CHAPTER 11: HIGHWAY SURVEY

11.1 Introduction of the Unit of Learning

This unit specifies the competencies required to Perform Highway Survey**.** It involves undertaking preliminary site survey, performing levelling activities, conducting tacheometry works and drafting road cross-sections. It also includes carrying out setting out activities, performing traversing works and performing traffic engineering survey.

11.2 Performance Standard

Undertake preliminary site survey, carry out setting out activities, conduct tacheometry works, perform levelling activities, draft road cross-sections, perform traversing works, and perform traffic engineering survey in accordance with contract document, standard road construction procedures and SOPs.

11.3 Learning Outcomes

11.3.1 List of Learning Outcomes

a) Undertake preliminary site survey
b) Carry out setting out activities
c) Conduct tacheometry works
d) Perform levelling activities
e) Draft road cross-sections
f) Perform traversing works
g) Perform traffic engineering survey

11.3.2 Learning Outcome No 1: Undertake Preliminary Site Survey

11.3.2.1 Learning Activities

Learning Outcome No 1: Undertake Preliminary Site Survey	
Learning Activities	**Special Instructions**
1.1 Prepare preliminary site survey plan 1.2 Identify and mobilize ***survey resources*** 1.3 Obtain and interpret survey drawings 1.4 Assess and record findings of ***site conditions*** 1.5 Establish and document original ground level (OGL) is 1.6 Establish reference points 1.7 Prepare preliminary survey report	• Written tests • Observation • Case study • Oral questions • Third party report

11.3.2.2 Information Sheet No11/LO1: Undertake Preliminary Site Survey

Introduction to learning outcome

This learning covers preparing of contract documents, interpreting of the documents, assessing of site conditions as well as following laid procedures in the standard road construction procedure.

Definition of key terms

Site survey; It is the process of interpreting construction plans and marking location of planned new projects, such as roads or buildings. Site survey is necessary before any construction starts, it helps in determining the precise location, access, best orientation for the site & the location of the obstacles. Site survey provides insights to the project manager, it also saves a lot of trouble and potential dangers that are identified before the project starts.

Contract document; those documents which include a contract. For example; Construction contract documents define the agreement basis including the roles, obligations of both parties and a detailed description of the work or service, such as drawings, specifications, procedures, any other conditions, etc.

Reference points; these are objects or places used in determining if something is in motion. They may include buildings, trees or signs.

Content/Procedures/Methods/Illustrations

1.1 Prepare preliminary site survey plan in accordance with contract document

Preliminary site assessments are undertaken to determine the most appropriate land-use. With current growth in population with limited land, development properties maximize the available land. In preliminary site survey it involves collection of adequate data for map preparation to be used for planning and design.

There are three types of preliminary survey; ***control surveys***, ***aerial surveys***, ***topographical surveys***. The preliminary survey results form the basis for the project's design, detailed plans and cost estimates. The following are guides when preparing preliminary survey;

- Calibration reports for devices and the calibration worksheets
- Field notes
- Preliminary survey scope form
- Field notes
- Presurvey conference meeting.
- Special use permits
- Traffic control plans indicating possible access routes
- GPS specification of the proposed site
- GPS planning and network reports to indicating possible future connections.
- Final land survey control diagrams
- Copies of utility maps

1.2 Identify and mobilize *survey resources (*Human resources, tools, equipment, stationery, legal documents, power back-ups and location maps) as per the contract document

Contract document contains the responsibilities of personnel and their duties that they are obligated to perform by the contract.

Human resources; each project requires both skilled and unskilled labour to make sure that the work specified is done as dictated. For example, **Land surveyor**;

Tools & Equipment; these are various device that are used in surveying e.g. theodolites, dumpy lever, rods etc.

Legal documents; these are documents that are tied to the proposed site. They include Purchase certificate, Permit survey form**.** Such documents should be ensured that are in order to avoid lengthy court cases which may delay construction.

