usually about 500 to 1000 ft).
- Semi-permanent monuments will be used (reinforcing bars with metal caps or better). Also an adequate description and “to-reach” shall be prepared.
- GRN ties will, in most cases, be supplied by ERA or any local Authority ground control crews committee.

- GPS Surveys shall meet First Order (1:100000) accuracy standards as an absolute minimum. One part in one million closures for GPS control work is preferred.
- Project control surveys will traverse the length of the project and shall originate and terminate at GRN tied control points at the beginning, end, and, if appropriate, along the length of the project. Since these surveys originate and terminate at points with datum adjusted local plane coordinates.
- Project control surveys shall meet Second Order Class II Standards (1:20000).
- For loop type horizontal angle $e \leq \pm 10''\sqrt{n}$ or $e \leq \pm 20''\sqrt{n}$ or $e \leq \pm 30''\sqrt{n}$ or $e \leq \pm 1'\sqrt{n}$ used accordingly.
- They may be performed by either of Total Station – Traverse or Global Positioning System
- After the raw field data for project control has been compiled, computed and minimum standards met, traverses shall be adjusted by least squares adjustment or compass rule adjustment.

b) Vertical

- Global Positioning System (GPS) methods may be used for vertical control for projects provided approved procedures are followed.
- The geoid model published by the National Geodetic Survey shall be used for height calculations.

Known third order or better benchmarks are occupied in the project control sessions and used for vertical ties and adjustment. For leveling operation from 2mm to 24mm error per kilometer is permissible depending on the accuracy requirement. i.e. $e \leq \pm 24mm\sqrt{D}mm$. Where, e is the error and D is the length of the measured route in kilometer.

The measuring accuracy of all EDM equipment is specified in manufacturers' literature in different ways but often in the form of +a mm +b ppm or ±(a mm + b ppm). This can be a little misleading as the constant uncertainty, a mm, is unrelated to the uncertainty of scale error, b ppm. Therefore, these statements should be interpreted as being that the total uncertainty (σ) is given by $\sigma = (a^2 + (bL \times 10^{-6})^2)^{1/2}$ mm where L is the length of the line in kilometers. Using a typical example of a = 3 mm and b = 5 ppm the uncertainty of a measured distance if 1.2 km would be $\sigma = (3^2 + (5 \times 1.2)^2)^{1/2}$ mm = 7 mm.

In the above specification, a is a result of errors in phase measurement (θ) and zero error (z), i.e. $a^2 = \sigma^2\theta + \sigma^2 z$ In the case of b, the resultant error sources are error in the modulation frequency f and in the group refractive index ng, i.e. $b^2 = (\sigma f / f)^2 + (\sigma ng / ng)^2$ The reason why the specification is expressed in two parts is that θ and z are independent of distance, whilst f and ng are a function of distance. For short distances such as a few tens or even hundreds of meters, as frequently encountered in engineering, the a component is more significant and the b component can largely be ignored.

1.3Safety and signage requirements

Advance planning will minimize the survey crew's exposure to hazardous situations and minimize the delays to the public. Safety should be a prime consideration in all survey planning and especially with engineering surveys, which often require work in and around traffic.

A meaningful safety program requires that each employee acknowledge that "it can happen to me." Each must also ask, "What is my responsibility?" and "What can I do to keep it from happening?"

1.3.1 Legal Requirements

The Safe Employment Act requires every employer to provide a safe and healthy place of employment. The Occupational Safety and Health Administration (OSHA) of the Department of Consumer and Business Services administers the Act and has a staff of Occupational Safety Compliance Officers who are authorized to inspect employees' working conditions throughout the state. They may issue citations for violations of safety regulations which can result in penalties, including fines.

1.3.2 Wearing of Personal Protective Equipment

As stated in the Safety and Health Policies and Procedures Manual, all personnel are required to wear the appropriate personal protective equipment during all operations where exposure to hazardous conditions exists. Frequently, surveyors operate tools that, if not used correctly, can cause harm.

Safety footwear is a substantial boot or shoe, made of leather or other equally firm materials, with the sole and heel designed and constructed for slip resistance. Acceptable safety footwear meets the safety shoe requirements established by the Occupational Safety and Health Act [OSHA] or the American National Standards.

Safety-toe footwear is a boot that meets the definition above and extends above the ankle, with a defined heel, slip resistant sole, and a puncture resistant shank, and either steel or composite protection for the toe areas built into the boot.

1.3.3 Use of Traffic Control Devices

Basically, there are two categories: signs and channelizing devices.

I) Signage requirements

a) Warning Signs

Install warning signs prior to the start of all survey work that is on pavement and within15 feet of the edge of the traveled way. Use them all the time you are working in traffic. Since surveyors are constantly moving on the highway, it is important that warning signs be moved as the work progresses. There are three signs used most frequently: **workers, survey crew, and flagger**.

Signs warning of lane closings ahead, may also be used as appropriate. Survey crew symbol or sign is the principle advance warning sign used for traffic control through survey work zones and may replace the ROADWORK AHEAD or ROADWORK sign when lane closures occur, at the discretion of the party chief.

Use Type B light or dual orange flags at all times to enhance the survey crew sign or symbol.

Use advance warning signs at an extended distance of one-half mile or more when limited sight distance or the nature of the obstruction might require a motorist to bring the vehicle to a stop. Color, sizes, wording, and placement of signs must conform to approve standards as specified and other safety standards that are adopted.

b) Channelizing Devices

The function of channelizing devices is to warn and alert drivers of conditions created by work activities in or near the traveled way, to protect workers in the temporary traffic control zone, and to guide drivers, cyclists, and pedestrians safely. Channelizing devices include but are not limited to cones, tubular markers, vertical panels, drums, barricades, temporary raised islands, and barriers. Channelizing devices are elements in a total system of traffic control devices for use in temporary traffic control zones. If it is necessary to place an instrument or tripod within the traveled way or within 15 feet of the traveled way, protect the tripod with cones according to field conditions.

Arrow Displays: Arrow display signs are intended to supplement other traffic control devices when closing a lane.

Variable Message Signs: Surveyors may use variable message signs to advise the traveling public of survey work being done on the highway. The information on these signs is to make the drivers more aware of surveyors on the highway and increase the surveyors' safety. They are used to supplement the standard signing in the survey work zone.

Flagging Operations: When operations are such that signs, signals, and barricades do not provide adequate protection on or adjacent to a highway or street, provide flaggers or other appropriate traffic control. Ensure that all flaggers are well trained and possess valid flagging cards.

Position flaggers far enough ahead of the work zone so that approaching traffic has sufficient distance to stop before entering the work zone. STOP/SLOW paddles are the primary hand-signaling device. To control traffic, use the flagger symbol sign before any point where a flagger is stationed. A distance legend may be displayed on a supplemental plate below the symbol sign. The sign may be used in conjunction with appropriate legends or with other warning signs, such as BE PREPARED TO STOP.

Vehicle Warning Lights: The use of flashing amber lights is another tool used by surveyors to let motorists know that they are working in the area. Temporary traffic control activities often create conditions on or near the traveled way that are particularly unexpected at night, when drivers' visibility is sharply reduced. It is often desirable and necessary to supplement retro-reflectorized signs, barriers, and channelizing devices with lighting devices during daytime and nighttime operations.

1.3.4 Animal Hazards

- Assume that all animals are potentially dangerous.
- Have owners secure hostile-acting animals before entering enclosures containing such animals.
- Do not enter an enclosure with high fences if a hazardous animal is within.
- Be especially wary of sick-appearing animals, animals with young, stallions, bulls, bears, and guard dogs.
- Do not handle dead or seemingly dead animals.

Snakebites

Snakebites of surveyors are quite rare. Even if preventive measures fail, current knowledge and treatment offer the best prognosis ever for snakebite victims.

- Always assume snakes are active. Do not relax your vigil on sunny winter days.
- Do not make "solo" trips across snake country, which is remote from habitations and frequently used roads.

1.3.5 Poisonous Plants

Poison ivy, poison oak, and poison sumac can cause skin irritation. Learn to recognize these plants so that you can avoid them. Furthermore, if you know when you have touched them, you can start first aid before symptoms appear. If exposed to a poisonous plant, wash the affected area of your body promptly and thoroughly with water and soap.

The rash starts with redness and intense itching. Later, little blisters appear. If a rash had already developed, do not wash it. Avoid scratching. Get medical attention.

1.3.6 Power Lines

- Avoid actual contact with or possible arcing to any equipment from electrical lines.
- In damp conditions, double your precautions.
- Do not tape across terrain where a tape might possibly be pulled up, into, or lowered atop a power line. Use an E.D.M. instead of taping.

- Power line elevations - do not make a "direct" measurement of the height of a power line, even with a fiberglass rod.

1.3.7 Training

New field personnel are required to have a definite understanding of what will be expected of them concerning on-the-job safety. This training is to be accomplished by the supervisor to familiarize new, promoted, transferred, or reassigned employees that will be involved in surveying activities.

1.4Tools and equipment

These instruments help in determining positions, distances, angles, elevations, and other relevant information for mapping and construction purposes.

Measuring Tapes, Measuring Wheel, Surveying Chains, Arrow, Peg, Ranging Rods, Offset Rods, Plumb Bob, Cross Staff, Optical, Square, Prism Square, Site Square, Tripod, Spirit Level, Drawing Paper, Instruments for Direct Leveling, Distance meter, Plumb Laser, Level, Staff, Prismatic Compass, Surveyor's Compass, Theodolite, Total Station, GPS/GNSS, 3D Scanner, Drones and others.

Major Surveying Instruments

a. GPS (Global Positioning System) : is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
b. Total Station: is an electronic instrument used in modern surveying and building construction that uses electronic transit theodolite in conjunction with electronic distance meter (EDM) and used to measure sloping distance of object to the instrument, horizontal angles and vertical angles.
c. Auto Level/Dumpy Level: used to establish or verify points in the same horizontal plane. It is used in surveying and building with a vertical staff to measure height differences and to transfer, measure and set heights.
d. Theodolite: used for measuring angles in the horizontal and vertical planes. It is used mainly for surveying applications, and has been adapted for specialized purposes in fields like metrology and rocket launch technology.
e. Optical Square: a pentaprism to reflect and refract a beam or sighting 90 degrees, it is used in pairs in surveying and in a singular block in metrology
f. Dot-plumb laser: a type of laser level that projects a small dot onto a surface. These dots are used for transferring points from wall to wall or ceiling to floor. It's a handy tool for making sure a wall is plumb or even installing wall-to-wall.

g. LDM (Laser Distance Meter): work based on the principle of reflection of a laser beam. To measure a distance
h. Prismatic Compass: used to find out the bearing of the traversing and included angles between them, waypoints (an endpoint of the Closure) and direction
i. Prisms: used to to reflect EDM beam back to its source with both a wide angle of incidence and with high precision.
j. Levelling Staff(levelling rod, is a graduated feet and meter on aluminum rod, used with a levelling instrument to determine the difference in height between points or heights of points above a vertical datum. It cannot be used without a leveling instrument.
k. Prism pole: Can be used to measure the elevation of a specific ground point by using a sight level, which is important if you want to get accurate results.
l. The measuring wheel (surveyor's wheel): used to measure distances. Measuring wheels have a counting mechanism that counts the number of rotations and uses the circumference of the wheel to calculate the distance covered.
m. Tripod: a portable three-legged frame or stand, used as a platform for supporting the weight and maintaining the stability to other survey instruments as total station, auto level, etc.

1.5 Environmental protection requirements

It is essential to collect data about the natural and built environment that could be affected by a proposed road project. This data is used to assess the potential impacts of the project and to develop mitigation measures to minimize those impacts. The specific requirements of surveying for environmental protection will vary depending on the location of the project and the type of road being constructed. However, some common types of surveys that may be conducted include:

- A topographic survey can be used to identify a route for the road that avoids sensitive habitats, such as wetlands.
- A vegetation survey can be used to identify areas of high biodiversity that need to be protected.
- A soil survey can be used to identify areas of erodible soil that need to be stabilized.
- A hydrological survey can be used to identify areas that are prone to flooding and need to be protected.
- Soil surveys: These surveys assess the type and condition of the soil in the area.
- Cultural surveys: These surveys identify any cultural resources, such as archaeological sites, in the area.

The data collected from these surveys is used to assess the potential impacts of the road project on the environment. These impacts can include:

Changes in the hydrology of the area, such as increased flooding or erosion

- Loss of habitat for wildlife
- Degradation of air quality
- Increased noise pollution
- Damage to cultural resources

Once the potential impacts have been assessed, mitigation measures can be developed to minimize those impacts. These measures may include:

- Relocating the road to avoid sensitive areas
- Using construction techniques that minimize disturbance to the environment
- Planting trees and other vegetation to buffer the road from the surrounding environment
- Monitoring the environmental impacts of the road after construction

Surveying can contribute to environmental pollution in a few ways:

- **The disposal of surveying waste.** Surveying waste, such as batteries, fuel, and other hazardous materials, can be harmful to the environment if not disposed of properly.
- **The disturbance of natural habitats.** Surveying activities can disturb natural habitats, such as forests and wetlands. This can disrupt the ecosystem and contribute to pollution.
- **The use of chemicals.** Some surveying activities, such as groundwater sampling, may require the use of chemicals. These chemicals can pollute the environment if not handled properly.

However, it is important to note that surveying can also be used to help protect the environment. For example, surveying can be used to identify and map contaminated sites, to assess the impact of development on the environment, and to monitor the effectiveness of environmental remediation efforts. Overall, the environmental impact of surveying depends on the specific activities involved and how they are carried out. When done responsibly, surveying can be a valuable tool for protecting the environment.

The following are some ways to minimize the environmental impact of surveying:

- Dispose of surveying waste properly, in accordance with local regulations.
- Avoid disturbing natural habitats whenever possible.
- Use chemicals only when necessary and handle them with care.

- Educate surveyors about the environmental impact of their work and encourage them to adopt sustainable practices.

Figure. 1.1 Major Surveying Instruments

Self-Check 1

Part 1) choose the best answer among the alternatives

1. Which one is used to establishes control points to steer the construction of new installations and markers.
   a) Topographic surveying.
   b) Route surveying.
   c) Construction surveying.
   d) Photogrammetric surveying
2. Which one of the following is FALSE about control point?
   a) pairs of intervisible monuments should exist along the length of the project
   b) Semi-permanent monuments will be used
   c) Write adequate description about the monuments
   d) GPS Surveys shall meet third Order accuracy standards.
3. If you have skin contact with poison plant and a rash had already developed, what do you do?
   a) Wash it with soap and water.
   b) Scratching to remove the poison.
   c) Cover with adhesive plaster
   d) Get medical attention.

Part 2) Write TRUE for the correct statements and FALSE for the wrong ones.

1. A Project Surveyor conducts pre-job meeting with the project Manager before planning.
2. A work plan for engineering surveys is prepared by the project structural engineer.
3. Levelling is used to measure sloping distance, horizontal angles and vertical angles and calculate the horizontal distance, coordinates of a point and reduced level of point.

Part 3) Answer the questions below accordingly

1.What does mean Legal Requirements from safety context?

2.What is the difference among warning signs and channeling devices?

3.Write major surveying instruments and their corresponding uses.

Unit Two: Traversing

This unit is developed to provide trainee the necessary information regarding the following content coverage and topics:

- Overview
- Types of traverses
- Azimuth and bearing
- Area computation
- Traverse fieldwork

This unit will also assist the trainee to attain the learning outcomes stated in the cover page. Specifically, upon completion of this unit, the trainee will be able to:

- Identify Types of traverses
- Measure Azimuth
- Carry out Traversing
- Compute Azimuth and bearing
- Fill the traverse field book
- Calculate area

2.1 Overview of traversing

A traverse consists of a series of straight lines connecting successive established points along the route of a survey. The points defining the ends of the traverse lines are called traverse stations or traverse points. Distances along the line between successive traverse points are determine either by direct measurement using a tape or electronic distance measuring (EDM) equipment, or by indirect measurement using tacheometric methods. At each point where the traverse changes direction, an angular measurement is taken using a transit or theodolite.

Traverse stations: any temporary or permanent point of reference over which the theodolite is set up is called a traverse station. On most surveys the traverse station is a peg, called a hub, driven flush with the ground and having a tack driven in its top to mark the exact point of reference for measurement. On pavements, the traverse stations may be a driven nail, a cross cut in the pavement or curb, or a tack set in a hole drilled with a star drill and filled with lead wool. In land surveying the stations are often iron pipes, stones, or other more or less permanent monuments set at the corners, In mountainous country, often the station marks are cut in the natural rock.

Lines connecting traverse stations are called traverse lines. Both in the field notes and as part of the identification mark left in the field.

A traverse station number is preceded by the symbol ⊙

□ represent a monumented station and

the symbol Δ represent geodetic control station. (All geodetic control stations are monument).

2.2 Types of traverses

A. Open traverse:

The open traverse originates at a point of known position and terminates at a point of unknown position. No computational check is possible to detect errors or blunders in distances or directions. To minimize errors, distances can be measured twice, angle turned by repetition or reiteration methods, magnetic bearings observed on all lines, and astronomic observations made periodically. Should not be used for any of application where high accuracy is required.

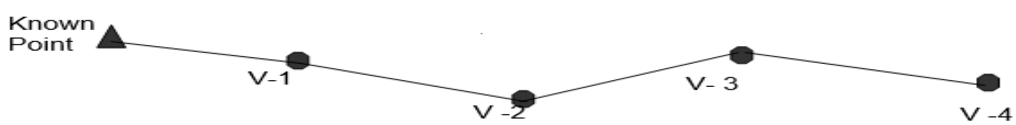


Fig 2.1 open traverse

B. Closed traverse:

The Closed traverses originate at a point of known position and close on the same or another point of known horizontal position. In Fig 2.2points marked by bold triangles (Δ) represent known points. This type of traverse is preferable to all others since computational checks are possible which allow detection of systematic errors in both distance and direction. Closed traverse further categorized in to two as **closed link and closed loop(ring) traverse**.

I. **Closed link traverse**: starts from known point, pass through known and unknown points and ends to the other known point. It is mainly used for route surveying such as road

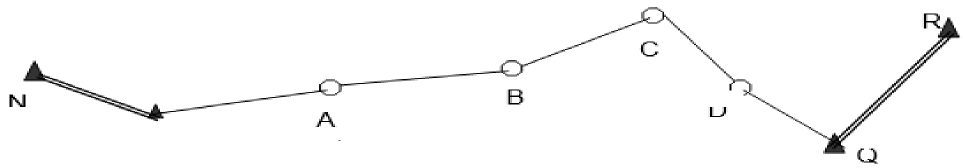


Fig. 2.2 closed link traverse

Closed loop traverse: A traverse that originates and terminates on a single point of known horizontal position is called a closed - loop traverse. In figure 2.3 traverse 1–2 –3-4 -5 -6 -7-1, which originates and close on point 1, is an example of a closed –loop. This type of traverse permits an internal check on the angle. Has no check on systematic errors in distance and the points are not located on any datum and have no relationship with points in any other survey. The use of such a method of running a traverse is to be discouraged except under extenuating circumstances, where no feasible alternative is possible.

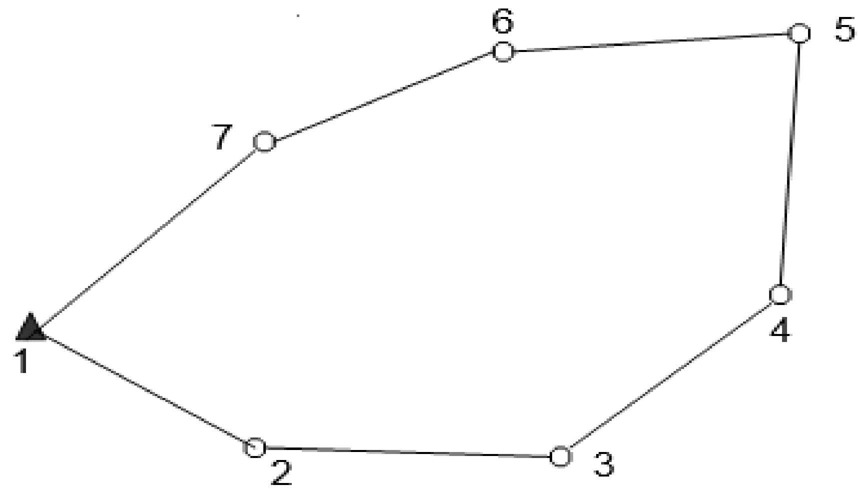


Fig 2.3 closed – loop traverse

Traverses according the method of turning angles

1) Traversing by intersection angles

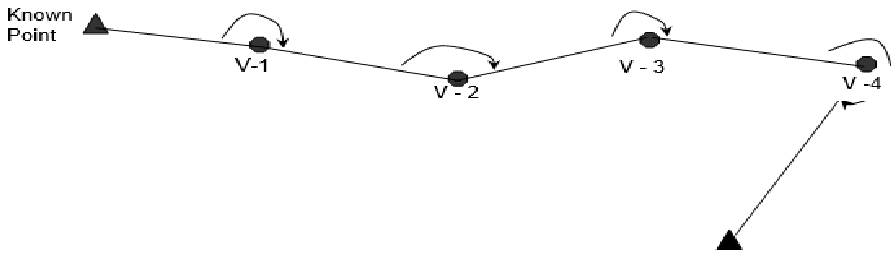


Fig 2.4 Traversing by intersection angles

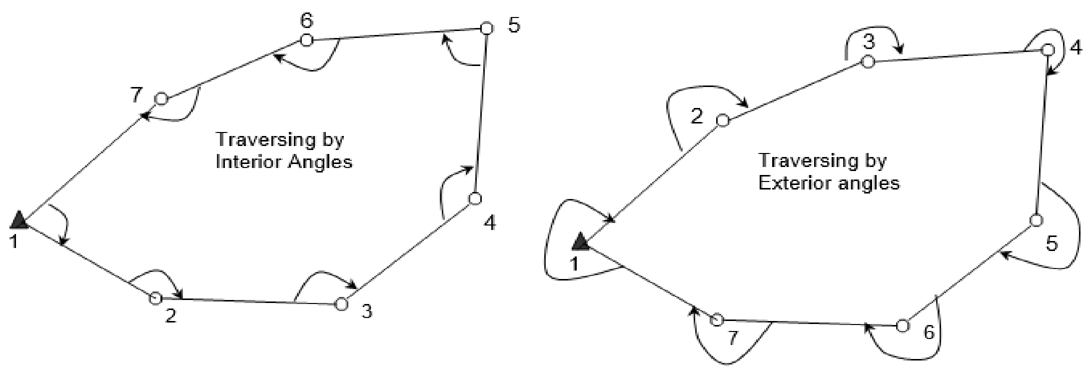


Fig 2.5 Loop traverse by intersection angles

In a loop traverse the angles can be measured internally (interior angles) or externally (exterior angles). Notice that at Interior angles the loop traverses is routed and numbering at anticlockwise direction; and at exterior angles; the loop traverse is routed and numbering at clockwise direction

2) Traversing by deflection angles

The deflection angle can be measured clockwise (right deflection angle) or anticlockwise (left deflection angle) from the prolongation of the back tangent to the fore tangent.

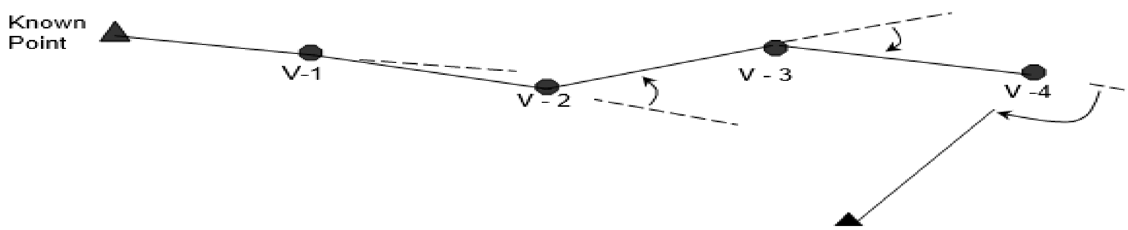


Fig 2.6Traversing by deflection angles

Right deflection angle = Intersection angle - 1800

Left deflection angle = 1800 – Intersection angle

3) Traversing by azimuth

Traversing by azimuth is not a suitable method since the magnetic north – south meridian is not parallel at control points due to the local magnetic declination, in addition some magnetic fields such as electric lines, iron objects near the control points and even solar magnetic storms can disturb the magnetic meridian position, consequently a high accuracy is not reachable.

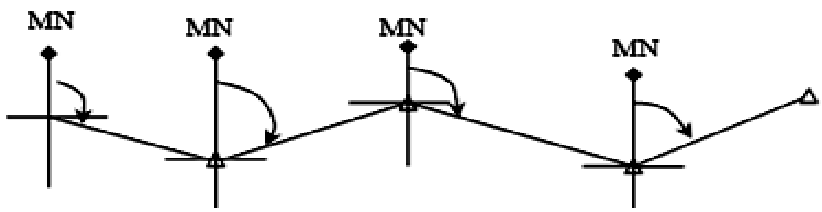
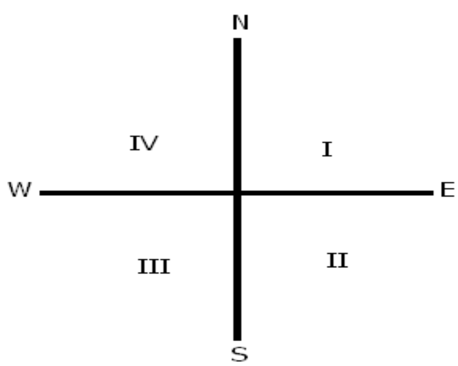


Fig 2.7 Traversing by azimuth

2.3 Azimuth and bearing

Azimuths: It is an angle measured clockwise from a reference north. It is always measured clock wise and north direction and it range is [0,360]. Unlike bearing the direction will not mentioned. Azimuth sometime called Whole Circle Bearing

Range of Azimuth in different quadrants



In I Quadrant Azimuth between 0^0 - 90^0

In II q quadrant Azimuth is between 90^0 - 180^0

In III- Quadrant Azimuth is between 180^0 -270^0

In IV quadrant Azimuth is between 270^0 - 360^0

The relationship between azimuth and bearing

The relationship b/n bearing and azimuth in different quadrants is different.

In I quadrant Angular Value of bearing = Azimuth

In II quadrant Azimuth = $180^{\,0}$ - angular value of bearing

In III quadrant Azimuth = $180^{\,0}$+ angular value of bearing

In IV Quadrant Azimuth = 360^0-angular Value of bearing

Back azimuth

Similarly, to bearing the back azimuth is the reverse of forward azimuth

Back azimuth of AB = Azimuth of BA

The angular difference b/n forward and backward azimuth is equal to 180^0

Computing a back azimuth from forward azimuth

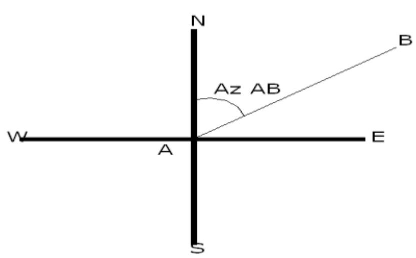
If a forward azimuth is less than 180^0, Backward azimuth = forward Az + 180^0

If a forward azimuth is greater than 180^0 ,Backward azimuth = foreword azimuth +180^0

Example: Find the backward azimuth of the following lines having foreword azimuth

Line	Forward azimuth
AB	$43^0$11'20''
BC	112^0 20'15''
CD	197^0 18'36''
DE	320^0 17'40''

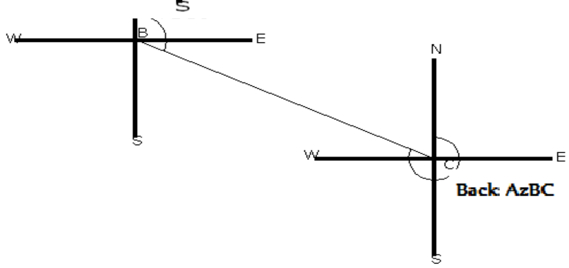
Solution



Since Az AB < 90^0

Az BA = Azimuth of AB +180^0 = $43^0$11'20'' + 180^0

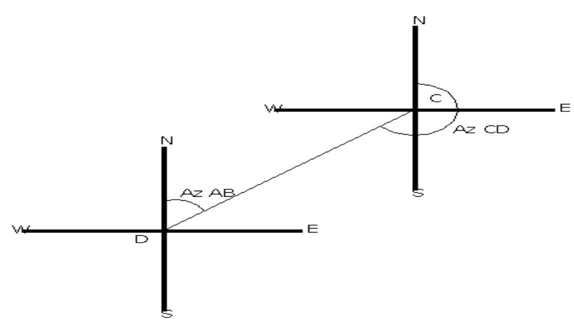
= 223^0 11'20''



Since 90^0 < Az BC< 180^0

Back azimuth of line BC= $112^0$29'15+180^0

= $290^0$29'15



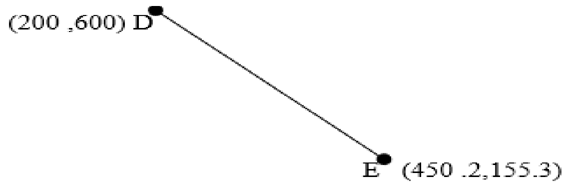
Since 180^0 < Az CD< 270^0 , Back azimuth of CD = Az CD-180^0

=$197^0$18'36''-180^0 = 17^0 18'36''

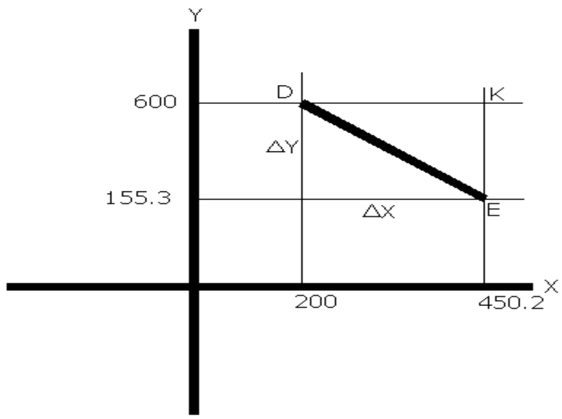
D. Since 270^0 < Az DE < 360^0 , Back azimuth DE = Az DE -180^0 = $320^0$17'40''-180^0 = 140^0 17'40''

2.4 Azimuth and coordinate determination

Illustrative example-1. Calculate bearing and azimuth of line DE below,



Soln



1. Draw Parallel lines through E and D Parallel to the X-and Y- axis
2. Since it lines in II quadrant, bearing will be measured from south direction
3. Calculate ΔX and ΔY

$$\Delta X_{DE} = X_E - X_D = 450.2 - 200 = \underline{\mathbf{250.2}}$$

$$\Delta Y_{DE} = Y_E - Y_D = 155.3 - 600 = \underline{\mathbf{-444.7}}$$

$$\tan\Theta = \Delta X/\Delta Y = \Theta \tan^{-1}(250.2/-444.7) = \Theta = \mathbf{-\underline{29^{o}21'21''}}$$

Since ΔY = - ve and ΔX = +ve the line lies in the III quadrant. Therefore , Bearing or DE = S $29^{0}21'48''$E, Azimuth of DE = 180^{0} -Bearing of DE = 180^{0} -29^{0} $21'48''$ = $\underline{150^{0}38'12'}$

Order of computation for link traverse:

1. Preparation of a computation sketch that must contain the reference points, the reduced distances and the measured traverse angles, taken from the angular measurement field book (do not forget the sum check).
2. Computation of the first azimuth a B,A and the last azimuth a C,D in the table "Azimuth and Distance".
3. Transfer of the coordinates of A and C and of the previously calculated nominal azimuths a B,A and a C,D to the respective locations of the table "Traverse Computation"

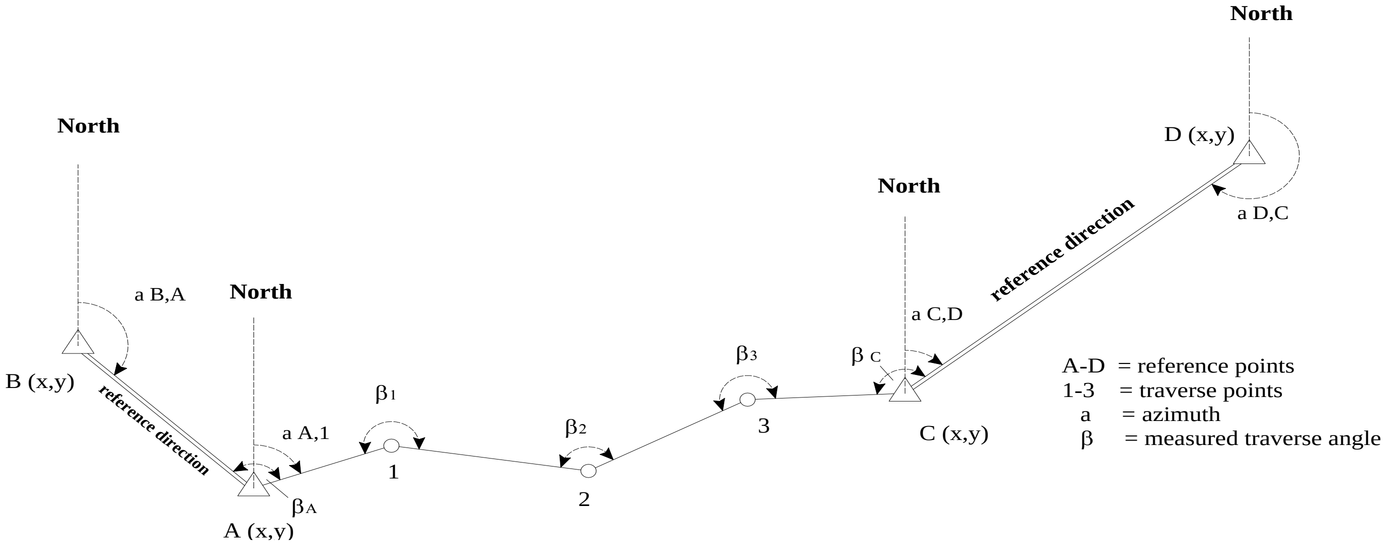


Fig 2.8 link traverse

4. Computation of the actual azimuth a C,D based on the azimuth a B,A and the measured traverse angles β:

- actual azimuth a C,D = nominal azimuth a B,A + $[\beta]$ - n 200 GON (180°) with: n= number of instrument stations

5. Computation of the angular misclosure f $^{\beta}$ by comparing the nominal azimuth a C,D with the actual azimuth a C,D:

- angular misclosure f $^{\beta}$ = nominal azimuth a C,D- actual azimuth a C,D

6. Computation of the allowable angular misclosure f $^{\beta}$ (allowable):

f $^{\beta}$ (allowable):=1' (18 mgon) $\sqrt{n}$; n= number of instrument stations.The allowable error should not be exceeded.

7. Computation of the corrections for each measured traverse angle:

correction per angle "cor $^{\beta}$ " = $\dfrac{f_{\beta(actual)}}{n}$

n= number of instrument stations

8. Computation of the azimuths of each traverse side:

a A,1= a B,A+"cor $^{\beta}$ " + β_A + 200 GON (180°)

a 1,2= a A,1 +"cor $^{\beta}$ " + β_1 + 200 GON (180°)

a 2,3= a 1,2 +"cor $^{\beta}$ " + β_2 + 200 GON (180°), etc.

Check: The actual azimuth a C,D, computated now with the corrected traverse angles, has to be equal to the nominal azimuth a C,D calculated in step 2.

9. Calculation of the nominal coordinate differences, based on the given coordinates of the points A and C:

nominal $\Delta_X = X_C - X_A$ nominal $\Delta_Y = Y_C - Y_A$

10. Calculation of each coordinate difference (departure and latitude):

$\Delta_{X1} = d_{A,1} \sin a\ A,1$ $\Delta_{Y1} = d_{A,1} \cos a\ A,1$

$\Delta_{X2} = d_{1,2} \sin a\ 1,2$ $\Delta_{Y2} = d_{1,2} \cos a\ 1,2$

etc. etc.

Check: $\Delta_X + \Delta_Y = d\ \sqrt{2}\ \sin(a+50\text{gon})$

11. Calculation of the sum of the actual coordinate differences:

actual $\Delta_X = [\Delta_X]$ actual $\Delta_Y = [\Delta_Y]$

12. Computation of closure of departure "cl $_{DEPARTURE}$" and closure of latitude: "cl $_{LATITUDE}$"

closure of departure = nominal Δ_X - actual Δ_X and closure of latitude = nominal Δ_Y - actual Δ_Y

13. Computation of the error of closure f_S: $f_S = \sqrt{cl^2_{Departure} + cl^2_{Latitude}}$

14. Computation of the sum of all traverse sides = [d]

15. The relative accuracy is computed as follows: 1: $\frac{[d]}{f_S}$

The allowable relative accuracy should not be exceeded.

16. Distribution of closure of departure "cl $_{DEPARTURE}$" and closure of latitude: "cl $_{LATITUDE}$", proportional to the length of each traverse side:

correction for each departure = "cl $_{DEPARTURE}$" (respective d / [d])

correction for each latitude = "cl $_{LATITUDE}$" (respective d / [d])

The corrections are added to each respective departure and latitude:

final departure = Δ_X (step 10) + correction for departure and final latitude =Δ_Y (step 10) + correction for latitude

17. Computation of the final coordinates using now the corrected coordinate differences:

$X_1 = X_A$ + final departure Δ_{X1} $Y_1 = Y_A$ + final departure Δ_{Y1}

$X_2 = X_1$ + final departure Δ_{X2} $Y_2 = Y_1$ + final departure Δ_{Y2} etc.

Check: Finally, the in this step calculated coordinates for the end point (here point C), must be equal to the given coordinates of point C!

Computation and adjustment azimuth and coordinate with closed-loop traverse

After collecting all traverse's planimetric data such as:

- Azimuth of the first line (in case of magnetic azimuth method)
- Intersection angles
- Traverse's partial distances

The office tasks starts for angular and linear adjustments and finally, the determination of the adjusted planimetric coordinated of the traverse.

General Step (for a loop traverse)

a. Angular Stage

I Computing the angular closure error ec= $\sum \alpha - 1800\ (n-2)$

II Determining the angular permissible error = 1' √n or 30''√n 0r 10''√n

III Determining the angular correction $c = \frac{ec}{n}$

IV Appling the angular correction to interception angles α(corrected) = α ± c

(the correction is introduced into the angle with the error appositive sign)

V Checking the angular correction: ∑α(corrected) = 1800 (n – 2)

VI Computing the azimuth of every line ABC = AAB + α(corrected) ± 1800

VII Determining the bearing upon the azimuth of every line.

b. Linear Stage

I . Computing the differences in X and Y: ΔX1 = dist1 * sin Azimuth1-2

ΔY1 = dist1 * cos Azimuth1-2

II. Determining the total error in X : X e = ∑ΔX total error in Y: Ye = ∑ΔY

III. Determining the linear absolute error Ae = √ ∑ΔX2 + ∑ΔY2

IV. Computing the Precision or liner relative error: $P = \frac{1}{\frac{D}{Ae}}$

V. Comparing the achieved Precision with the expected Precision or Project Precision, It must to be fulfilled that: P > PP (otherwise the field data are not acceptable)

VI. Computing the correction for ΔX and Δy: $C = \frac{\sum \Delta X}{D} * dist$

$C = \frac{\sum \Delta Y}{D} * dist$

VII .Appling the correction to ∑ΔX and ∑ΔY : ∑ΔX(corrected) = ΔX ± C,

∑ΔY(corrected) = ΔY ± C

VIII. Checking the linear correction now it must be fulfilled That

$$\sum \Delta X = 0$$

$$\sum \Delta Y = 0$$

IX. Computing the final coordinate of every traverse vertex:

$$Xb = Xa \pm \sum \Delta X(\text{corrected})$$

$$Yb = Ya \pm \sum \Delta Y(\text{corrected})$$

X . Filling out the calculus compendium

Example (loop traverse)

Table 2.1closed loop traverse data for figure 2.9

Point	Line	Distance	Interception Angle
1	1 – 2	365.01	550 30’ 06’’
2	2 – 3	246. 57	2190 57’ 02’’
3	3 – 4	469. 65	790 07’ 00’’
4	4 - 5	274.17	530 38’ 02’’
5	5 – 6	318.54	2000 54’ 14
6	6 - 1	354. 51	1100 53’ 10’’

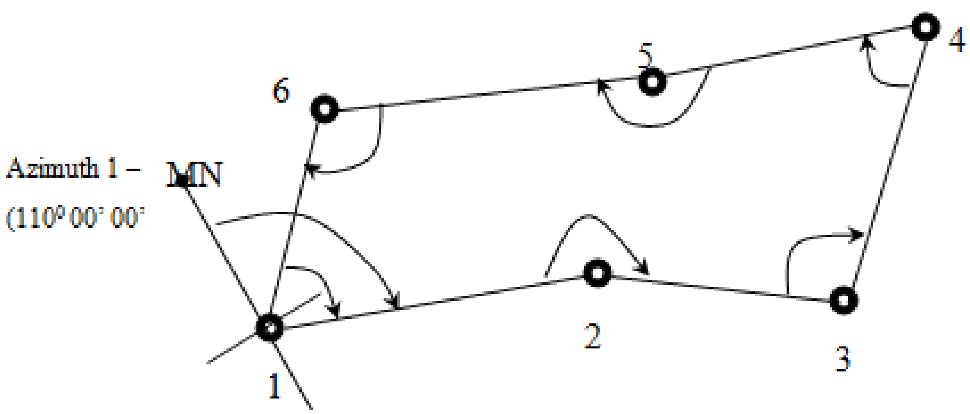


Figure 2.9 Closed loop traverse by interior and magnetic azimuth

Known data: Pp = 1 : 10 000 X1 = 5000.00 Y1= 2000.00

I – Determining the angular closure error : ec= ∑ α – 1800 (n – 2)

ec = 7190 59’ 34’’ – 1800 (6 – 2) = 7190 59’ 34’’ – 7200 00’ 00’’ = 26’’

II .Determining the angular permissible error: pe = 1’ √n

pe = 1’√6 = 1’ x 2.4494897 = 2’ 27’’ then ce < pe therefore the current angular error is acceptable.