Power backups; Source of electricity near the site should be surveyed. If electricity is not reliable consider providing for backups

Location maps; Locations maps should be produced based on site visits and observations at the site. These maps should be able to capture a lot on useful information to be used in planning and design stage**.**

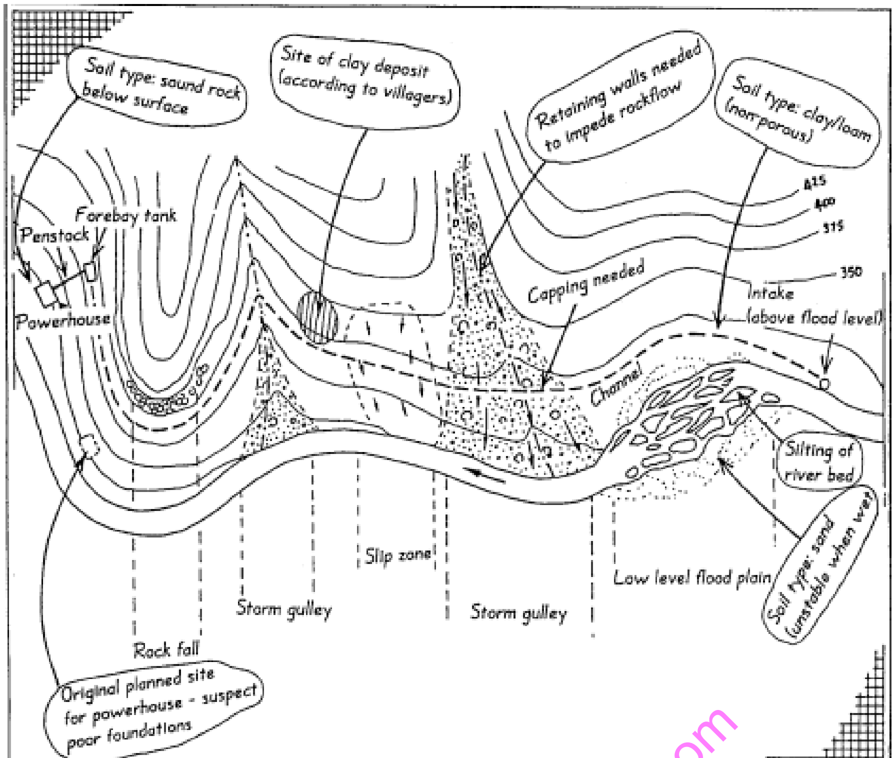

Figure 107: A geological sketch based on site observations
Source; Surveying Manual

1.3 Obtain and interpret survey drawings as per the contract document Assess and record findings of site conditions according to standard road construction procedures

a) **Topography;** Aerial photographs are used to study the topography of the proposed site. With advance technology the mosaic prints of digitized images from where, the GPS coordinates of the points can be mapped.

b) **Soil Types Profiles;** Soil type and profile have a great influence on the project. The soil type and profiling of the soil of the proposed site is recommended to have better understanding of the geotechnical properties of the underlying soil.

c) **Vegetation;** in reconnaissance stage the vegetation covering the site should be noted in order to procure the right machinery and for the purpose of cost estimation costs**.**

d) **Settlement;** this can be captured in the local map; this is necessary for design purposes of the proposed project. This is necessary for evaluation of possible future expansion or estimation of unoccupied land. Settlement properties should be well laid out.

e) **Utility services;** these include water connection to the mains, supply of power, existing underground communication cables. Utility services should be well indicated in consultancy with the municipal council existing within the project limits

f) **Water Table level;** wetland surveys should be done to determine the water level where the projects will be situated. It should be controlled and oversee by the relevant body in Kenya its NEMA.

1.4 Establish and document original ground level (OGL) is as per standard road construction procedures

Original ground level is level achieved after applying machinery to make the ground after clearing and grubbing. Natural level ground is the ground elevation in its original form, to achieve the original ground level which is suitable for construction of roads, railway & highway, areas and volume of the sections of the road need to be evaluated. The following sub-topics should be covered in class to have idea on original ground level.

- Mass haul curves
- Mid ordinate rule
- Average ordinate rule
- Simpsons rule
- Areas and volumes.
- Transversing
- Tacheometry

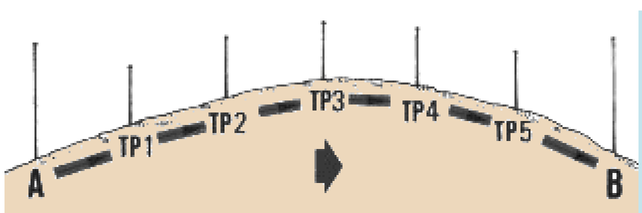

Figure 108: Tacheometry
Source; Google

From point A of a known elevation, survey through five turning points, TP1 ... TP5, and discover point B elevation. To check on the levelling error, survey by traversing BA through four other turning points, TP6 ... TP9; Then measure the A rise. If the established starting point A elevation is 153 m, and the measured amount of A at the end of the survey is 153.2 m, the closing error is 153.2 m-153 m = 0.2 m.