III - Determining the angular correction $c = \frac{ec}{n} = \frac{26''}{6} = 4.3''$

IV . Appling the angular correction to interception angles α(corrected) = α ± c

(the correction is introduced into the angle with the error appositive sign)

α(corrected 1) = 550 30’ 06’’ + 5’’ = 550 30’ 11’’

α(corrected 2) = 2190 57’ 02’’ + 4’’ = 2190 57’ 06’’

$\alpha_{(corrected\ 3)} = 79^0\ 07'\ 00'' + 4'' = 79^0\ 07'\ 04''$

$\alpha_{(corrected\ 4)} = 53^0\ 38'\ 02'' + 4'' = 53^0\ 38'\ 06''$

$\alpha_{(corrected\ 5)} = 200^0\ 54'\ 14'' + 4'' = 200^0\ 54'\ 18''$

$\alpha_{(corrected\ 6)} = 110^0\ 53'\ 10'' + 5'' = 110^0\ 53'\ 15''$

Total = 26’’ Now $\sum\alpha = 180^0\ (n - 2) =$ **$720^0\ 00'\ 00''$**

VI . Computing the azimuth of every line **$A_{BC} = A_{AB} + \alpha_{(corrected)} \pm 180^0$**

Azimuth of line 1 – 2 is known = $110^0\ 00'\ 00''$

Azimuth of line 2 – 3 = Azimuth of line 1 – 2 + $\alpha_2 \pm 180^0$

Azimuth of line 2 – 3 = $110^0\ 00'\ 00'' + 219^0\ 57'\ 06'' - 180^0$

Azimuth of line 2 – 3 = $329^0\ 57'\ 06'' - 180^0 =$ **$149^0\ 57'\ 06''$**

Azimuth of line 3 – 4 = Azimuth of line 2 – 3 + $\alpha_3 \pm 180^0$

Azimuth of line 3 - 4 = $149^0\ 57'\ 06'' + 79^0\ 07'\ 04'' - 180^0$

Azimuth of line 3 – 4 = $229^0\ 04'\ 10'' - 180^0 =$ **$49^0\ 04'\ 10''$**

Azimuth of line 4 – 5 = Azimuth of line 3 – 4 + $\alpha_4 \pm 180^0$

Azimuth of line 4 – 5 = $49^0\ 04'\ 10'' + 53^0\ 38'\ 06'' + 180^0$

Azimuth of line 4 – 5 = $102^0\ 42'\ 16'' + 180^0 =$ **$282^0\ 42'\ 16''$**

Azimuth of line 5 – 6 = Azimuth of line 4 – 5 + $\alpha_5 \pm 180^0$

Azimuth of line 5 – 6 = $282^0\ 42'\ 16'' + 200^0\ 54'\ 18'' - 180^0$

Azimuth of line 5 – 6 = $483^0\ 36'\ 34'' - 180^0 =$ **$303^0\ 36'\ 34''$**

Azimuth of line 6 – 1 = Azimuth of line 5 – 6 + $\alpha_6 \pm 180^0$

Azimuth of line 6 – 1 = $303^0\ 36'\ 34'' + 110^0\ 53'\ 15'' - 180^0$

Azimuth of line 6 – 1 = $414^0\ 29'\ 49'' - 180^0 =$ **$234^0\ 29'\ 49''$**

Azimuth of line 1 – 2 = Azimuth of line 6 – 1 + $\alpha_1 \pm 180^0$

Azimuth of line 1 – 2 = $234^0\ 29'\ 49'' + 55^0\ 30'\ 11'' - 180^0$

Azimuth of line 1 – 2 = $290^0\ 00'\ 00'' - 180^0 =$ **$110^0\ 00'\ 00''$**

VII Determining the bearing upon the azimuth of every line.

Azimuth 1 - 2 = 110^0 00’ 00’’

Bearing 1 -2 = 180^0 – Azimuth = 180^0 - 110^0 00’ 00’’ = 70^0 00’00’’ **SE**

Azimuth 2 - 3 = 149^0 57’ 06’’

Bearing 2 – 3 = 180^0 – Azimuth = 180^0 - 149^0 57’ 06’’ = 30^0 02’ 54’’ **SE**

Azimuth 3 - 4 = 49^0 04’ 10’’

Bearing 3 – 4 = Azimuth = 49^0 04’ 10’’ **NE**

Azimuth 4 - 5 = 282^0 42’ 16’’

Bearing 4 – 5 = 360^0 - Azimuth = 77^0 17’ 44’’ **NW**

Azimuth 5 - 6 = 303^0 36’ 34’’

Bearing 5 – 6 = 360^0 – Azimuth = 56^0 23’ 26’’ **NW**

Azimuth 6 -1 = 234^0 29’ 49’’

Bearing 6 – 1 = Azimuth – 180^0 = 54^0 29’ 49’’ **SW**

Linear Stage

I Computing the differences in X and Y: ΔX_1 **= dist$_1$ * sin Azimuth$_{1\text{-}2}$**

ΔY_1 **= dist$_1$ * cos Azimuth$_{1\text{-}2}$**

ΔX Computing

ΔX_1 = 365.01 x sin (110^0 00’ 00’’) = 342.997

ΔX_2 = 246. 57 x sin (149^0 57’ 06’’) = 123.465

ΔX_3 = 469. 65 x sin (49^0 04’ 10’’) = 354.822

ΔX_4 = 274.17 x sin (282^0 42’ 16’’) = -267.458

ΔX_5 = 318.54 x sin (303^0 36’ 34’’) = -265.290

ΔX_6 = 354. 51 x sin (234^0 29’ 49’’) = -288.601, **$\sum\Delta X$ = - 0.065**

ΔY Computing

ΔY_1 = 365.01 x cos (110^0 00’ 00’’) = -124.841

ΔY_2 = 246. 57 x cos (149^0 57’ 06’’) = -213.432

ΔY_3 = 469. 65 x cos (49^0 04’ 10’’) = 307.688

ΔY_4 = 274.17 x cos (282^0 42’ 16’’) = 60.296

ΔY_5 = 318.54 x cos (303^0 36’ 34’’) = 176.321

ΔY_6 = 354. 51 x cos (234^0 29’ 49’’) = -205.880 , **$\sum\Delta Y$ = 0.152**

III Determining the linear absolute error Ae = $\sqrt{(\sum\Delta X^2 + \sum\Delta Y^2)}$

Ae = $\sqrt{}$ $-0.065^2 + 0.152^2$ = **0.165**

IV Computing the Precision or liner relative error: $P = \dfrac{1}{\dfrac{D}{Ae}}$

$$P = \dfrac{1}{\dfrac{2\,028.45}{0.165}} = 1{:}\ 12\,293 \approx \mathbf{1{:}\ 12\,200}$$

V. Comparing the achieved Precision with the expected Precision or Project Precision, It must to be fulfilled that: P > PP (otherwise the field data are not acceptable)

P > PP since 1: 12 200 > 1: 10 000 therefore OK

VI. Computing the correction for ΔX and Δy: $C = \dfrac{\sum \Delta X}{D} * dist$

$$C = \dfrac{\sum \Delta Y}{D} * dist$$

C ΔX

$$C = \dfrac{\sum \Delta X}{D} * dist$$

$C_1 = \dfrac{-0.065}{2028.45} \times 365.01 = 0.012\text{ m} = 12\text{ mm}$

$C_2 = \dfrac{-0.065}{2028.45} \times 246.57 = 0.008\text{ m} = 8\text{ mm}$

$C_3 = \dfrac{-0.065}{2028.45} \times 469.65 = 0.015\text{ m} = 15\text{ mm}$

$C_4 = \dfrac{-0.065}{2028.45} \times 274.17 = 0.009\text{ m} = 9\text{ mm}$

$C_5 = \dfrac{-0.065}{2028.45} \times 318.54 = 0.010\text{ m} = 10\text{ mm}$

$C_6 = \dfrac{-0.065}{2028.45} \times 354.51 = 0.011\text{ m} = 11\text{mm}$, $\mathbf{\sum CX = 0.065\ m = 65\ mm}$

C ΔY

$C_1 = \dfrac{0.152}{2028.45} \times 365.01 = 0.027\text{m} = 27\text{ mm}$

$C_2 = \dfrac{0.152}{2028.45} \times 246.57 = 0.019\text{ m} = 19\text{ mm}$

$C_3 = \dfrac{0.152}{2028.45} \times 469.65 = 0.035\text{m} = 35\text{ mm}$

$C_4 = \dfrac{0.152}{2028.45} \times 274.17 = 0.021\text{m} = 21\text{ mm}$

$C_5 = \frac{0.152}{2028.45} \times 318.54 = 0.024$ m = 24 mm

$C_6 = \frac{0.152}{2028.45} \times 354.51 = 0.026$ m = 26 mm , $\sum$**CY = 0. 152 m = 152 mm**

VII Appling the correction to $\sum\Delta X$ and $\sum\Delta Y$: $\sum\Delta \mathbf{X}_{(corrected)} = \Delta \mathbf{X} \pm \mathbf{C}$

$$\sum\Delta \mathbf{Y}_{(corrected)} = \Delta \mathbf{Y} \pm \mathbf{C}$$

In this case the correction is going to be applied with positive sign since the error is negative. (correction must be applied with appositive sign of error)

Correction in ΔX

$\Delta X_{1\ (corrected)} = 342.997 + 0.012 = 343.009$

$\Delta X_{2(corrected)} = 123.465 + 0.008 = 123.473$

$\Delta X_{3(corrected)} = 354.822 + 0.015 = 354.837$

$\Delta X_{4(corrected)} = -267.458 + 0.009 = -267.449$

$\Delta X_{5(corrected)} = -265.290 + 0.010 = -265.280$

$\Delta X_{6(corrected)} = -288.601 + 0.011 = -288.590$

VIII. Checking the linear correction now it must be fulfilled that $\sum\Delta \mathbf{X} = \mathbf{0}$

Correction in ΔY

In this case the correction is going to be applied with negative sign since the error is positive (correction must be applied with appositive sign of error)

$\Delta Y_{1(corrected)} = -124.841 - 0.027 = -124.868$

$\Delta Y_{1(corrected)} = -213.432 - 0.019 = -213.451$

$\Delta Y_{1(corrected)} = 307.688 - 0.035 = 307.653$

$\Delta Y_{1(corrected)} = 60.296 - 0.021 = 60.275$

$\Delta Y_{1(corrected)} = 176.321 - 0.024 = 176.297$

$\Delta Y_{1(corrected)} = -205.880 - 0.026 = -205.906$

VIII. Checking the linear correction now it must be fulfilled that $\sum\Delta \mathbf{Y} = \mathbf{0}$

IX. Computing the final coordinate of every traverse vertex :

$\mathbf{X_b = X_a \pm \sum\Delta X_{(corrected)}}$ and $\mathbf{Y_b = Y_a \pm \sum\Delta Y_{(corrected)}}$

Computing coordinate X :

$X_2 = X_1 + \Delta X_1 = \mathbf{5000.00} + 343.009 = 5\,343.009$

$X_3 = X_2 + \Delta X_2 = 5\,343.009 + 123.473 = 5\,466.482$

$X_4 = X_3 + \Delta X_3 = 5\,466.482 + 354.837 = 5\,821.319$

$X_5 = X_4 - \Delta X_4 = 5\,821.319 - 267.449 = 5\,553.87$

$X_6 = X_5 - \Delta X_5 = 5\,553.87 - 265.280 = 5\,288.59$

$X_1 = X_6 - \Delta X_6 = 5\,288.59 - 288.590 = \mathbf{5000.00}$ OK.

Computing coordinate Y :

$Y_2 = Y_1 - \Delta Y_1 =$ **2000.00** - 124. 868 = 1 875.132

$Y_3 = Y_2 - \Delta Y_2 =$ 1 875.132 - 213. 451 = 1 661.681

$Y_4 = Y_3 - \Delta Y_3 =$ 1 661.681 + 307.653 = 1 969.334

$Y_5 = Y_4 - \Delta Y_4 =$ 1 969.334 + 60.275 = 2 029. 609

$Y_6 = Y_5 - \Delta Y_5 =$ 2 029. 609 + 176.297 = 2 205. 906

$Y_1 = Y_6 - \Delta Y_6 =$ 2 205. 906 - 205. 906 = **2000.00** OK

X Filling out the calculus compendium:

Traverse: ______ Coordinate system: _________Measured By: __________omputed by: _________

Station	**side**	**Adjusted Horizontal Angle**	**Azimuth**	**Bearing**	**Distance**	**Prelim ΔX**	**C**	**Adjusted ΔX**	**Prelim ΔY**	**C**	**Adjusted ΔY**	**Coordinates X**	**Y**
1		55^0 30’ 11’’										5000.00	2000.00
	1 – 2		110^0 00’ 00’’	70^{0}00’00’’**SE**	365.01	342.997	0.012	343. 009	-124.841	-0.027	- 124. 868		
2		219^0 57’ 06’’										5343.009	1 875.132
	2 – 3		149^0 57’ 06’’	30^{0}02’54’’**SE**	246. 57	123.465	0.008	123.473	-213.432	- 0.019	- 213. 451		
3		79^0 07’ 04’’										5 466.482	1 661.681
	3 – 4		49^0 04’ 10’’	49^{0}04’10’’**NE**	469. 65	354.822	0.015	354. 837	307.688	- 0.035	307.653		
4		53^0 38’ 06’’										5 821.319	1 969.334
	4 – 5		282^0 42’ 16’’	77^{0}17’44’’**NW**	274.17	-267.458	0.009	- 354. 837	307.688	- 0.021	60.275		
5		200^0 54’ 18’’										5 553. 87	2 029. 609
	5 – 6		303^0 36’ 34’’	56^{0}23’26’’**NW**	318.54	-265.290	0.010	- 265.280	176.321	- 0.024	176.297		
6		110^0 53’ 15’’										5 288.59	2 205. 906
	6 – 1		234^0 29’ 49’’	54^{0}29’49’’**SW**	354. 51	-288.601	0.011	- 288.590	-205.880	- 0.026	- 205. 906		
1						**∑ΔX = - 0.065**		**∑ΔX = 0**	**∑ΔY = 0.152**		**∑ΔY = 0**	5000.000	2000.000

ec = 26’’ pe = 1’√6 = 1’ x 2.4494897 = **<u>2’ 27’’</u>** then **ce < pe** therefore the current angular error is acceptable.

Ae= 0.165 $P = \dfrac{1}{\dfrac{2\,028.45}{0.165}}$ = 1: 12 293 ≈ **<u>1: 12 200</u>** Pp = 1 : 10 000

2.5 Area computation

It is often necessary to compute the area of a tract of land which may be regular or irregular in shape. Land is ordinarily bought and sold on the bases of cost per unit area. To compute volume of earthwork to be cut or filled in planning a highway, it is necessary to computes the areas of cross sections. The S.I unites of area is square meters, square kilometers, hectare. 1 hectare = 10,00m^2.

2.5.1 Methods of computing area

There are many methods of measuring area. But in this module we will see the following

A. Coordinate method

B. Meridian distance method(MD)

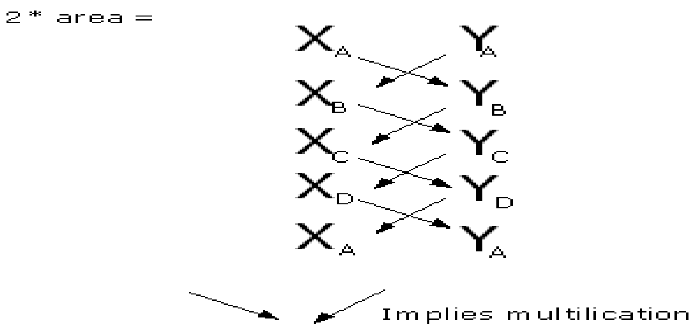
C. Double meridian distance method

A. Coordinate method.

In this method independent coordinates of the points are used in the computation f areas.

To avoid negative sign, the origin O is chosen at most southerly and westerly point.

Total area of the traverse ABCD can be calculated as follows.



Two sums of products should be taken

1. Product of all adjacent terms taken down to the right i.e. $\mathbf{X_AY_B}$ **,** $\mathbf{X_BY_C}$ **,** $\mathbf{X_CY_D}$ **,** $\mathbf{X_DY_A}$
2. Product of all adjacent terms taken up to the left i.e. $\mathbf{Y_AX_B}$ **,** $\mathbf{Y_BX_C}$ **,** $\mathbf{Y_CX_D}$ **,** $\mathbf{Y_DX_A}$

The traverse area is equal to half the absolute value of the difference between these two sums. In applying the procedures, it is to be observed that the first coordinate listed must be repeated at the end of the list.

Example: Calculate the area enclosed by a traverse given below

Solution

Point	X	Y
A.	500.00	1000.000
B.	416.693	578.866
C.	1047.169	395.856
D.	1297.375	564.653
E.	1330.387	650.165
F.	861.433	1090.090
A.	500.00	1000.000

X_AY_B = 500.00 * 578.866 = 289433 $\qquad$ Y_AX_B =1000.000*416.693 = 416693

X_BY_C = 416.693 * 395.856 = 164950.4242 $\qquad$ Y_BX_C= 578.866 * 1047.169= 606170.5304

X_CY_D = 1047.169 * 564.653= 591287.1174 $\qquad$ Y_CX_D = 395.856 * 1297.375=513573.678

X_DY_E = 1297.375 * 650.165= 843507.8169 $\qquad$ Y_DX_E =564.653*1330.387 = 751207.0107

X_EY_F = 1330.387 * 1090.090= 450241.565 $\qquad$ Y_EX_F =650.165*861.433 = 560073.5864

X_FY_A = 861.433 * 1000.000 = 861433.0 $\qquad$ Y_FX_A = 1090.090 *500.00 = 545045.0

$\sum 1 = \mathbf{4200852.923m^2}$ $\qquad$ $\sum 2 = \mathbf{3392762.806}$

Area $= \dfrac{\sum 1 - \sum 2}{2} = \dfrac{808090.1175}{2} = \underline{404045.059\text{sq.m}}$

B. Meridian distance method

The meridian distance of a line is the perpendicular distance from the line's midpoint to a reference meridian (north-south line) to avoid negative signs, the reference meridian is generally chosen as passing through the most westerly corner of the traverse or further away from it. The fig below shows the different associated term. EF is the meridian distance of AB.

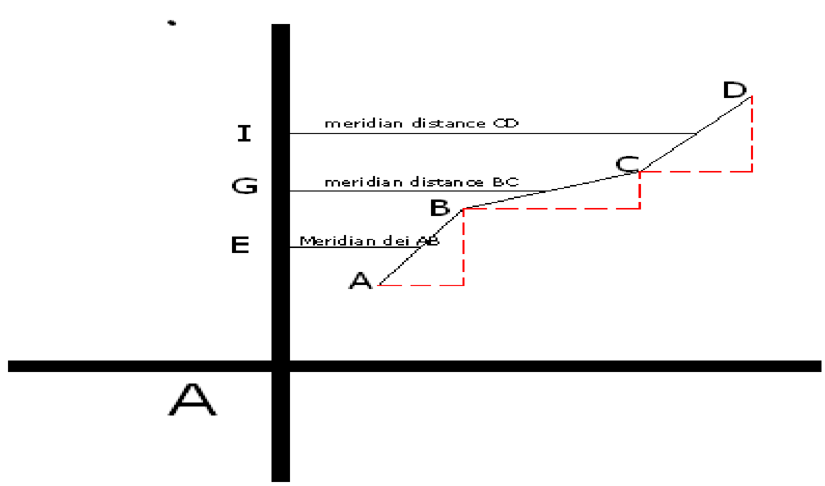


Fig.2.10 Meridian distance method

GH is the meridian distance of BC. Mathematically meridian distance of BC is equal to meridian distance of AB plus half the departure of AB plus half the departure of BC. Similarly, meridian distance of CD is equal to the meridian distance of BC plus half the departure of BC plus half the departure of BC plus half the departure of CD. Thus, the meridian distance of any line is equal to:

The meridian distance of the preceding line + ½ [the departure of the preceding line] + ½ [the departure of the line itself].

For applying this rule, the sign of the departure should be considered

East departure = +ve and West departure = -ve

Similarly for latitudes North latitudes = +ve and South latitude = -ve

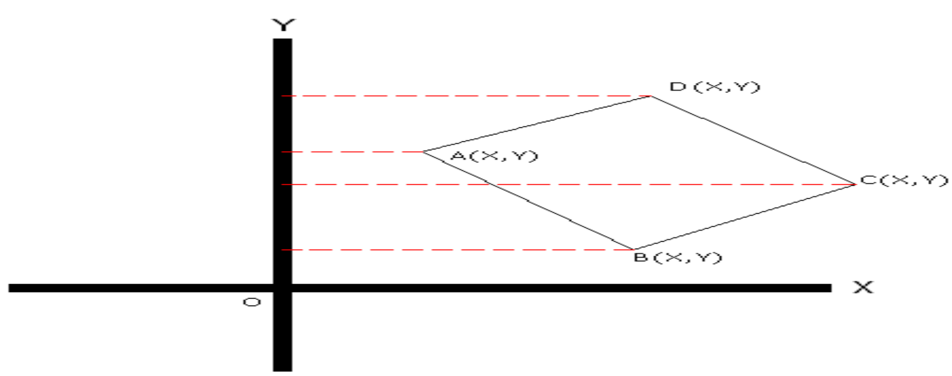
Finally Area = ∑L * MD. Where L = latitude and MD = meridian distance.

Example :A closed traverse ABCDA is run along the boundaries of a built up area with the following results:

Side	Azimuth	Distance
AB	69^0 55’	262.00
BC	166^0 57’	155.00
CD	244^0 20’	268.00
DA	347^0 17’	181.00

Determine the area enclosed by A, B, C and D.

Solution



Line	Latitude Dis*cos Az	Dep. Dist*sinAz
AB	89.97	246.07
BC	-151.00	35.00
CD	-116.08	-241.56

DA	176.56	-39.84

Computations meridian distances (MD)

Line	MD
AB	½ [dep AB] = ½ [246.39]= 123.20
BC	MD of AB + ½ [dep AB] + ½ [dep BC]
	= 123.2 +123.2+ 17.5 = 263.9
CD	MD of BC + ½ [dep BC] + ½ [dep CD]
	= 263.9 + 17.5 + -120.78 = 160.62
DA	MD of CD + ½ [dep CD] + ½ [dep DA]
	= 160.2 + -120.78 + - 19.92 = 19.5

Therefore

Line	Latitude * MD	
AB	89.97*123.20	= 11084.304
BC	-151.00*263.9	= -39848.9
CD	-116.08*160.62	= -18644.7696
DA	176.56*19.5	= 3442.92
		∑ -43966.446

Therefore area is the absolute value of the result **= 43966.446 sq.m = 4.38 hectare**

C. Double Meridian distance method

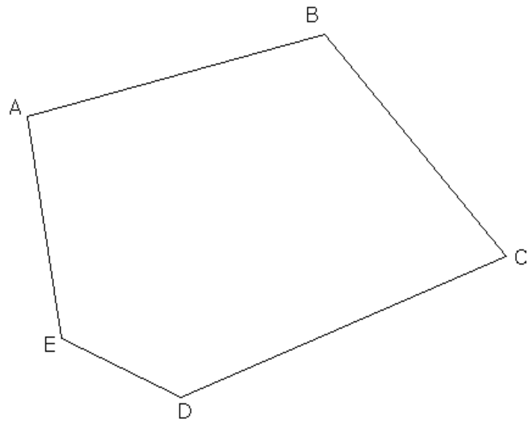
In order to avoid working with half departures, surveyors use the double meridian distance. i.e. twice the meridian distance in making computations. Thus DMD of BC is equal to the DMD of AB plus the departure of BC. The following are the rules for computing DMDs for a closed traverse.

i. The DMD of the first line is equal to the departure of the first line.
ii. The DMD of each succeeding line is equal to the DMD of the previous line plus the departure of the previous line plus the departure of the line itself.
iii. The DMD of the last line of a balanced closed loop traverse is equal to the departure of the line but in opposite sign.

Then the summation of products of DMD and latitudes of lines of a closed traverse with proper sign gives twice the area of the traverse.

If the traverse is covered clockwise, the area will be negative, if the counter clockwise, the area will be positive.

Example: Calculate the area of the following closed loop traverse by using DMA method.



Given	Line	dep	Lat.
	AB	8.08	5.175
	BC	2.915	-4.553
	CD	5.994	-1.243
	DE	-9.738	-5.898
	EA	-7.251	6.519

Solution

Line	DMD
AB	8.08
BC	DMD of AB + dep AB + dep. BC= 8.08 + 8.08 + 2.915 = 19.075
CD	DMD of BC + dep BC + dep. CD = 19.075 + 2.915 + 5.994 = 27.984
DE	DMD of CD + dep CD + dep. DE= 27.984 + 5.994 + -9.738 = 24.24
EA	DMD of DE + dep DE + dep. EA = 24.24 + -9.738 + -7.251 = 7.251

Then	Line	Latitude * DMD	
	AB	5.175 * 8.08	= 41.814
	BC	-4.553 * 19.075	= -86.848
	CD	-1.243 * 27.984	= -34.784
	DE	-5.898 * 24.24	= -142.968
	EA	6.519 * 7.251	= 47.269

∑ = -175.517 then ,Area = ½ [∑] **= 87.758 sq.m**

Self-Check 2

Part-I Matching

Instruction: select the correct answer form the given choice. You have given 2 Minute for each question. Each question carries 2 Point.

"A"	"B"
---------1. Azimuth	A. No mathematical checks
---------2. Open traverse	B. Used for road
---------3. Bearing	C. measure clock wise
---------4. Link traverse	D. distance along the X-axis
---------5. Departure	E. distance along the Y-axis
	F. measure clock wise or anticlockwise

Part **II** fill the blank space with appropriate words or phrases

1) _____________is a traverse starts from known point and terminates at unknown pint
2) _____________is a traverse used for area computation.
3) _____________is a horizontal angle measured clockwise from a reference north.

Part 2) **Short Answer writing**

4) Compare and contrast whole circle bearing and bearing
5) Write uses of traverse.

Operation sheet 2

Operation Title: Perform traversing

Purpose :

- to compute azimuth and bearing
- to calculate area
- to summarize the data wit traverse field book

Conditions or situations for the operations:

- ✓ Safe working area
- ✓ Proper operating tools and equipment
- ✓ Appropriate working PPE and instrument safety

Equipment Tools and Materials:

GPS	Magnetic-	Tripods	Rod-level/	Paint	Pencil
Meter	compass	Range pole	Plumb bob	Brush	Scientific
	Thedolite		Ink	Paper	calculato

Steps in doing the tasks

Take five points which form a close loop traverse to compute the coordinates of ach point and the area of a polygon with coordinate method, meridian distance and double meridian distance method.

Step 1: Wear appropriate PPE and care the instruments safely

Step 2: Prepare equipment and tools

Step 3: measure horizontal angle, horizontal distance and azimuth

Step 4: locate the coordinates of the first station with hand held GPS

Step 5: Compute the azimuth of every line

Step 6: Compute departure and latitude

Step 7: Make necessary correction and adjustment

Step 8: Compute the coordinates of traverse stations

Step 9: Calculate the area of the traverse

Quality Criteria: Assured performing of all the activities according to the procedures.

Use the allowable error of e≤±20’’√n or e≤±30’’√n for angular accuracy

Lap Tests 2

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Use necessary tools and materials required to perform the following tasks accordingly.

Task 1: Wear appropriate PPE

Task 2: Perform run closed loop traverse

Task 3: Perform necessary computations and checks

Task 4: Compute the area of the traverse with all possible methods.

Unit Three: Establish Triangulation, Intersection and Resection

This unit is developed to provide the trainee the necessary information regarding the following content coverage and topics:

- Selection of triangulation
- Monuments
- Angles and base line measurement
- Use of intersection
- Measurement of intersection

This unit will also assist the trainee to attain the learning outcomes stated in the cover page. Specifically, upon completion of this unit, the trainee will be able to:

- Select triangulation satiation
- Establish monuments
- Identify triangulation procedures
- Differentiate triangulation figures
- Measure angles and base line
- Use intersection and resection
- Perform intersection and resection measurement
- Compute stations coordinate

3.1 Selection of triangulation

Triangulation as a form of horizontal control is applied when a large area is to be surveyed and when the method of traversing would not be expected to maintain a uniformly high accuracy over the entire area. Horizontal control can be carried out by precise traversing, triangulation, intersection, resection, and satellite positioning. The selection of triangulation figure and method depends on the type of terrain and accuracy required.

3.1.1 Triangulation Figures

There are several different triangulation systems which can be used for particular survey. In each case a set of triangles which adjoin or overlap each other are used. Four types of systems which are used in triangulation are:

A. Chain of single triangles

There are only one route to compute the unknown side. Because of this it doesn't provide the most accurate result. This type of triangulation systems is employed in rather long and narrow surveys of low precision. The means of check in this system is by comparing the computed length of check base with the measured. (fg 3.1a)

B. Chain of Quadrilaterals formed with overlapping triangles

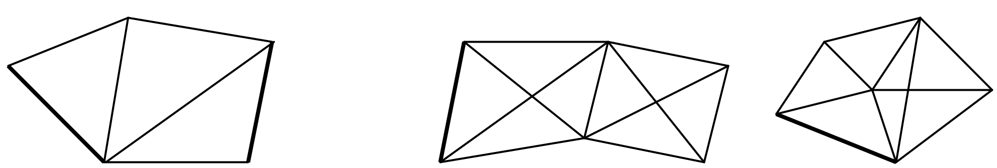
The most common triangulation system best adopted to rather long and narrow surveys where the high degree of precision is required. The sides can be computed with different route as well as different triangles and angles offering excellent checks on the computation (fg 3.1b).

C . A chain of central point figures

This type of triangulation system is used when horizontal control is to be extended over a rather wide area involving number of points. It is very strong and quite easy to arrange.

D. Central Point figure with extra diagonal

The central point figure is further strengthened by using diagonal as shown(fig 3.1c).The most common figure used is the braced quadrilateral (fg 3.1b) below. It is best suited to long narrow systems. Brace polygons (fig1.2c) can also be used in the case of wide systems.



(a) chain of triangles (b) chain of quadrilaterals (c) chain of polygons.

Fig 3.1 triangulation figures

3.2 Establish monuments

The points forming the triangulation stations are selected on the basis of visibility as for example on the top of hills or radio towers, or water tanks. As a result, the points are not uniformly spaced. Some of the points are obviously inaccessible and it is necessary to establish eccentric stations from them and to determine the distance and directions from the main stations to the eccentric stations. Sometimes it is necessary to build special towers for making the observations. These towers contain one tower built inside another so that the towers supporting the instrument and the instrument operator are independent. For triangulation of lower accuracy, a small pole signal about 2m high guyed in place, or an object already in place might be used for sighting. In general, the type of signal used depends on the length of the line and the accuracy required whereas its form depends on the locality and available materials.

Triangulation stations should be marked and referenced very carefully for use at later days. The signals used must permit centering the instrument if the station is to be occupied (for instance, an iron pipe set vertically so that a pole can be inserted in to it for sighting and this pole can be removed when centering the instrument over the station).the triangulation stations shuld be establish with relatively permanent and visible marks.

Application of triangulation surveys

Triangulation can be used for:

1. The establishment of accurately located control points for surveys of areas.
2. The accurate location of engineering works such as the location of large bridge structures, state and federal highways, dams, canals, tunnels, and others
3. The establishment of accurately located control points in connection with aerial surveying.

3.3 Classification of triangulation systems

Based on angular error of closure and discrepancy between the measured length of a base line and its length as computed through the system from an adjacent base there are three orders of triangulation based on their uses: first order (primary), second order (secondary) and third order (tertiary) triangulation.

First order (primary) triangulation is the highest accuracy. It furnishes accurately positioned national control networks upon which small surveys are based. Since it covers a large area, the effect of earth’s curvature is to be taken into account- geodetic triangulation. It may cover the whole country (for small countries) or primary grids may be provided (for large countries).

Second order (secondary) triangulation provides points at greater density than first order triangulation. This network is adjusted to fit its parent primary triangle or its surrounding primary control. Less refinement is needed as the network is surrounded by the primary control.

Third order (tertiary) triangulation is used to establish control for local developments and improvements , topographic and hydro graphic surveys or other such projects for which they provide sufficient accuracy.

Table 3.1 Standard classification

	1ST ORDER	2nd order		3rd order	
		Class I	Class II	Class I	Class II
Discrepancy b/n measured and computed length of baseline	1 part 100,000	1 part in 50,000	1 part in 20,000	1 part in 10,000	1 part in 5,000
Triangle angular error	1”	1.2”	2”	3”	5”
Recommended uses	Furnishes control for primary national net work metropolitan area surveys, scientific	Area control strengthens the national network	Area control which contributes to but supplemental to the national net work	General control surveys referred to national network and local control surveys.	

3.4 Triangulation procedure

1. Reconnaissance, select the location of stations
2. Evaluation of the strength of figure
3. Erection of signals, and in some cases, towers for elevating the signals and /or instruments
4. Observation of directions or angles
5. Measurement of base lines
6. Astronomic observation at one or more locations

7. Compute the lengths of all sides and coordinates for all stations.

3.5 Measure angles and base line

The methods of triangulation require a maximum number of precise angle measurements and a minimum number of distance measurements. The triangles are developed in to a net of interconnected figures, and lines, called **base lines**, must be measured with extreme precision in order to compute the sides in the net. In figure 3.2 base line AB and all angles must be measured in the field to calculate remaining sides. Base lines can be measured either by tapes or by EDM equipment. For measurement of higher precision, invar tape is always used.

Once systematic corrections have been applied to the measured lengths, the remaining step is to reduce all the triangle lengths to equivalent sea level distances in all extensive triangulation surveys.

If first-order work is desired, directional theodolites should be used with which directions can be read directly to 0.2”. For second-order work, it is necessary to use instruments capable of being read to 1”. For third –order triangulation, engineer’s transits that can be read to 20” or 30” may be used if the angles are measured by repetition.

When the directional theodolites are used, it is set up over a particular station and pointed to each of the desired stations. For first-order triangulation the set of readings is repeated from 8 to 16 times, while for second order work they are repeated from 4 to 8 times.

a) **Computation of lengths**

Two sides of each triangle are computed by using the law of sines, since one side of the triangle is always known and the three angles have been measured and adjusted. In computing the sides of the triangles in a quadrilateral, such as that in fig3.2, the solutions of two triangles is sufficient to compute the positions of the forward triangulation stations. The two triangles chosen must be the strongest route through the quadrilateral.

b) **Computation of Azimuths**

First azimuth should be computed to compute coordinate if the coordinates of stations A and B are known, the length of line BA computed by:

$$\tan\ \theta_{AB} = \left\{\frac{E_B - E_A}{N_B - N_A}\right\} \qquad \theta_{AB} = \tan^{-1}\left\{\frac{E_B - E_A}{N_B - N_A}\right\}$$

Azimuth of AB = $104^0 42'56.60''$

-b = $-84^0 18'20.37''$

Azimuth AC = $\mathbf{20^0 24'36.23''}$

-a = $-63^0 17'28.12''$

Azimuth AD = $317^0 07'08.11''$

Azimuth of BA = $284^0 42'56.60''$

+(d + c) = $+ 48^0 33'43.67''$

azimuth of BC = $\mathbf{333^0 16'40.27''}$

azimuth of CA = $200^0 24'36.23''$

+ angle f = $+ 66^0 35'55.3''$

Azimuth of CD = $267^0 00'31.53''$ = (f + e) for check.; azimuth CB = $-153^0 16'40.2''$

c) Position Computation

The coordinates of all the stations throughout the triangulation system are computed by using the strongest route of triangles in the network. When a station is reached whose coordinates are fixed, the positions of the intermediate stations can then be adjusted. If the triangulation system is of great extent and high precision, this adjustment should be made by application of the least-squares principle. If the system is moderate in extent, an application of the compass rule will give highly satisfactory results.

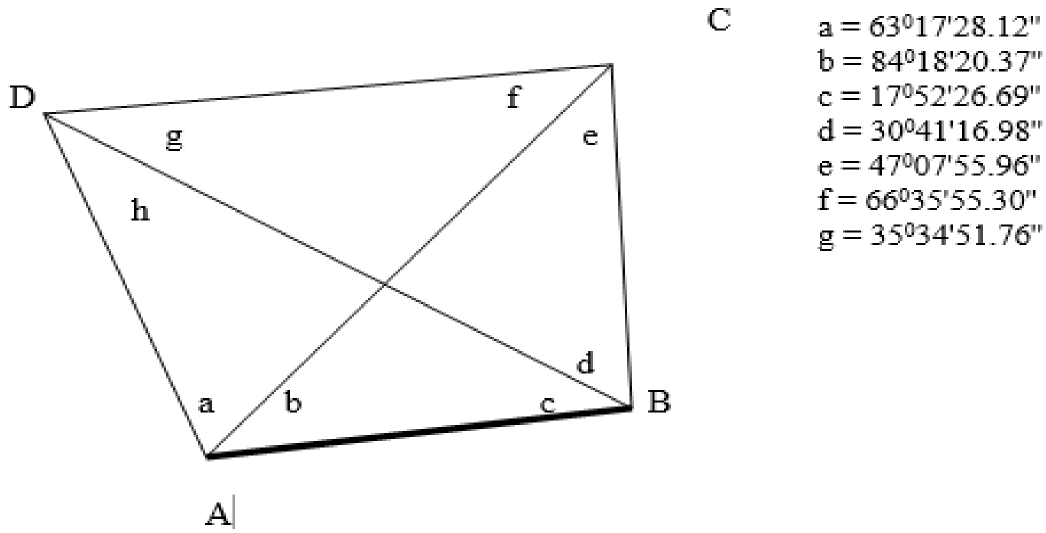


Figure 3.2 triangulation figure

In figure3.2, the side AB is the known or measured line of the quadrilateral, and the strongest route is obtained by considering triangle ABC and triangle DAC in that order with common side AC. To check the accuracy of the fieldwork or the consistency of the figure adjustment, the two triangles ABC and triangle BDC can be computed in that order with common side BC. This computation gives a check on the length of the side CD, which is the forward side of the quadrilateral. However, only the result for the strongest route will be used in the further computations. If the coordinates of stations A and B are known, the length of line BA computed by $\mathbf{D_{AB} = [(E_B - E_A)^2 + (N_A - N_B)^2]^{1/2}}$. With the side AB known, the sides AC and CB are computed by using the law of sins.

$$\frac{AC}{\sin(c+d)} = \frac{AB}{\sin e} \Rightarrow AC = AB * \frac{\sin(c+d)}{\sin e} \qquad \frac{CB}{\sin b} = \frac{AB}{\sin e} \Rightarrow CB = AB * \frac{\sin b}{\sin e}$$

The line CA = AC is then used as the starting side of triangle DCA.

3.6 Intersection

Intersection is a method of locating a point without actually occupying it. In figure below, points A and B are stations in a control network already surveyed and in order to coordinate unknown point C which lies at the intersection of the lines from A and B, angles α and β are observed.

3.6.1 Methods of intersection

i) Intersection from one base line(angle distance intersection)

In triangle ABC of figure 3.1, the length and bearing of base line AB are given by:

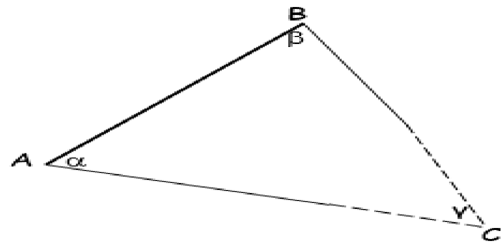


Fig 3.3) Intersection from one base line

$$\boxed{D_{AB} = [(E_B-E_A)^2 + (N_B-N_A)^2]^{1/2}}$$

$$\boxed{A_{AB} = \tan^{1}\left\{ \frac{E_B - E_A}{N_B - N_A} \right\}}$$

The sine rule gives:

$$\boxed{D_{BC} = \frac{\sin\alpha}{\sin\gamma} D_{AB}} \qquad \boxed{D_{AC} = \frac{\sin\beta}{\sin\gamma} D_{AB}}$$

Where, $\gamma = 180° - (\alpha+\beta)$

The Azimuth (WCB) in the triangle are given by

AzAC = AAB + α AzBC = ABA - β

These Azimuths (WCB) and distances are used to compute the coordinates of C along line AC as:

EC= EA+ DAC * sinAAC NC= NA+ DAC * cosAAC

The computations are checked along line BC using

EC= EB + DBC * sinABC NC= NB + DBC * sinABC

ii) Intersection from two baselines (distance-distance intersection)

One-method of detecting gross errors in the observations is to observe additional angles from a second baseline. This is shown in figure below, where the angles δ and φ have been added to those already observed in one baseline.

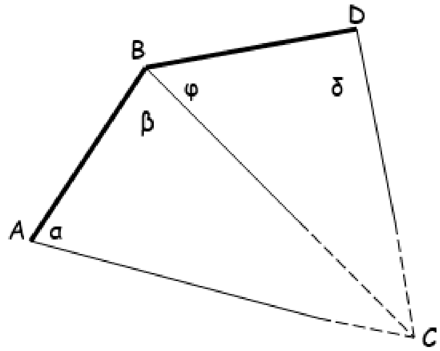


Fig 3.4 Intersection from two baselines

The coordinates of point C in the figure are found by solving the intersections formed by the triangles ABC and BDC, the two sets of coordinates obtained being compared. If the differences between the two intersections are small, it is assumed that the observations contain no gross errors and the average coordinates from the two sets are taken as final values.

Example: The coordinates of two control points A and B are XA= 602,105.32 and YA= 126,118.90m; XB= 601,048.82m and YB = 125,613.48m. The clockwise angle at A from B to unknown point P is 52018'46.2"; the counter clockwise angle at B from A to P is 37028'16". Compute the coordinates of P by intersection.

Solution

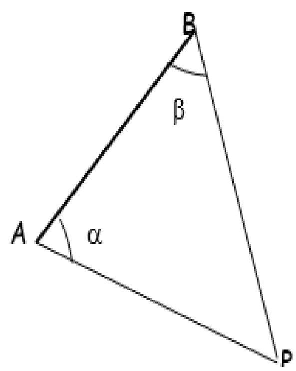


Fig 3.5 intersection figure

α = 52018'46.2" and β = 37028'16"

To compute coordinates of P, we should have to compute the azimuths of AP (AAP) or azimuth of BP (ABP) and length AP or BP.

Azimuth AP (AAP) = azimuth of AB (AAB) + A

Azimuth BP (ABP) = azimuth of BA (AAB) - B

AAB = tan-1 $\left(\frac{X_B - X_A}{Y_B - Y_A}\right)$ = tan -1 $\left(\frac{601,048.82 - 602,105.32}{125613.48 - 126,118.90}\right)$

= 64026'02.3" + 1800 = 244026'2.3"

A_{BA}= azimuth of AB +or - 180^0 = $64^0$26'2.3"

A_{AB} = 244^0 26’ 2.3’’ A_{BA} = $64^0$26’2.3’’

+A = $52^0$18’46.2’’ - B = 37028’16.0’’

A_{AP} = $296^0$44’48.5’’ A_{BP} = 26057’46.3’’

Using the sine Rule

D_{BP} = D_{AB} * SinA/sinB and D_{AP} = D_{AB} * Sin B/sinP

$$D_{AB} = \sqrt{(E_B - E_A)^2 + (N_B - N_A)^2}$$

$$= \sqrt{(601,048.82 - 602,105.32)^2 + (125,613.48 - 126,118.90)^2}$$

D_{AB} = 1171.171m

A + B + P =180^0

$52^0$18’46.2’’ + $37^0$28’16’’ + P =180 , P = $90^0$12’57.8’’

D_{AP} = D_{AB} * sinB/sinP = 1171.171 * sin $37^0$28’16’’/sin $90^0$12’57.8’’ = 712.500m

D_{BP} = D_{AB} * sin A/sinP = 1171.171 * sin $52^0$18’46.2’’/sin $90^0$12’57.8’’ = 926.825m

The coordinates of P along AP can be computed as

E_P = E_A+D_{AP}*sin (A_{AP}) = 602,105.32+712.500*sin296^0 44’ 48.5’’ = **601,469.055**

N_P = N_A+D_{AP}cos (A_{AP})= 126,118.90+712.500*cos296^0 44’ 48.5’’ =**126,439.560**

To check, compute along BP

E_P = E_B + D_{BP}*sinA_{BP} = 601,048.82 + 926.825*sin26^0 57’ 46.3’’ = **601,469.054**

N_P =N_B+D_{BP} cosA_{BP} =125,613.48+926.825*cos26^0 57’ 46.3’’=**126,439.560**

3.7 Resection

Resection is a method of locating a point by taking angle observations from it to at least three known stations in a network. In this method, the theodolite is set up over the unknown point and angle readings taken to at least three control points.

3.7.1 Select suitable station

Because the theodolite is only set up once over a free station, it is considered to give a less secure fix from the point of view of checks and accuracy. However, it is an ideal method for the positioning of an instrument station close to a particular piece of setting out work where it is difficult or impossible to set up a permanent control point.

3.7.2 Perform angle measurement

The theodolite set up over it and angle readings taken on three of the reference objects. The theodolite set up over point P and angles P" and P' should be measured from the unknown point P to the three known points B, A, and C. that means point P can be fixed by observing angles P" and P' subtended at resection point P by control stations A, B, and C.

3.7.3 Compute the coordinates

Total Station instruments have software incorporated, which will perform the calculations automatically. Setting out then continues using angles and distances calculated from co-ordinates.