1.5 Establish reference points based on standard road construction procedures

A **control point** is a point at the ground or some permanent structure known for its horizontal and vertical position. If these control points are used to determine other points, then they act as **reference point** to the new points.

The following procedure is used in establishing horizontal control;

i. Key points are identified and marked that would act as the control (reference) for the subsequent surveying. These could be points located at the boundary of the mapped area, maximum or minimum elevation points, significant characteristics, etc. There should be at least 3 points clear from each point.
ii. Establish the baseline, a distance precisely determined between 2 control points, which should occupy fairly level ground. Measure the baseline distance with a 50 m tape to closest 10 mm. If the distance is greater than mark 50 m with survey pins to the tape lengths. Measure the length of the average in both directions. When the 2 measurements vary by more than 50 mm repeat both measurements, using the mean of the two distances otherwise. Measure the vertical angle between controls points to that the length of the surface to a horizontal distance.
iii. The tripod is placed above a control point.
iv. Mount the transit onto the tripod (theodolite). Slide the transit laterally until it is placed as seen through the optical plunge, directly above the control point. Turn the 3 leveling screws device which centers the bubbles in the 2 orthogonal spirit levels.
v. Release the screw at the top of plate. Rotate the telescope around the vertical axis until the Vernier scale mark 0 is aligned with the outer horizontal scale proper magnetic declination. You can make small changes by tightening the set screw and using the tangent screw.
vi. Document horizontal angle visible from the instrument station to each of the control points. View of a rod or pole ranging on a stadium. The focusing screw is mounted outside the normal and does not contain the vertical circle. The centering ring for the crosshairs is on the eye piece.
vii. Document horizontal angle visible from the instrument station to each of the control points. View on a stadium rod or pole frame.
viii. By 1800, rotate the telescope around its vertical axis. Adjacent to the telescope is the telescope set screw. The tangent screw with the focusing screw for fine adjustment of the telescope 's inclination is located on normal.
ix. Push the transit and repeat instructions 3-8 until horizontal angles between all the control points are formed.

1.6 Prepare preliminary survey report according to SOPs

The following are what is included in a preliminary survey report;

1. **Introduction:** This provides general description of the preliminary surveying process
    - It contains the surveying activities to be carried out, projects schedule & safety in the site.
2. **The preliminary survey processes:** The following are under this stage.
    - Survey meeting held by engineer to determine schedule and assign responsibilities.
    - Land ownership permission to survey; Map studying, avail of permit documents to survey.
3. **Preliminary and supplemental survey data:** A preliminary survey consists of field data collected used to construct mapping files for the project. Collecting, editing and submission of data is done here.
4. **Carrying out of the appropriate type of preliminary survey:** Control, Aerial geological, wetlands, land survey etc. to be carried and report documented.
5. **Distribution of survey and mapping files:** Production of previewing of the finalized documents.

Conclusion

This learning covered preparing of contract documents, interpreting of the documents, assessing of site conditions as well as following laid procedures in the standard road construction procedure.

Further Reading

Read further on how to establish the Original Ground Level in pavement construction.

11.3.2.3 Self-Assessment

Knowledge Based Evidence

Written Assessment

1. Theodolite should be provided with calculation__________ to measure the magnetic bearing of a line
    a) Extra telescope
    b) Compass
    c) Spirit level
    d) Through compass
2. If both ends are inter-visible, to run a straight line between two lines. We define intermediate points via
    a) Line of sight
    b) Balancing
    c) Use of a random line
    d) Backsight
3. Evaluate theodolite can be used for horizontal angle setting.
4. Summarize the reasons as to why the instrument should be levelled.
5. Define setting out with respect to theodolite.
6. The following offsets were taken from a chain line to hedge:

Distance	0	20	40	60	80	120	160	220
Offset	9.4	13.6	11.2	9.6	8.4	7.5	6.3	4.5

Compute the area included in the chain area, hedge and the offset by

I. Mid-ordinate
II. Average ordinate
III. Simpsons rule
IV. Trapezoidal area

7. Evaluate the following:
    a) Theodolite
    b) Vertical axis
    c) Bubble axis
    d) Collimation axis
    e) Horizontal axis
8. Distinguish the adjustments of a common theodolite type.
9. Explain the adjustment of a transit by collimatica.