The three control stations will form a triangle, and there are therefore two possible relationships between the unknown instrument station. Steps to compute the coordinates of station P illustrated as follows:

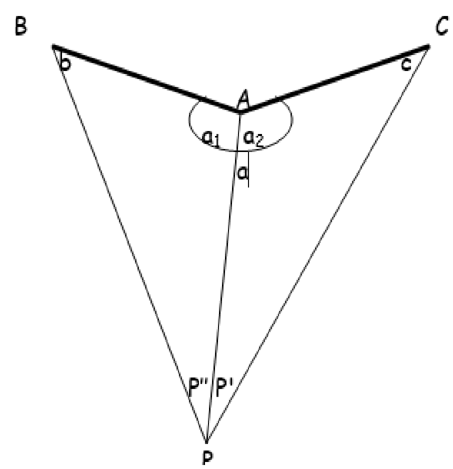


Fig 3.6 Sample resection figure

1. From the known coordinates of A, B, and C calculate lengths b and c, and angle α at station B.
2. Subtract the sum of angles X, Y, and α in figure ABCP from $360^0$to obtain the sum of angles X + Y.

$360^0 - (\alpha + p' + p'') = X + Y$

3. Calculate angles X and Y using the following: X+ y = 360 - (α + p' + p")

$1/2\ (X + y) = 180^0 - 1/2\ (\alpha + p' + p'')$ ------------------- (a)

$$\frac{AP}{SinY} = \frac{b}{SinP'}$$

$$AP = b\frac{\sin Y}{\sin P'} = c\frac{\sin X}{\sin P''}$$

$$let\frac{\sin Y}{\sin X} = \frac{C\sin P'}{B\sin P''} = \tan Z$$

$$Z = \tan^{-1} = \left(\frac{C\sin P'}{B\sin P''}\right)$$

$$\tan\frac{1}{2}(x-y) = \cot\left(Z+45^0\right)\tan\frac{1}{2}(X+Y)--------b$$

$$u\sin g \quad equation\ a\ \&\ b\ compute\ X\ \&\ Y$$

$$\frac{1}{2}(X+Y) = 180 - \frac{1}{2}(\alpha + P' + P'')$$

$$\frac{1}{2}(X-Y) = \tan-1\left(\cot\left(Z+45^0\right)\tan\frac{1}{2}(X+Y)\right)$$

4. From angles X and azimuth BA, calculate azimuth BP in triangle ABP. Then solve for length AP using the law of sines, where α1=1800 - X - p". Calculate the departure and latitude of BP followed by the coordinate of P.
5. In the manner outlined in step 4, use triangle BCP to calculate the coordinates of P to obtain a check.

Example

1based on Fig 3.6, angles X and Y were measured.

P' = $30^0$42’37’’ and P" = $25^0$12’15’’

Coordinate points A, B, and C have coordinates (in metre) of:

XB = 12750.000 XA = 16820.540 XC = 22190.788

YB = 10271.000 YA = 10105.772 YC = 11317.229

Calculate the coordinates of P.

Solution

1. Compute b, c, and α

$$c = \sqrt{(E_B - E_A)^2 + (N_B - N_A)^2} = \sqrt{(16820.540 - 12750.000)^2 + (10105.772 - 10271.000)^2}$$

$$= \sqrt{(4070.54)^2 + (-165.228)^2} \quad \mathbf{= 4073.892}$$

$$b = \sqrt{(E_C - E_B)^2 + (N_C - N_B)^2} = \sqrt{(22190.788 - 16820.540)^2 + (11317.229 - 10105.772)^2}$$

= **5505.197**

α = azimuth of AB – azimuth of AC

= AzAB - AzAC

AzAB = $\tan^{-1}\left(\frac{E_B - E_A}{N_B - N_A}\right)$ = $\tan^{-1}\left(\frac{12750.000 - 16820.540}{10271.000 - 10105.772}\right)$ = 272019’27. 9’’

AzAC = $\tan^{-1}\left(\frac{E_B - E_A}{N_B - N_A}\right)$ = $\tan^{-1}\left(\frac{22190.788 - 16820.540}{11317.229 - 10105.772}\right)$ = $77^0 17’15.43’’$

α = AzAB - AzAC = $272^0 19’27.9’’ – 77^0 17’15.43’’$ = $195^0 02’12.47’’$

1. **Compute X + Y**

1/2(X + Y) = 360^0 – (α +p" + p') = 360 – ($195^0 02’12.47’’$ + $30^0 42’37’’$ + 25012’15’’) $109^0 02’55.53’’$

2. **Calculate X and Y**

1/2 (X+Y) =180^0-1/2(α + P' + p")

=180^0-1/2($195^0$02'12.47"+$30^0$42'37"+$25^0$12'15") =$54^0$31'27.76"

1/2(X-Y) =tan-1[cot (Z+450) tan1/2(X+Y)]

$$butZ = \left[\frac{c\sin p'}{b\sin P''}\right]$$

$$= \tan^{-1}\left[\frac{4073.892 * \sin 25^0 12'15''}{5505.197 * \sin 30^0 42'37''}\right]$$

$$= 31^0 4^0 '36.93''$$

$$Z + 45 = 76^0 40'36.93''$$

$$\cot(Z+45) = \frac{1}{\tan(Z+45)} = \frac{1}{\tan 76^0 40'36.93}$$

$$= 0.2368$$

$$ie\ \frac{1}{2}(X-Y)\tan{-1}\left[(0.2368)(1.4032)\right]$$

$$+\left[\frac{1}{2}(X-Y) = 18^0 22'54.25''\right]$$

$$\left[\frac{1}{2}(X+Y) = 54^0 31'27.76\right]$$

$$X = 72^0 54^{'} 22.01''$$

$$Y = 36^0 08'33.51''$$

3. Compute:

i) ABP ii) α1

iii) BP iV) ΔXBP and ΔYBP and

iiv) XP and YP

ABP = ABA + X

= 92019'27.9" +72054'22" = 165013'49.9"

α1 = 180 - A - P = 180 - 72054'22" - 30042'37"=76023'01"

BP = AB * sin76023'01"/sin30042'37" = 7752.912m

ΔXBP = BP * sin ABP = 7752.912 * sin 165013'49.9" = 1976.454m

ΔYBP = BP * cos 165013'49.9" = -7496.751m

XP = XB + ΔXBP = 12750 +1976.454 = 14726.454

YP = YB + ΔYBP= 10271-7496.751 =2774.249

4. To check use triangle BCP.

Self-Check 3

Part 1 write true for the correct statement otherwise write false

1. Minimum of one point with known coordinate is required in resection.
2. In resection the measurement is done unknown to known point.
3. The totalstation can easily compute the free station coordinate automatically.

Part 2 multiple choices

Choose the right answer for the given questions. 2 minute are given for each question (1poin each).

4.Which triangulation figure best employed in long and narrow surveys of low precision?

A. Chain of Quadrilaterals
B. Chain of single triangles
C. A chain of central point figures
D. Central Point figure with extra diagonal

5.Which order of triangulation is best for national control networks establishment?

A. First order B. Second order C. Third order D. Fourth order

Part 3 fill the blank space with appropriate words or phrases. Each question has 1 Points

6.______________is a previously known side of triangulation used to compute all sides of the triangle

7.______________ a method of locating a point without actually occupying it.

8._____________is method of detecting gross errors in the observations form a second baseline.

9.__________ a method of locating a point by setup the instrument over the unknown point itself.

10. _____________is method of detecting gross errors in the observations form a second baseline.

Part 4 Short Answer writing

11. Write the difference between intersection and resection
12. List down triangulation procedure
13. Write the difference between intersection and traversing

Operation sheet 3

Operation Title: Title: Perform triangulation, intersection and resection

Purpose:

- to compute length
- to determine the coordinate

Conditions or situations for the operations:

- ✓ Safe working area
- ✓ Proper operating tools and equipment
- ✓ Appropriate working PPE and instrument safety

Equipment Tools and Materials:

Hand held GPS	Surveying compass/ magnetic compass	Thedolite Tripods	Rod-level/ Plumb bob	Brush Paper	Scientific calculator
Measuring tape		Range pole	Ink Paint	Pencil	Totalstation

Steps in doing the tasks

Step 1: Wear appropriate PPE and care the instruments safely

Step 2: Prepare equipment and tools

Step 3: perform reconnaissance survey

Step 4: Erect signals

Step 5: Measure horizontal angle, base line length and azimuth

Step 6: Locate the coordinates of the first station with hand held GPS

Step 7: Compute the sides of the triangle

Step 8: Select convenient station for resection

Step 9: Compute the azimuth of every line

Step 10: Compute departure and latitude

Step 11: Determine the coordinates of traverse stations

Quality Criteria: Assured performing of all the activities according to the procedures.

Use the use accuracy order of 1 part in 5,000 for distance.

Lap Tests 3

Name: ______________________________ **Date:** ________________

Time started: ________________________ **Time finished:** ________________

Instructions: Use necessary tools and materials required to perform the following tasks accordingly.

Task 1: Wear appropriate PPE

Task 2: Perform triangulation, intersection and resection

Task 3: Perform necessary computations and checks

Task 4: Compute the coordinates of points.

Unit four: Station description

This unit is developed to provide the trainee the necessary information regarding the following content coverage and topics

- Description writing.
- Station referencing
- Documentation

This unit will also assist the trainee to attain the learning outcomes stated in the cover page. Specifically, upon completion of this unit, the trainee will be able to:

- Write descriptions for satiation.
- Locate stations with reference.
- Document station information

4.1 Description writing

When writing the station description, include information on how to reach the general location of the monument from some prominent feature such as a highway intersection. The actual monument is a metal cap, stamped with an agency name and individual identification, firmly set in the ground.

The point placed on natural basalt bedrock approximately 80cm by 60cm wide and 50cm high from the natural ground. The point is a drilled hole inscribed in an engraved triangular shape with appropriate arrows guiding towards the point. The point is located at the peak point of mount Nitto Deber. This control point is located driving 2km towards Dessie city from Debre Berhan town and taking left gravel road by driving around 3.8km towards Nitto Deber village. About walking 15minutes towards the mountain peak point the point is easily visible.

Fig 4.1 Natural basalt bedrock monument

The monument is established with concrete PVC pipe having 150mm diameter and 600mm depth. The point is 100mm high from natural ground and materialized with an iron bar of 8mm diameter inserted at a depth of 30cm inside the concrete and 8mm higher from top of concrete monument. The point is located at the exit of Ankober town near to Ankober lodge.

Fig 4. 2 PVC pipe monument

4.2 Station referencing

The description about the stations or bench marks is used to express the field location where they are located relative to reference monuments. These descriptions expressed in distances and direction. The field book must contain sufficient description about the bench mark or station established. The bench mark M is found in reference to existing fixed monuments (fig 8.1) 20m from B, 30m from A, 55m from C and 65mfrom D.

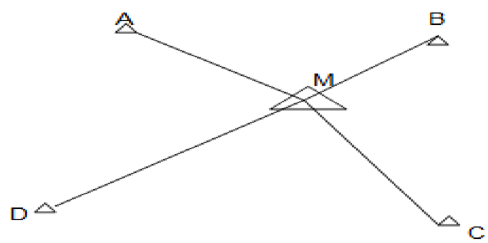


Figure 4.3 locating the position of station with reference

All primary horizontal and vertical control stations shall be monumented and described. A monument can be both a horizontal and a vertical control point. Monuments set by ERA is used monuments set by other agencies can be used if they are in a good location. For example, an existing

Set monuments in firm ground and away from the traveled way so that they can be occupied without danger from traffic. Consider the possibility of frost heave or ground settling.

Place a witness post near the monument to help in finding it again at a later date and to protect it from accidental destruction. Vertical control monuments must be measured in the metric system. Primary vertical control monuments must be tied to National Geodetic Survey (NGS) bench marks by using equipment and procedures meeting second order specifications.

4.3 Documentation

The best evidence of a monument's original position is a continuous chain of history by acceptable records, usually written, back to the time of the original monumentation. As part of this, surveyors must contribute to the body of public records by documenting monument work appropriately and by striving to preserve and perpetuate existing monuments.

It is mandatory to file a record of survey under certain circumstances. Any monument set by a land surveyor be permanently marked or tagged with the certificate number of the land surveyor setting it. When monuments are set for a new project or to replace old monuments, they should be a permanent nature, clearly identified referenced, recorded with the legal requirements and located on the local coordinate system.

If a monument is offset from the point that it is intended to represent, the record must show the offset and direction between the point and the monument.

Public knowledge of the location of the monuments and their relation to the point that they represent will eliminate many problems that have occurred in the past where monuments were destroyed and there was no public record that showed references to remaining points.

Table 4.1Sample control point data documentation format

POINT	NORTH	EAST	ELEV.	STATION	OFFSET
S1	460,512.0120	1,417,231.8940	520.7730	100+76.50	253.5824
S2	461,350.7600	1,417,172.0970	538.4500	108+74.06	-12.8205
S3	462,446.8280	1,417,446.0830	557.0590	120+03.83	-19.8765
S4	462,785.4470	1,417,328.7590	557.8100	123+02.66	-217.6868
S5	462,218.7960	1,417,385.1590	558.8310	117+67.82	-22.2078
S56	462,724.3300	1,417,773.8720	555.1660		
S101	462,751.2340	1,417,834.9240	552.9990		
S168	462,768.3990	1,417,518.0770	558.9040	123+33.21	-30.0730

Self-Check 4

Part 1. Write true if the statement is correct otherwise false

1. Secondary vertical control, designed to supplement the primary control
2. Secondary vertical control monuments must be tied to the primary vertical control monuments.
3. The best evidence of a monument's original position is a continuous chain of history by acceptable records

Part 2. Fill the blank space with appropriate words or phrases

4. _____is a monuments must be tied to National Geodetic Survey
5. _____ is place near to the monument to help in finding it again at a later date.

Part 3. Short Answer writing

6. Write the importance of descriptions for stations

Unit Five: Horizontal and vertical alignment

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Alignment selection
- Horizontal curves
- Vertical curves.
- Labor based setting out methods
- Documentation of leveling result

This unit will also assist the trainee to attain the learning outcomes stated in the cover page. Specifically, upon completion of this unit, the trainee will be able to:

- Select route alignment
- Sett out of horizontal curve.
- Sett out of vertical curve.
- Use labor based methods
- Document of leveling result

5.1 Alignment selection

When constructing a new road, there are several possible choices of alignments. Although the shortest connection between two points is a straight line, the road alignment will very seldom be entirely straight. for various reasons:

(a) a straight and short alignment may cross through villages, farms or other public or private property.

(b) in rolling, hilly or mountainous terrain, the gradients on a straight alignment would often be too steep or the earthworks required excessive;

(c) the straight alignment may pass through extremely difficult terrain (rocks, dense forest, swamps, etc.) which should be avoided to minimize construction costs;

(d) if a river or other obstacle has to be crossed, another alignment may be necessary in order to find a crossing at the most suitable location;

(e) by choosing a slightly longer alignment, the road can be constructed on a soil type more suitable for road construction. In addition, the choice of alignment may be influenced by the location of suitable sources of water and the location of gravel deposits. When rural roads are built to provide access, existing tracks should be followed whenever possible to minimize earthworks. The following points are used as a check list:

- Locate the best sites for river crossings.
- Avoid rocky areas.
- Avoid areas with heavy bush-clearing.
- Try to avoid complicated drainage solutions.
- Try to follow existing alignments of roads and tracks.
- Avoid steep gradients (maximum 10%).
- Keep earth-moving at a minimum.
- Be considerate with existing farming activities in the area.
- Avoid triggering soil erosion.

5.1.1 Factors Affecting Choice of Route

Where several alignments are possible, the engineer will decide on the detailed design after considering:

(a) **Construction costs** - e.g. an alignment of a certain length with steep gradients up to 20 percent (Alignment 1) will be cheaper to construct than an alignment of the same length with gradients up to 5 percent (Alignment 2).

For the latter, the necessary earthworks will be far more extensive. Try to avoid steep side long ground even if the existing road is cut into it.

Although it is possible to overcome the problem, any solution is expensive in terms of labour, materials and finance. Route selection is therefore important. If possible, relocate the line lower down the hill side where the ground is flatter.

(b) **Costs to future traffic** - these costs will be greater for Alignment 1 than for Alignment 2. More energy is used to climb/descend steep gradients and will cause more wear to brakes. Stronger means of transport will be required for Alignment 1. For village roads, it is to assume that these may become market roads as the country develops. Steep gradients should therefore be avoided.

(c) **Maintenance costs** - the costs to maintain steep gradients are considerably higher than the costs to maintain gentle gradients.

(d) **Social costs and benefits** - in many cases, the higher construction costs of a longer alignment may be justified if the road also serves public facilities (e.g. school, health center). The engineer also has to consider existing land use and to whom the land belongs.

(e) **Watershed route** - normally cross drainage is expensive but can be avoided if the road follows the line of the watershed. Ditching may then be unnecessary and considerable cost savings will derive.

For changes in direction, to avoid abrupt change, horizontal curves are provided between the straights in both planes. In horizontal alignments the design runs without sudden changes from easy to sharp. It also proved comfort and aesthetic value to the passengers. Good drainage is recommended.

5.2 Tangent or straight section

It should not be long because increase the danger from headlight glare and usually lead to excessive speeding and the driver forget his driving due to comfort. Long distance of tangent section in hot climate is difficult in safety aspect. And due to the broken back effect, short tangents b/n curves in the same direction should not be used.In the geometric design of motorways, railways, pipelines, etc., the design and setting out of curves is an important aspect of the engineer’s work. The intersections of pairs of straights are connected by horizontal curves.In the vertical design, intersecting gradients are connected by curves in the vertical plane.

Curves can be listed under three main headings, as follows:

(1) Circular curves of constant radius.

(2) Transition curves of varying radius (spirals).

(3) Vertical curves of parabolic form.

5.3 Horizontal or Circular curves

A. Simple circular curves

Curve consists of a single arc of constant radius throughout the curve connecting two tangents.

Two straights, D1T1 and D2T2 in Fig 5.1, are connected by a circular curve of radius R:

(1) The straights when projected forward, meet at I: the intersection point.

(2) The angle _ at I is called the angle of intersection or the deflection angle, and equals the angle T10T2 subtended at the centr of the curve 0.

(3) The angle φ at I is called the apex angle, but is little used in curve computations.

(4) The curve commences from T1 and ends at T2; these points are called the tangent points.

(5) Distances T1I and T2I are the tangent lengths and are equal to R tan_/2.

(6) The length of curve T1AT2 is obtained from:

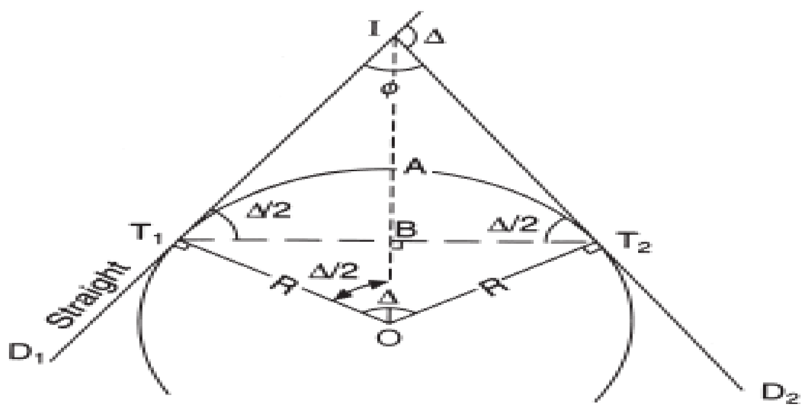


Fig 5.1 of Circular curves with elements

5.3.1 Curve designation

Curves are designated either by their radius (R) or their degree of curvature (D◦). The degree of curvature is defined as the angle subtended at the centr of a circle by an arc of 100 m.

- Thus R = 100m/D rad = $(100*180^o)/(D^o*\prod)$ = R= $5729.578/D^o$
- Thus a 10^o curve has a radius of 572.9578m
- T = tangent distance T = R tan $\triangle$ /2
- L = curve length L = $\prod$ R$\triangle$/180
- C = chord length C = 2R sin $\triangle$ /2
- E = external distance E = R ([sec $\triangle$/2 - 1]) or E =T tan $\triangle$/4
- M = middle ordinate M = R (1-cos $\triangle$ /2) or M = E cos $\triangle$/2
- P.C = station of point of curve Stn of P.C = Stn P.I. – T
- P.T. = station of Point of tangency Stn P.T= Stn P.C+L

5.3.2 Setting out of Circular Curve

There are various methods for setting out circular curves. Some of them are:

I. Perpendicular Offsets from Tangent

$$y = R - \sqrt{(R^2 - x^2)} \quad (exact)$$
$$= \frac{x^2}{2R} \quad (approximate$$

where *x* = the measured distance from *T*1 along the tangent.

II. Radial Offsets

$$r = \sqrt{(R^2 + x^2)} - R^2 \quad (exact)$$
$$= \frac{x^2}{2R} \quad (approximate$$

Were X = the measured distance from T_1 along the tangent

B. Compound curves

It has two or more circular curves contained between the two main straights or tangents.

The individual curves meet tangentially at their junction point. Smooth driving characteristics require that the larger radius be more than 1 times larger than the smaller radius.

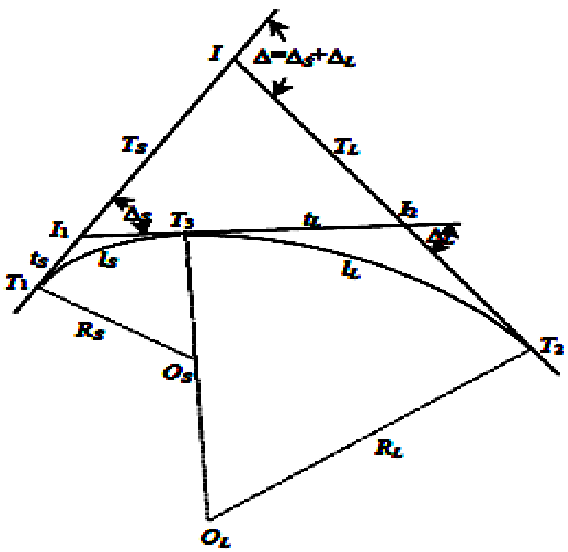


Fig 5.2 compound curve

- $T_S = R_S \tan \Delta s /2$
- $t_L = R_L \tan \Delta /2$
- $T_S= (t_S + t_L) (\sin \Delta_L / \sin \Delta)+t_S$
- $T_L= (t_S + t_L) (\sin \Delta_S / \sin \Delta)+t_L$
- Where $\Delta = \Delta s + \Delta_L$

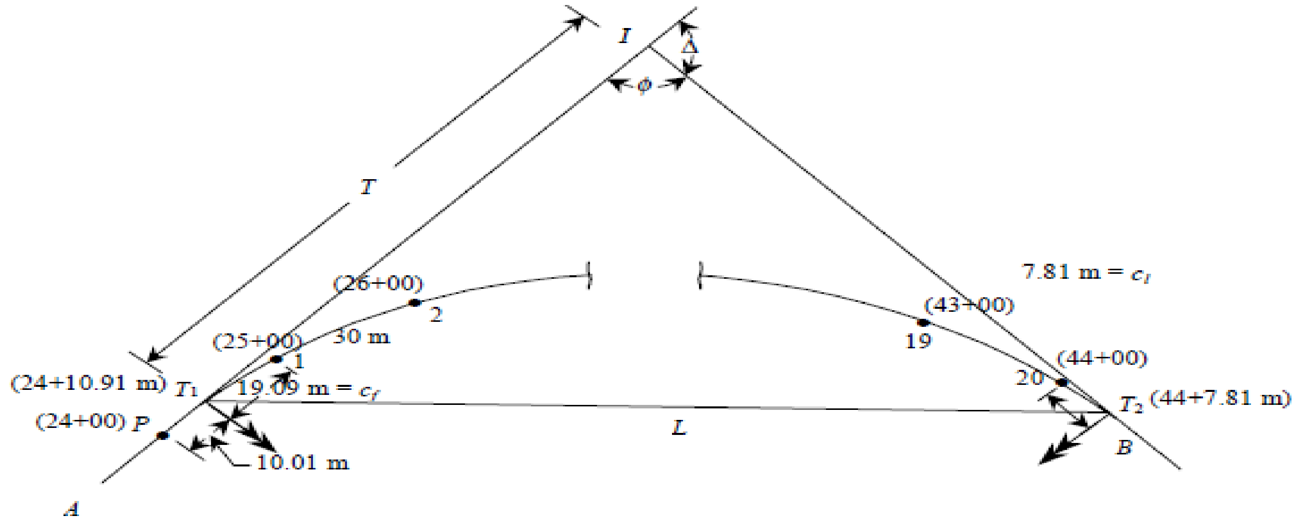
- length of curves
- $ls = \prod Rs \Delta s/180$
- $l_L = \prod R_L \Delta_L/180$
- $l= ls + l_L$
- $l= (\prod/180) (R_S\Delta_S + R_L\Delta_L)$

Chainages

chainage of T_1 = chainage of P.I. – T_{S} , chainage of T_3 = chainage of $T_1 + l_S$ and

chainage of T_2 = chainage of $T_3 + l_L$

Example 1. The chainage of the intersection point of two straights is 1060 m, and the angle of intersection is 120°. If radius of a circular curve to be set out is 570 m, and peg interval is 30m, determine the tangent length, the length of the curve, the chainage at the beginning and end of the curve, the length of the long chord, the lengths of the sub-chords, and the total number of chords.



Solution

Deflection angle $\triangle = 180^o – \Phi = 180^o – 120^o = 60^o$. $\triangle/2 = 30^o$

Tangent length T= R tan$\triangle$/2 = 570*tan 30^o = 329.09m

Curve length l= ∏R$\triangle$/180 = ∏*570*60/180 = 596.9m

Chainage of P.I. = 1060m = (35*30+10)m = s5 full chain + 10 m = 35 + 10

T = 329.09m = 10+ 29.09 an d l=596.9m = 19+26.9

Chainage of T_1= Chainage of P.I. – T= 35 + 10 – (10 +29.09) = 24 + 10.91

Chainage of T_2 = Chainage of T_1 +l = 24 +10.91 + (19+26.9) = 44 +7.81

Long chord L = 2Rsin $\triangle$/2 = 2*570* sin30^o = 570m.

(iv) On the straight AI, the chainage of T1 is (24 + 10.91). Therefore, a point P having chainage (24 + 00) will be 10.91 m before T1 on AI. Since the peg interval is 30 m, the length of the normal chord is 30 m. The first point 1 on the curve will be at a distance of 30 m from P having chainage (25 + 00) and 30 – 10.91 = 19.09 m from T1. Thus the length of the first sub-chord = 19.09 m. Similarly, the chainage of T2 being (44 + 7.81) a point Q on the curve having chainage of (44 + 00) will be at a distance of 7.81 m from T2. Thus the length of the last sub-chord = 7.81 m.

To calculate the length of the sub-chords directly, the following procedure may be adopted. If chainage of T1 is (F1 + m1) and the length of the normal chord C is m then the length of the first sub-chord cf = m – m1 = 30 – 10.91 = 19.09 m. If the chainage of T2 is (F2 + m2) the chainage of the last sub-chord cl = m2 = 7.81 m.

(v) The total number of chords N = n + 2

where n = Chainage of the last peg – chainage of the first peg = (44 + 00) – (25 + 00) = 19

Thus N = 19 + 2 = 21.

C. Set out cross sections

General Procedure

When a cross-section is set out in the field, survey pegs and multi-purpose pegs show:

- the center line of the road,
- the level of the road (flat/hilly/mountainous terrain, cut, fill),
- the location of the ditches,
- the limit of excavation (cut, side long cut), and
- the foot of the embankment (fill).

Normally, the road camber is set out together with the side drains. Once the position and levels of the center line have been determined, it is possible to construct the camber and side drains. The cross-section pegs should be set out at a right angle to the center line pegs.

Cross-section of Standard Formation (flat terrain)

In this case, the survey pegs serve to mark the center line as well as the road level. When it is necessary to cut or fill to reach the required level, this is shown on the peg.

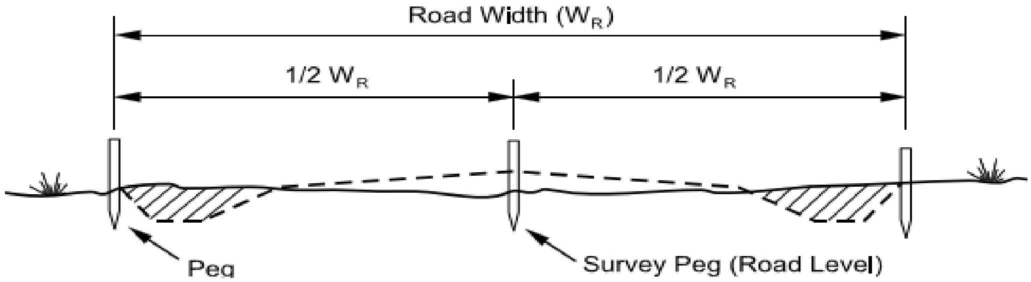


Fig 5.3 Cross-section of flat terrain

Cross-section of Side Cut

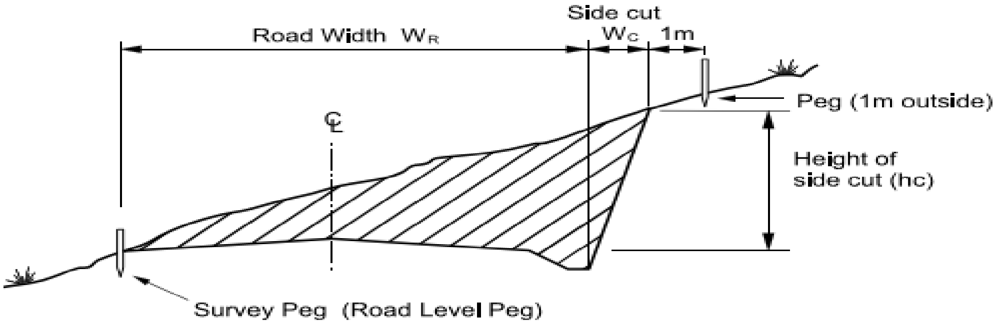


Fig 5.4 Cross-section of Side Cut

Here the survey peg marks the road level. After the road has been excavated to level, the center line and ditch slope pegs will be placed.

Cross-section of Cut to Fill

Again, the survey peg marks the future level of the road. The figure below shows that the volume of the excavation is approximately twice the volume of the fill and that a bench-notch should be dug to provide a stable foundation for the fill side of the road.

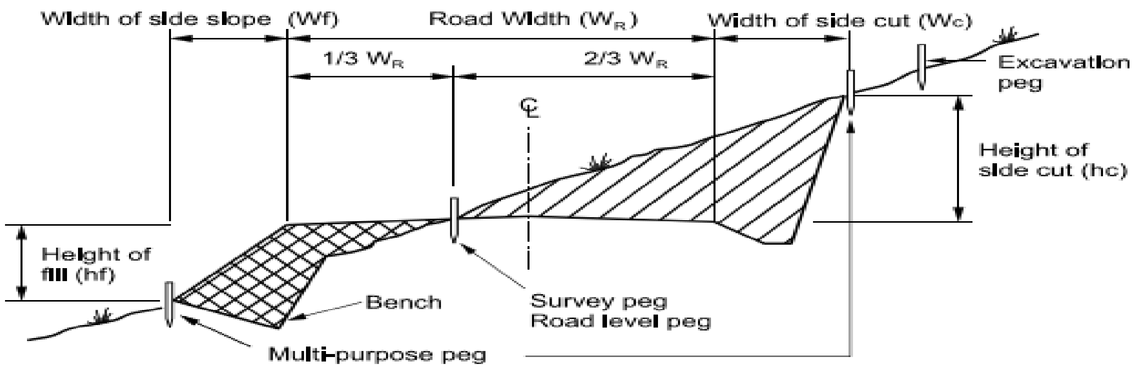


Fig. 5.5 Cross-section of Cut to Fill

Cross-section of a Fill

The survey pegs on both sides of the road show the height to be filled. The height is marked on the peg and measured from the top of the peg. With a slope of 1:1 on both sides, the formation width can be calculated by adding hf1 and hf2 to the road width.

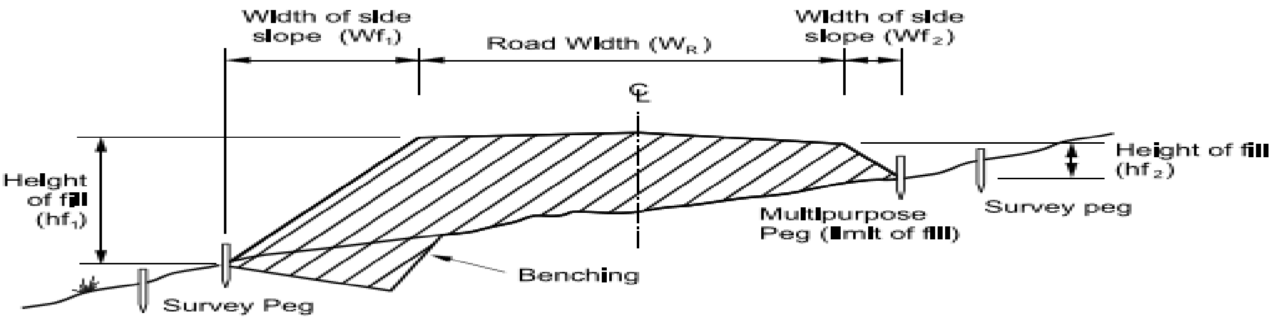


Fig. 5.6 Cross-section of Fill

D. Setting Out the Road Camber

When setting out the road camber and side drains, it is important to reduce the amount of excavation to a minimum by following the existing level of the terrain along the road line. The procedure described below is an efficient way of setting out the road levels, achieving a well-placed road with good drainage and which does not involve massive excavation and/or fill works.

Step 1: Using the previously set out center line, set out ranging rods at 10m intervals along the center line for a section of 50 to 100 meters. At the start of the section, measure out the position of the road shoulders and the outer end of the side drains from the center line. Repeat this exercise at the other end of the section. Place a wooden peg next to each of the ranging rods.

Step 2: Once the key positions of the road have been set out at the start and the end of the road section, sight in intermediate ranging rods at every 10m along the road shoulders and side drains. Place wooden pegs next to each of the intermediate ranging rods.

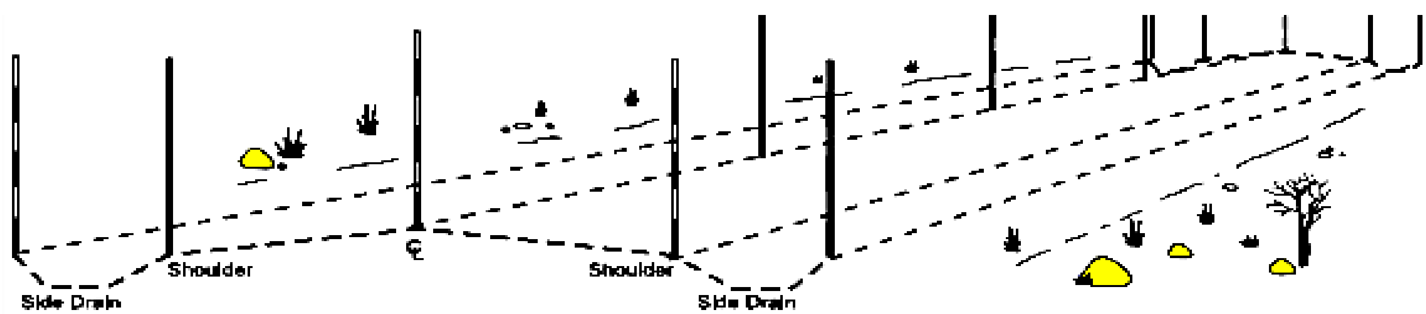
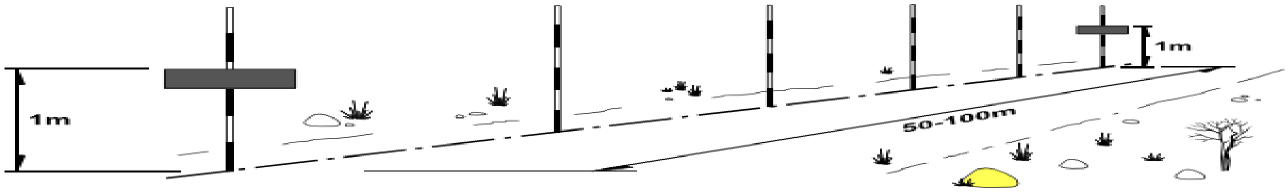


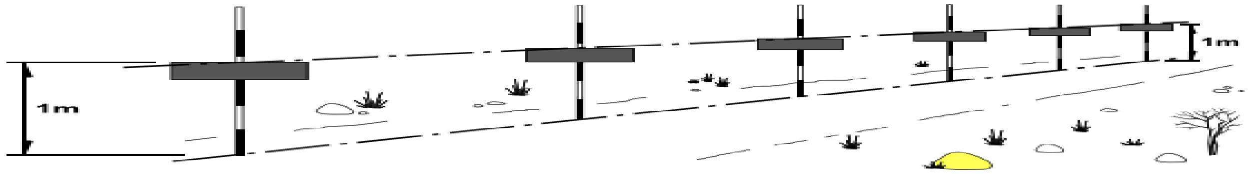
Fig 5.7 labor-based cross sections setting out

Step 3: On the center line of the road, fix the first profile board. This profile may already be in position as the last profile from the previous set out section. If not, measure 1m up from the existing ground level, and mark this level on the ranging rod. Fix a profile board to the ranging rod so that the top edge of the profile board is at the mark made on the road.

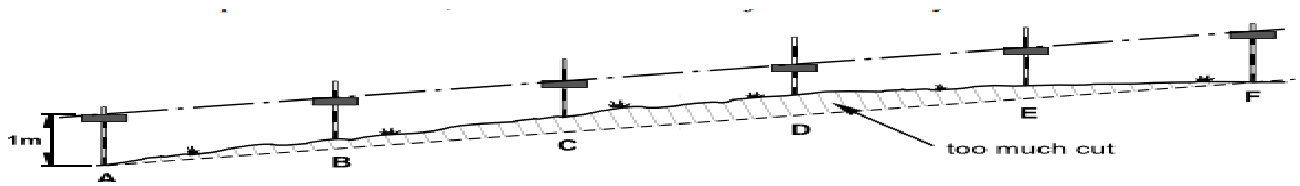
Step 4: Go to the center line ranging rod at the other end of the road section and repeat the procedure, measuring up 1m from the ground level.



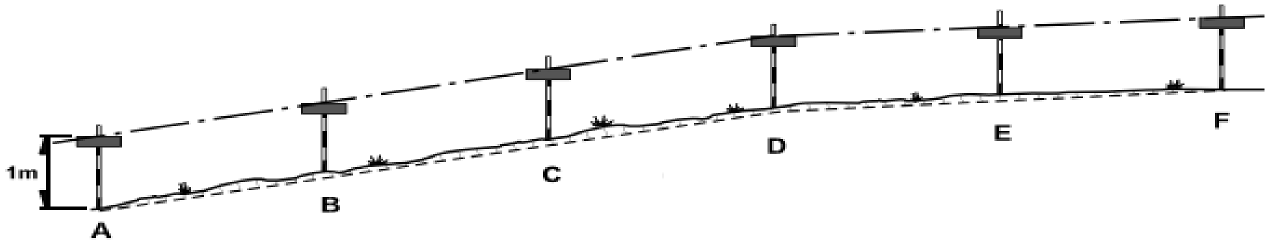
Step 5: By sighting in the intermediate profiles from one end, fix profile boards on the intermediate ranging rods along the centre line so that they are all at the same level.



Step 6: Check the height of each profile board above the ground level. If the height is approximately 1m, there is no need to adjust them and you can use the level of the profile as it is.



If the height of the profile boards is greater or less than 1m by 10cm, then inspect the line. There may be humps or depressions along the line. The set-out line will in most cases smooth out these variations. However, it may be that the set-out line is over a hill or a dip in the terrain. In such cases, it is necessary to adjust the profiles to avoid too much excavation works. Adjust the profile at position D so that it is 1m above the ground and then lift the profiles at B, C and E to sight in line with the profiles at A to D and D to F. This exercise will reduce the amount of excavation works.

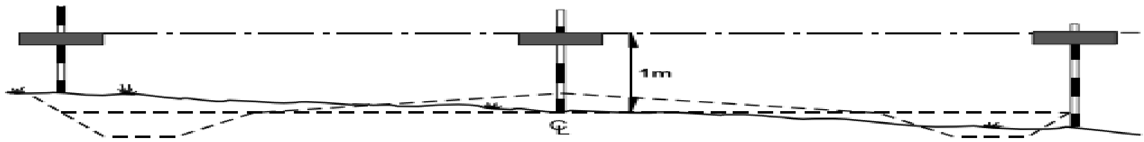


General Rules

- It is better to lift profiles than to drop them.
- Try to keep lifts and drops less than 10cm.
- Try to match the road levels to the terrain.
- Use the profiles to get a picture of the vertical road alignment

Before starting on the next step, make sure that the side drains can be emptied. It is important to spend time on this step to get the levels right. All other levels will be set out based on the profiles along the center line of the road.

Step 7: Transfer the levels to the ranging rods at the outer end of the side drains. Start with the beginning of the road section. Using a string and a line level, transfer the level of the profile board at the center line to the ditches on both sides of the road. Once the levels are set out with profile boards, mark the levels on pegs next to each ranging rod.

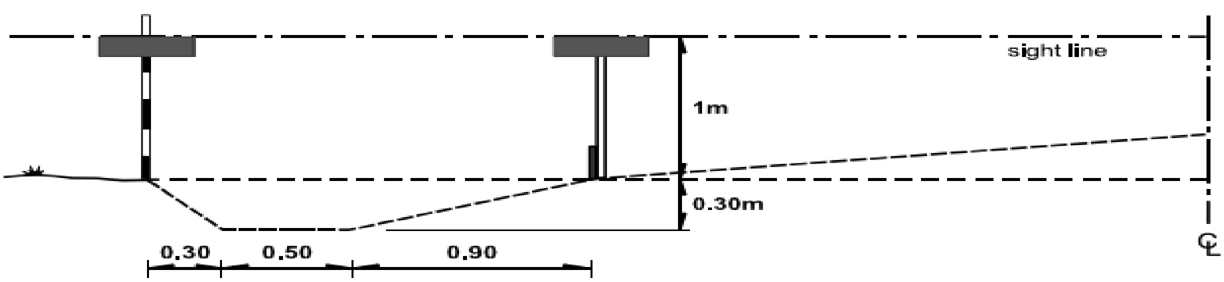


Repeat this procedure for the same two ranging rods at the other end of the road section and for any intermediate profile along the center line that was lifted or lowered to reduce excavation works. Then, sight in the intermediate side drain levels. In most cases, the height of the drain profile on the low side of the center line is more than 1m. This is because we have started from higher grounds, and since the road is level, the lower side drains will be less deep.

Step 8: Mark the levels for the center line on pegs placed next to the ranging rods along the center line. Now, use the center line profile boards to set out intermediate pegs, placed at every 5 m along the center line. This is easily carried out with a 1m traveller. Mark these pegs at the point where the bottom of the traveller touches the peg, when lined up with the profiles. On all the center line pegs, mark the level of the crest of the camber.

Levels are usually written as three-digit numbers, showing the required cut or fill in meters (e.g. +0.20 means that a fill of 20 centimeters is required). When the level is indicated, always measure from the top of the peg. You have now set out the profiles for the levelling of this road section.

Step 9: Place the levels of the shoulders along the road. For this, it is useful to have a traveller 1m high. If we line up the traveller along the line between the two side drain profiles, the bottom of the traveller will show the correct level of the shoulder.



Place pegs every 5m along the edge of the shoulder, and using the traveller, mark these pegs at the point where the bottom of the traveller ends when it lines up with the profiles.

Step 10: Locate and set out the miter drains. It is important that the miter drains are set out before the excavation works for the side drains and camber is commenced.

Step 11: Set out with string line the side drains that need to be excavated. Remember to leave out the miter drain block-offs.

E. Super elevation

On horizontal curves, the roadway is tilted so that the edge of the pavement at the outside of the curve is higher than the edge of the pavement at the inside of the curve. This is called super elevation and is done to counteract the centrifugal force which tends to push the vehicle off the roadway at the outside of the curve. The rate of super elevation is a function of the radius of the curve and the design speed. As the radius shortens for a given design speed or as the design speed increases for a given radius, the super rate must increase to keep the vehicle on the road. The maximum super rate is 0.10.

Going from a tangent section which has a normal crown to a curve section which has full super, there is a gradual change in the rate of super elevation called a transition. Approximately three fourths of the transition is in the tangent section of the roadway and one fourth is in the curve. See the Design Manual for super elevation transition designs. The edge of the pavement that is on the outside of the curve begins to rise in relation to the center line (or reference point).

The edge rises until the roadway is on one (sloping) plane from edge to edge. This is called crown slope and is usually 0.02(see the fig 5.3). The entire roadway then rotates about the pivot point until it reaches its maximum or full super. Exiting a curve, the process is simply reversed, going from full super to crown slope to normal crown. The survey crew should not have to design supers but may have to compute grades for a station or offset on a section in transition. The contract plans will contain superelevation diagrams on the same sheet as the roadway profiles. The contract plans and/or the roadway elevation listing (grade sheets) show the stations of the beginning of the transition, crown slope, and full super.

To find the super rate for any station in a transition:

1. Subtract the begin transition station from the end transition station.
2. Subtract the desired station from the end transition station.
3. Subtract, algebraically, the crown slope from the full super rate.
4. Divide the super difference (#3) by the station difference (#1).
5. Multiply the desired station difference (#2) by the rate of change (#4).
6. Subtract #5 from the full super rate which gives the super rate for the station in question.

Example: Find the super rate at station 1+535 on the right edge of the pavement using Figure 5.8.

1. 1+554.940 - 1+489.110 = 65.830 m
2. 1+554.940 - 1+5350 = 19.940 m

3. 0.06 - (-0.02) = 0.08 m/m
4. 0.08/65.830 = 0.0012150 m/m/m = rate of change
5. 0.001215 x 19.940 = 0.02423 m/m
6. 0.06 - 0.02423 = 0.03577 m/m

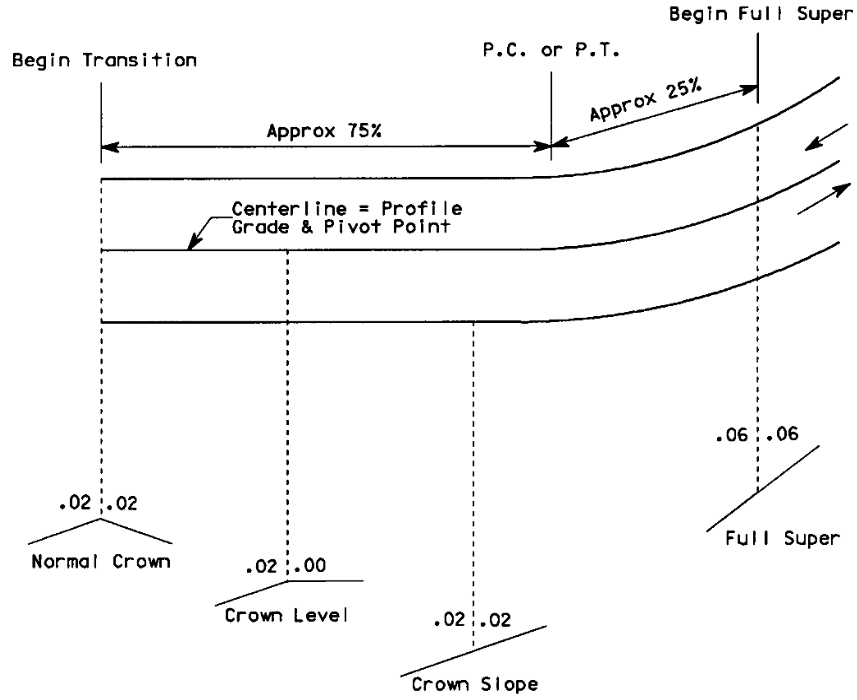


Fig 5.8 Supper elevation

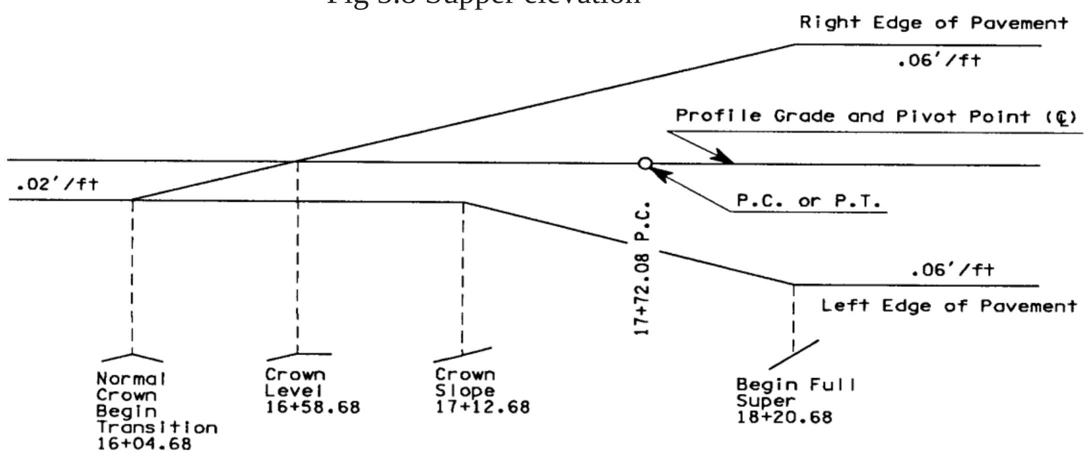


Fig 5.9 Super elevation diagram for two lane highway

5.4 Vertical curves

Vertical curves are introduced at the intersection of two gradients either as summit curves or sag curves. The requirement of a vertical curve is that it should provide a constant rate of change of grade, and a parabola fulfills this requirement. For flat gradients it is normal to assume the length of curve (2*L*) equal to the length along the tangents the length of the long chord *AC* its horizontal projection. (Fig. 5.10)

When a change in grade of more than about 0.5 percent occurs at a VPI, a vertical curve is required. The vertical curve lengths taken from design. Once the grades are established and the lengths of the curves are chosen; the vertical offsets of the curves can be computed. A vertical curve is a parabolic curve.

When the grades form a peak or hill at the VPI, the curve is known as a crest vertical or summit vertical

When the grades form a valley or dip at the VPI the curve is known as a sag vertical.

When l_1 does not equal l_2 the curve is nonsymmetrical. The vertical curve is computed by figuring offsets from the tangent grades.

Subtract the offsets from the tangent grade elevations for crest verticals and add the offsets to the tangent grade elevations for sag verticals.

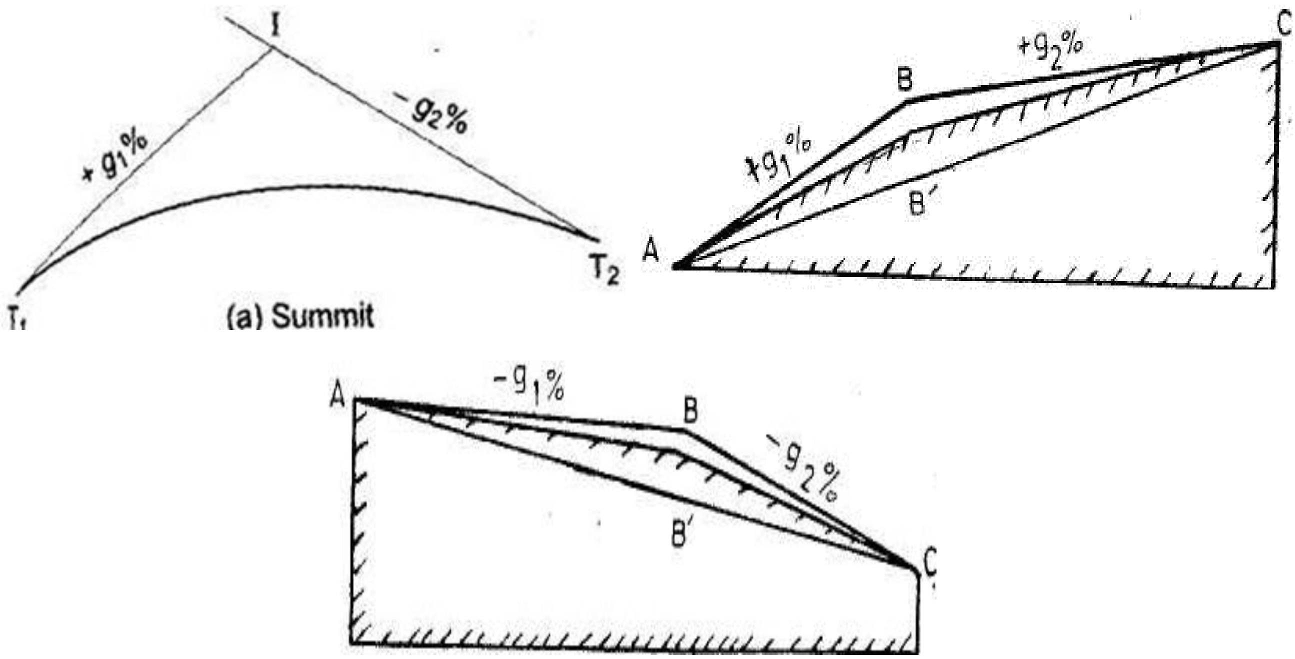


Fig.5.10 Types of summit vertical curves

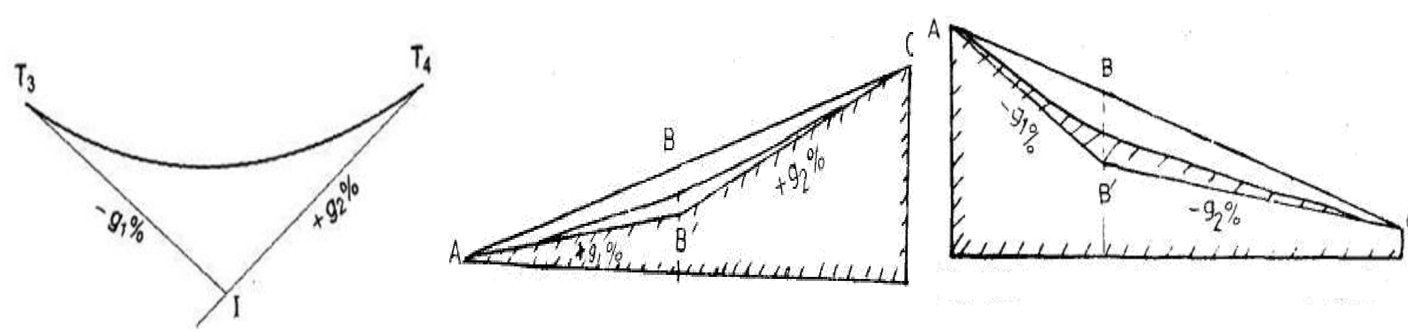


Fig.5.11 Types of sag vertical curves

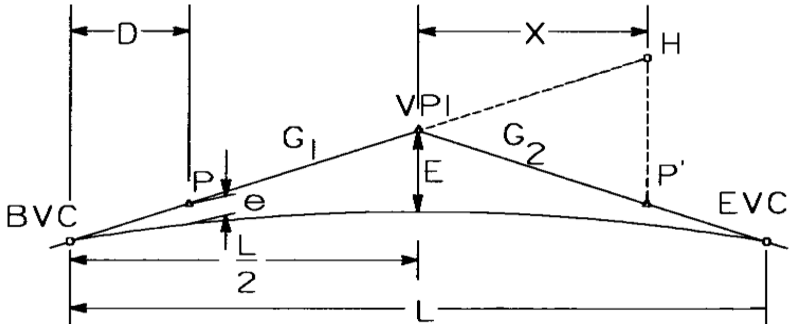


Fig 5.12 Crest Vertical Curve

Equations for Crest Vertical Curve

$E = AD^2/200L$

$L1 = 2(AX+200e+20\sqrt{AXe} + 100e^2)/A$

$Do = |G_1|L/A$

$X = 100(ElveH – ElevP')/A$

$K = L/A$

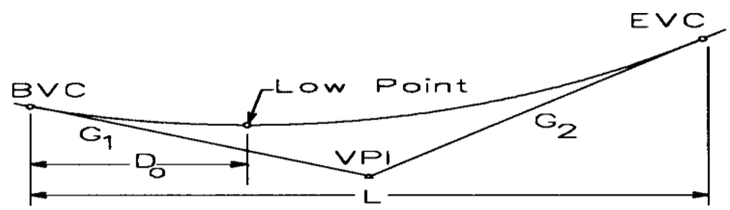


Fig. 5.13 Sag Vertical Curve

Equations for Sag Vertical Curve

$E = AL/800$, $E = ½((Elv\ BVC+ElveEVC)/2)- Elv.\ PVI)$,$E = 4ED^2/L^2$

Note that all equation use units of length (not station or increment)

The variable A is expressed as absolute in %.

Nonsymmetrical Vertical Curve

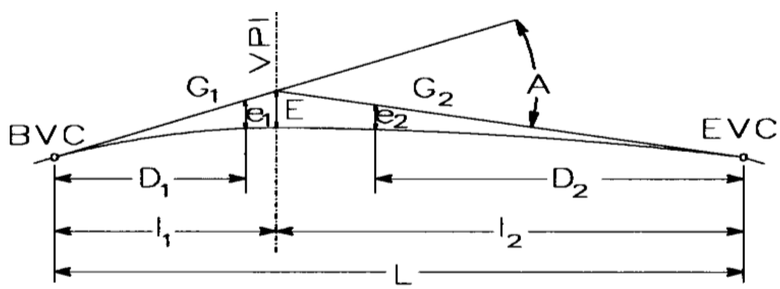


Fig 5.14 Nonsymmetrical Vertical Curve

Equations for Nonsymmetrical Vertical Curve

$A = G_1 - G_2$

$L = l_1 + l_2$

$e_1 = M(D_2/l_2)^2$

$E = l_1 l_2/(200(l_1+l_2))$

$e_1 = M(D_1/l_1)^2$

5.4.1 Elements of vertical curve

G1&G2 tangent grades in %

A= absolute algebraic difference of grades in %

BVC= Beginning of vertical curve

EVC= Ending vertical curve

l1= length of second section vertical curve

l2= length of second section vertical curve

L= length of vertical curve

D1= Horizontal distance to any point on the curve from BVC towards the VPI

D2= Horizontal distance to any point on the curve from EVC towards the VPI

E1= vertical distance from any point on the curve to the tangent grade between BVC and VPI

E2= vertical distance from any point on the curve to the tangent grade between EVC and VPI

E= vertical distance from VPI to curve

5.4.2 Profile Grade

Grade is the rate of change in vertical elevation per unit of horizontal length. This rate is expressed in percent. Since the elevation ahead on line is higher than the elevation of the beginning station it is a plus grade. If the ahead Elevation was lower, it would be a minus grade. This profile grade describes the vertical alignment of the roadway and is shown on the profile sheets of the contract plans.

A finished roadway is not a flat plane. Instead, the roadway is sloped slightly to the sides to allow water to run off. This requires that a definite point on the cross section be chosen to “carry” the grade. The lateral location of profile grade is shown in the roadway sections portion of the contract plans.

On construction, it is important to study the profile sheets and roadway sections and know where every change in the profile grade occurs. Serious staking errors can be made in the field by overlooking a lateral shift in the location of the profile grade.

For example, a 1 percent grade means a rise or fall of 1 unit in 100 units of horizontal distance (rise over run as shown in Fig. 5.10). To determine the grade between two points on a line, divide the difference in elevation by the distance between the two points and multiply by 100 so the result will be in percent. For stations 24+160 and 25+670 with repective elevation 1m and 84.23m the distance is 1+510 and the grade in % is (63.29/1510)*100 = 4.19%

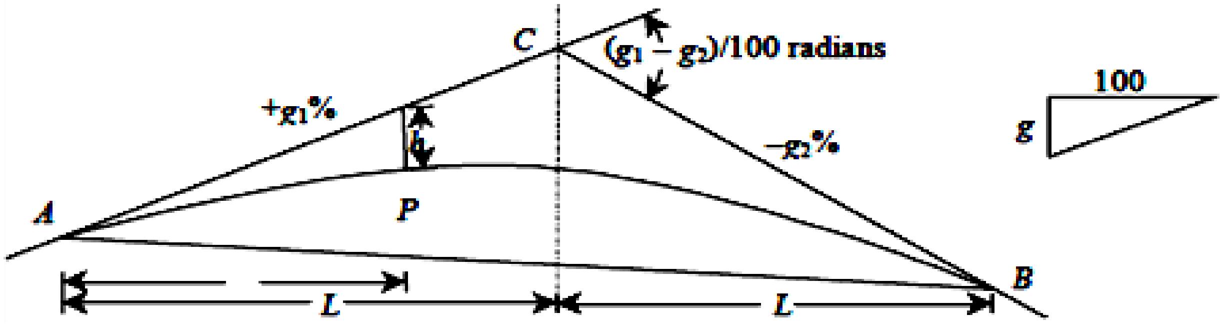


Fig 5.15 parabolic vertical curve

5.4.3 Tangent correction

h= kN^2, Where k = $e_1 – e_2$ /4n

N = the number of chords counted from A (total length l = 2n),

n = the number of chords of length l on each side of apex of the curve, and

e1, e2 = the rise and fall per chord length of l corresponding to +g1 and –g2, respectively.

Chainage of A = Chainage of apex C – nl and Chainage of B = Chainage of apex C + nl

Elevation of A = Elevation of apex C _ ne_1 (take – ive when e_1 + ive and vice-versa)

Elevation of B = Elevation of apex C ± ne_2 (take + ive when e_2 –ive and vice-versa)

Elevation of tangent at any point (n′) = Elevation of A + $n'e_1$

Elevation of corresponding point on curve = Elevation of tangent + tangent correction (algebraically)

For the positive value of K, the tangent correction is negative, and vice-versa.

n^{th} chord gradient = e_1 – (2n – 1) k

Elevation of nth point on curve = Elevation of $(n – 1)^{th}$ point + n^{th} chord gradient.

5.5 Labour-based Works Technology for vertical alignment

5.5.1 Types of Equipment and Use

Reference pegs are used to mark the alignment and road levels. They are invariably of wood, tree branches or stakes cut to length, ideally 40 cm long and 5 cm diameter or 5 cm x 5 cm square. It is advisable to paint them white or yellow for visibility and paint the chainage on a prepared face.

Survey pegs are usually set on the centr line, but unless there are no earthworks to be undertaken, they should be off-set from the road width. Multipurpose pegs may be needed to stake out cross-section, tasks, levels, etc. They are normally sharpened sticks 30 cm long used in conjunction with a string line to define horizontal or vertical alignment.

Measuring Tape : for length and width setting out as well as setting tasks or defining contract limits.

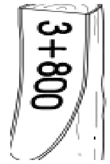


Fig 5.16 Surveying peg

Profile Boards and Ranging Rods are useful for setting out levels. Also, the ranging rods are used for setting out straight lines and curves. A long-lasting profile board is made from thin steel plate which is welded to a short length of metal tubing that can slide up and down and be clamped to a metal ranging rod. A useful size for the metal profile boards has been found to be 40 cm by 10 cm, painted red to make it easy to see. 12.5mm diameter and 2 meters long minimum 20 profile boards is regarded.

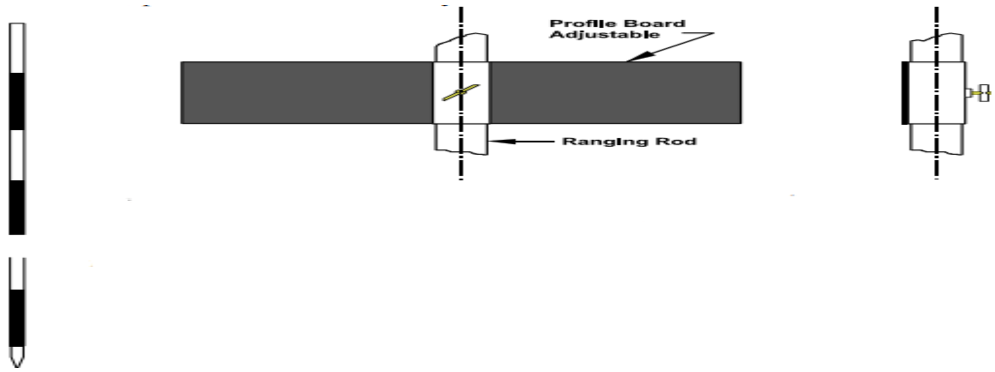


Fig 5.17 Profile Boards

Line Level

The level of each of the profile boards can be controlled by using a line level. The line level is a short spirit level (about 100 mm long) with a hook at each end to hang it from a nylon string.

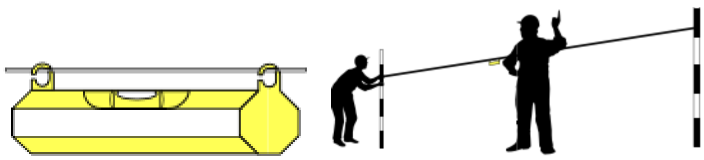


Fig 5.18 Line Level

The line level has a range of up to about 50 meters. It is easy to carry around and with care can be used for setting out levels and slopes not less than 1 in 300. Points to remember when using a line level:

- The string used should be a thin nylon fishing line, enabling the line level to easily slide along the string.
- The line level must be placed half-way between the two ranging rods. Use a measuring tape to find the exact middle point.
- Keep the string tight - do not let it sag.
- The line level is an delicate instrument, look after it - do not throw it around and treat it roughly.

- Check the accuracy of the line level regularly in the field. Use steps as follow:

a. Take two ranging roads across the road and transfer a level from one rod to another and make the level on the second road
b. Keeping the string in the same position on the first rod take the line level and turn it around on the spring
c. Adjust the string on the second rod until the bubble is in the middle again and mark the new level
d. Check to see if the two marks are at the same place. If not measure the difference between the two marks
e. If the difference between the two marks less than 10cm, you can get the right level by taking the point half way between the two marks.
f. If the difference between the two marks less than 10cm, you should relace the line level for a new and more accurate one.

Boning rods are generally manufactured on site from wooden laths to a " T " profile and of uniform height. A simple stand can also be manufactured.

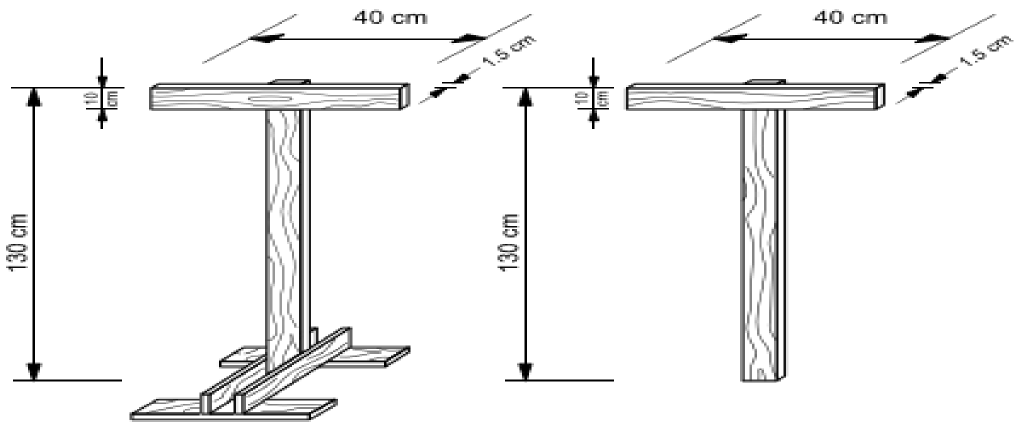


Fig 5.19 Boning rods

Boning rods are used in sets of 3 and the crosspiece is frequently painted, ideally each with a different colour. They are used to establish additional levels between fixed levels (interpolation) or beyond (extrapolation). They are particularly useful to check gradients of ditches and culverts. In the figure below, it can be seen that the ground level at point 3 is too low and the boning rod is positioned too far to the right. By raising this boning rod and aligning it with rods 1 and 2, the bottom of rod 3 indicates the required level and its location is on a straight line.

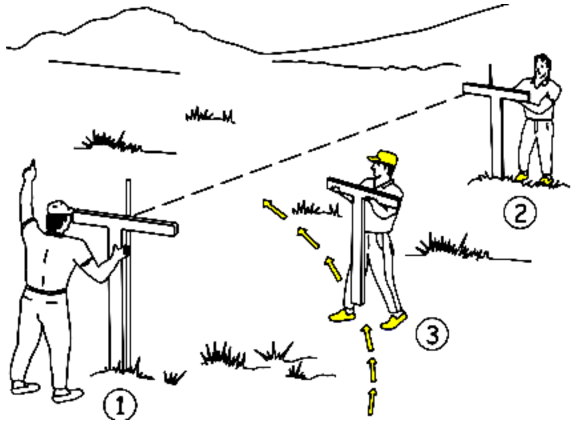


Fig 5.20 checking the level with boning rods

Profile Board Method: A commonly used setting out procedure is based on the use of a series of profile boards and a string line level giving control of levels during construction. The basic principle when using profile boards is that when they are set out we are placing a series of level boards that show the level 1 metre above the completed construction levels. Imagine that a ditch is to be excavated from A to B at the level shown in by the dotted line

Fig 5.21 Profile Board Method

To ensure that the correct level is obtained in the ditch, profile boards are placed at positions A and B, 1 metre above the level of the planned ditch

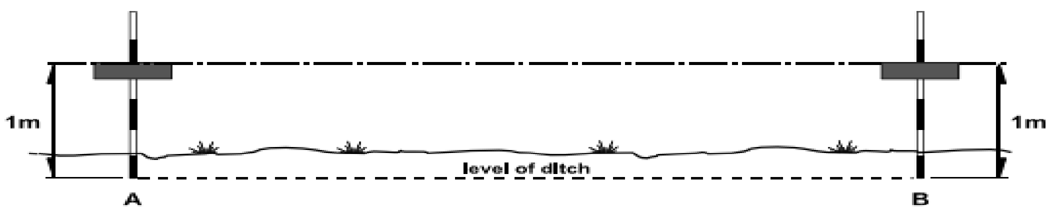


Fig 5.22 Traveller

Traveller A travelling profile is used to obtain levels between two profile boards. A boning rod or a profile can be used as a traveller. Along the line from A to B, slots are excavated to the level of the ditch. By placing the traveller in a slot and sight from the profile board in position A to the profile board in position B, we can see if the traveller lines up with the two fixed profile boards. If the traveller is too low, the slot has been dug too deep. If the traveller sticks up above the sight line, the slot needs top be dug deeper.

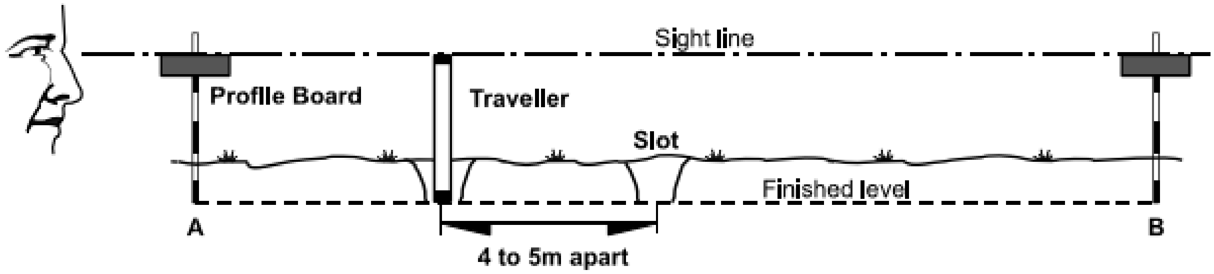


Fig 5.23 Checking the level with traveller

Temporary travellers It is also possible to take measurements below the line sighted between two profile boards by using a temporary traveller.

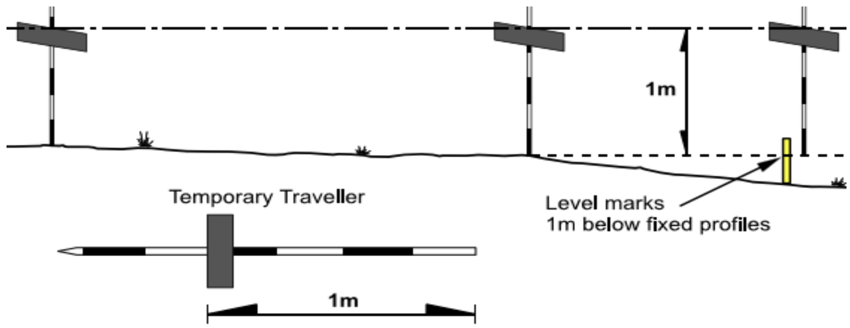


Fig 5.24 Using temporary traveller

The temporary traveller is easily made on site by measuring the length needed from the blunt end of a ranging rod to the further edge of the profile, which is then clamped in position. The temporary traveller is then ready for use. When used with fixed set out profiles, the traveller will give an indication of the finished construction levels anywhere along the sight line of the set out profiles. This is very useful for the site supervisor when setting out. There are other uses for the traveller:

- to guide and check excavation below earthwork levels (eg. for excavation for drift base construction),
- to find out whether large boulders are above or below road levels before the road levels are finally decided upon,
- to estimate the amount of fill needed if the road is "lifted", or when the road crosses low areas - this will help estimate the work involved and help decide on the optimal road levels,
- to locate the end of drains and approaches, and
- to provide a quick check on work, levels, string lines etc.

Triangles: Triangle sets can be manufactured by the site carpenter from laths and used for various purposes: to set out a right angle to the centr line (which has to be done when cross-sections are set out); to control or estimate the steepness of gradients - in this case a spirit level or plumb line is also required. Optical square also used to set out right angle.

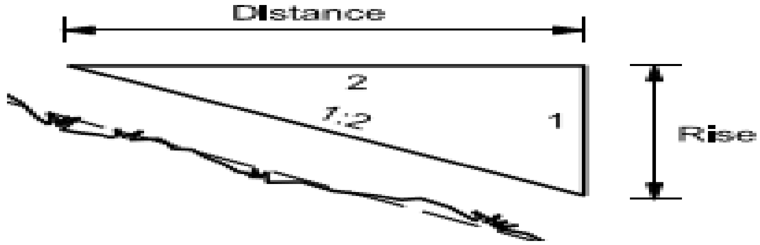


Fig 5.25 Triangles

The steepness of gradients is described as a ratio. For example, a gradient of 2:1 means two meters horizontal one meter vertical. Existing gradients are measured using the triangle principle, incorporating a spirit level as the horizontal member with pinned joints rather than fixed. The triangle can also be useful in establishing a right angle to the road center line as illustrated in the figure below.

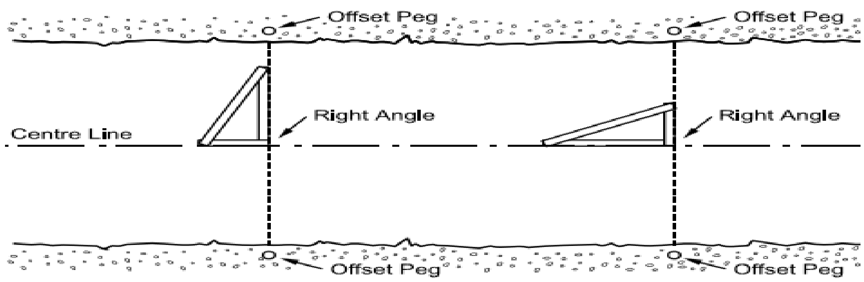


Fig 5.26 Using triangles to set out right angle

The observer can see both point B, through a narrow opening left in the optical, square and point C in the mirror or prism. When two ranging rods are placed at points B and C, the observer will see ranging rod B direct and ranging rod C reflected as illustrated in the figure below.

When points A and B on the survey line are known and point C has to be found, as shown in the figure above, the person holding ranging rod C should move forwards or backwards until the observer see the reflection of rod C in one line with his direct view of rod B. At this point angle CAB, is now at a right angle

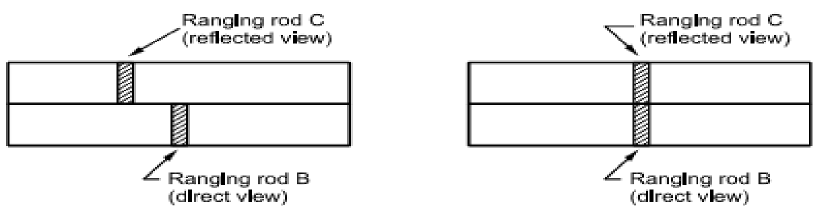


Fig 5.227optical

Straight Edge is a simple beam, usually wooden, which in conjunction with a spirit level and tape measure, can be used to establish a gradient/or road camber. The straight edge is usually 3 metres long and set horizontally with the aid of a spirit level. This method should be used for the measurement of gradients which continue only for short distances, e.g. culvert beds, drain slopes and road camber. The figure below shows how a gradient of 1:15 is measured.

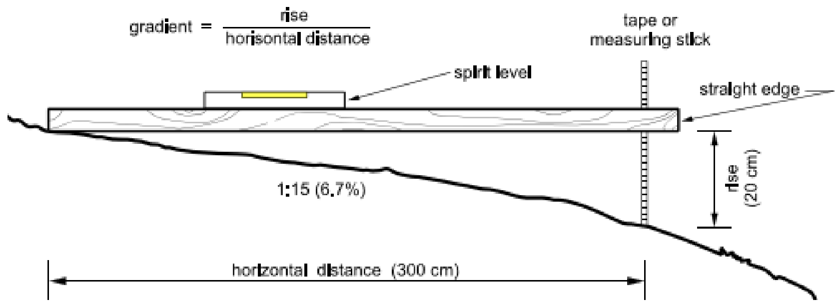


Fig 5.28 Straight Edge

Tube Water Level

A very accurate and simple instrument for measuring the level differences of two points is the "tube water level". This level, illustrated in the figure below, consists of a length of clear plastic pipe clipped at each end to a wooden levelling staff. The two levelling staffs should be of the same length, about 1.5 m long. A graduated tape is attached to each stave, with the zero level with the top end of the stave. The tube is filled with water until the level is about 1 m high from the ground. The ends of the tube are fitted with rubber stoppers to prevent loss of water. The total length of tube, which defines the range of the instrument, is variable, but is usually limited to about 15 m by the difficulty of moving the level around

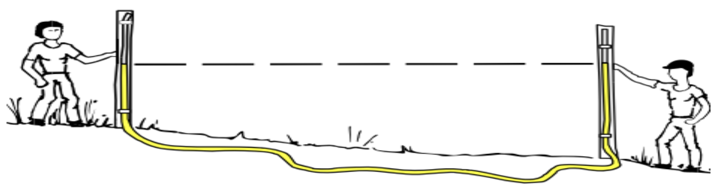


Fig 5.29 Tube Water Level

The two standpipes are brought together at the starting point, the stoppers removed and the readings taken level with the bottom of each meniscus. The readings should be the same (e.g. reading A = 50 cm, reading B = 50 cm). The surveyor takes his/her standpipe to the point being measured and takes another reading. The difference between the two readings is the difference in level (e.g. now reading A = 30 cm and reading B = 70 cm, the difference in level is now 70 - 30 = 40 cm). Range is limited only by the convenience of being able to carry the tube. The two points whose difference in level is being measured do not need to be in sight of one another. The level gives accurate results and with care can be used for setting level lines or slopes not less than 1 in 1,000

Abney Level can be used for the measurement of vertical angles for setting out levels. Vertical angles, are measured as follows: The sight is taken on to a point which should be at the same height above the ground as the eye of the observer. The line of sight will then be parallel to the ground surface between A and B (see Fig 5.30)

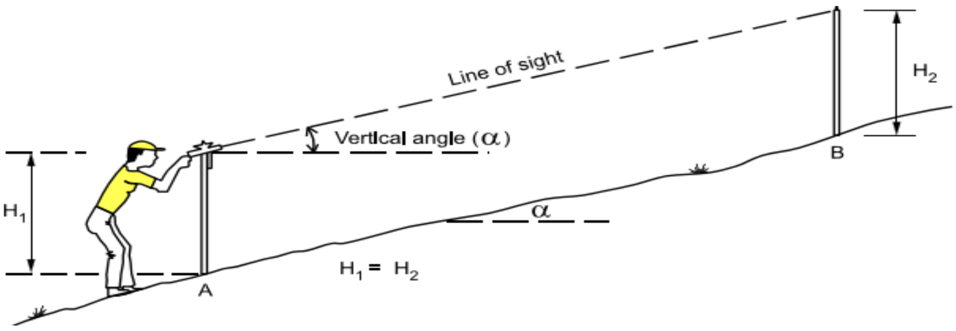


Fig 5.30 Using the abney level

Holding the abney level in this position (the cross hair intersects the target), the airbubble in the tube of the abney level should be positioned in the middle against the cross hair by turning the milled head. The angle of the line of sight with the horizontal can then be read on the arc. The abney level can also be used to set out gradients. The arc should be set at the required angle or gradient (e.g. 5o 40' or 1:10) and a line of sight established to a profile board which is moved up or down until the top of the profile board is at the correct height. Finally, the abney level can be used to measure distances and to transfer heights. The degree of accuracy that can be achieved, however, is not very high. Where greater accuracy is required it is recommended to use tape measures for distances and levelling instruments for heights. The dumpy level is used to measure height differences used in combination with a levelling staff. Levels can be transferred from a bench mark and new levels can be established very accurately over distances up to 100 meters. There are several types of dumpy levels on the market, each with its own system. It is recommended that engineers or surveyors should practice using the instrument by checking its accuracy before taking it into the field.

Note that all horizontal and vertical control establishment and detail measurements (angle and distance) can measure easily and accurately with the aid of modern surveying equipment.

5.5 Using Automatic level

Leveling is the process or an operation of measuring vertical distances above or below a given reference surface and a point on near or below the earth’s surface. It can also be defined as the processes of determining elevation differences between various points on, near or below the surface of the earth. By this operation the height of a point from a datum, known as elevation, is determined. Leveling is a method of surveying used for determination of the difference of elevations or levels of various points on the surface of the earth with the help of level and leveling staff. The collected data is record with standard format.

Table 5.1 Leveling field book

Staff Position	BS	IS	FS	Rise	Fall	RL	Remark
C	1.5					100	T. B. M.
D		2.5			1	99	
E	2		0.5	2		101	C. P.
F		2.5			0.5	100.5	
G			3.0		0.5	100	
Sum	3.5		3.5	2	2		

$$\sum BS - \sum FS = \sum Rise - \sum Fall = Last\ RL - First\ RL$$

Leveling results for horizontal and vertical alignment summarized also as follow:

Project Name:

- Date:
- Surveyor:
- Instruments Used:
- Description of the Area:
- Horizontal Leveling Results:
  - Start point: (X, Y)
  - End point: (X, Y)
  - Difference in elevation: (Z)
  - Standard deviation: (S)
- Vertical Leveling Results:
  - Start point: (X, Y, Z)
  - End point: (X, Y, Z)
  - Difference in elevation: (DZ)
  - Standard deviation: (SZ)
- The type of leveling method used
- The number of measurements taken
- The accuracy of the instruments used
- Any conditions that may have affected the accuracy
- The signatures of the surveyor and the client

Table 5.2 earth work leveling data

Volume Report

Alignment: MAIN HAL R01 050423

Sample Line Group: EARTHWORK R01

Start Sta: 0+000.000

End Sta: 0+175.033

Station	Cut Area (Sq.m.)	Cut Volume (Cu.m.)	Reusable Volume (Cu.m.)	Fill Area (Sq.m.)	Fill Volume (Cu.m.)	Cum. Cut Vol. (Cu.m.)	Cum. Reusable Vol. (Cu.m.)	Cum. Fill Vol. (Cu.m.)	Cum. Net Vol. (Cu.m.)
0+000.000	7.92	0	0	0	0	0	0	0	0
0+005.000	7.98	39.76	39.76	0	0	39.76	39.76	0	39.76
0+010.000	9.08	42.65	42.65	0	0	82.41	82.41	0	82.41
0+015.000	10.42	48.75	48.75	0	0	131.16	131.16	0	131.16
0+020.000	13.7	60.28	60.28	0	0	191.44	191.44	0	191.44
0+025.000	13.5	67.99	67.99	0	0	259.43	259.43	0	259.43

Self-check 5

Part 1. Write true if the statement is correct otherwise false(1point each)

1 Curves are designated either by their radius or their degree of curvature.

2 Compound curve consists of a single arc of constant radius connecting two tangents.

3 Horizontal curves are designed to bring smooth change of grade like vertical curves.

4 Straight and short alignment is always economical.

5 The best sites for river crossings with alignment is perpendicular crossing.

6 A finished roadway is a flat plane.

7 When a change in grade of more than about 0.5 percent vertical curve is required

8 When the grades forms a peak or hill at the VPI the curve is known as a crest vertical or summit vertical

Part 2. Multiple choice items. Select the best answer among the alternatives

9 What is the maximum gradient for vertical alignment?

A. 5% B. 8% C. 10% D. 15%

10 Which formula is used to compute the length of circular curve?

A. R tan Δ /2 B. $\prod$ RΔ/180 C. 2R sin Δ /2 D. E cos Δ/2

11 Which one of the following is the rate of change in vertical elevation per unit of horizontal length?

A. Tangent B. grade C. intersection D. alignment

Part 3. Fill the blank space with appropriate words or phrases(2 point each)

12 ______ is an element of the curve which connects the maximum point of the curve with the midpoint of the long chord.

13 _________is method of detecting gross errors in the observations form a second baseline.

Part 4 short answer type

14 Write Labor-based instruments and their respective uses for setting out of vertical alignment.(5point)

Part 5. Computation

15 A circular curve of 250 m radius is to be set out between two straights having deflection angle of 45°20′ right, and chainage of the point of intersection as 112 + 10. Calculate the necessary data for setting out the curve by the method of offsets from the chords produced. Take the length of one chain as 20 m.(5 point)

Operation sheet 5:

Horizontal and vertical alignment

Operation Title: Set out horizontal and vertical alignment

Purpose: To select alignment

To set out horizontal curve

To set out vertical alignment

Conditions or situations for the operations:

- Safe working area
- Proper operating tools and equipment
- Appropriate working PPE

Equipment, Tools and Materials:

- Hand held GPS
- Measuring tape
- Thedolite
- Tripods
- Range pole
- Rod-level/ Plumb bob
- Ink
- Paint
- Brush
- Paper
- Pencil
- Scientific calculator

Steps in doing the task

Step 1: Wear appropriate PPE

Step 2: Prepare equipment's, chemicals and materials

Step 3: Check the normal functioning of instruments

Step4: Sort setting out instruments.

Step5: perform reconnaissance survey

Step6. Select the best alignment

Step7. Set out horizontal alignment

Step 8. Set out vertical alignment

Step 9. Determine the gradient

Quality Criteria: Assured performing of all the activities according to the procedures

Precautions:

- Wearing proper PPE for the duty
- Make working area hazard free
- Make appropriate self and instruments safety

Lap Tests 5

Name: _______________________________ **Date:** _________________

Time started: __________________________ **Time finished:** _________________

Instructions: Get necessary templates, tools and materials required to perform the following tasks accordingly.

Task 1: Perform wear appropriate PPE

Task 2: Perform reconnaissance survey

Task 3: Perform alignment selection

Task 4: perform curve setting out

Task 5: Perform documentation activities

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