Essay questions

1. Explain how a transit theodolite is checked and calibrated to allow for accurate reading of vertical angles, if appropriate.
2. Enumerate the constant adjustments of a theodolite transit.

Oral Assessment

1. Briefly differentiate between traversing and tacheometry.
2. Classify the following terms ‘face left, ‘face right’, ‘swing right’, swing left’ operation of theodolite.

Project Assessment

Conduct a theodolite procedure

11.3.2.4 Tools, Equipment, Supplies and Materials

- Surveying tools and equipment
- Computers
- CAD & GIS Software
- Construction manuals and guidelines
- Projectors
- Flip charts
- Calculators
- Stationery
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos
- Printers
- Workstation
- Standard of specifications

11.3.2.5 References

Muhamid, D. I. (2014). Surveying Manual. City of Haii.
Roy, S. (2005). Fundamentals of Surveying. New Delhi.
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11.3.3 Learning Outcome No 2: Perform Levelling Activities

11.3.3.1 Learning Activities

Learning Outcome No 2: Perform Levelling Activities	
Learning Activities	**Special Instructions**
2..1 Identify and select ***levelling tools and equipment*** 2..2 Calibrate levelling tools and equipment 2..3 Set road levels 2..4 Carry out monitoring and control of road levels	• Written tests • Observation • Oral questions • Third party report

11.3.3.2 Information Sheet No11/LO2 Perform Levelling Activities

Introduction to learning outcome

The leaner should cover levelling tools and equipment, calibrate levelling tools, set, monitor and control of road levels per the standard construction requirements.

Definition of key terms

Levelling tools; Levelling tools are what aid us in determination of height in respect to one known height. Some of the tools include; dumpy level, levelling staff, tilting levels, tape measure, pegs & ranging rods.

Road levels; Road is said to be in level if it remains within the surface without the loss or gain through displacement. Road level is arrived after taking chainage and balance the cut and fills.

Equipment; it is a tangible property that is used for a particular purpose. Examples of equipment includes; machine, tools

Content/Procedures/Methods/Illustrations

2.1 Identify and select *levelling tools and equipment* (Dumpy level, tilting levels and automatic levels, levelling staff, tilting levels, Automatic levels, Tape measure, Pegs, ranging rods) according to contract document

Dumpy Level; is an optical instrument used to set horizontal or transfer measure in surveying & building. According to surveying manual, dumpy level operates under two conditions of adjustments;

i. Bubble tube

To **test**; the instrument is set up such that the bubble is directly over two levelling screws, the bubble is entered carefully. The instrument is rotated at an angle of 90 degree for the bubble to be placed over the remaining pair of screws. To reverse, the instrument is rotated at 180 degrees. To **adjust-**distance moved by the bubble is twice the error present. The bubble is brought back halfway to correct the error by turning the adjusting nuts at one end of the bubble tube. Two level screws are used to renter the bubble.

ii. Horizontal cross hair; Reticule is adjusted to the manner of the automatic levels.

Figure 109: Dumpy Level
Source: www.theconstructor.org

- **Tilting Level;** Tilting level consists of a telescope that enabled horizontal rotation and rotation in its vertical plane approximately 4 degrees. Tilting screw is used to center the bubble.

Figure 111: Tilting level
Source: www.theconstructor.org

- **Automatic Levels;** It similar to the dumpy level, it has a telescope fixed at its support. For approximate levelling the circular spirit level is attached at the of the telescope. Compensator is fixed inside the automatic level for accurate levelling. They are fast, accurate and easy to use.

Figure 112: Automatic Level
Source: www.theconstructor.org

- **Tape Measure**; It is a tool used for measuring distance. It is used in levelling to find the distance of chosen points.

- **Pegs**; they are used to mark boundaries and show points and position in a site. Usually made of wood.

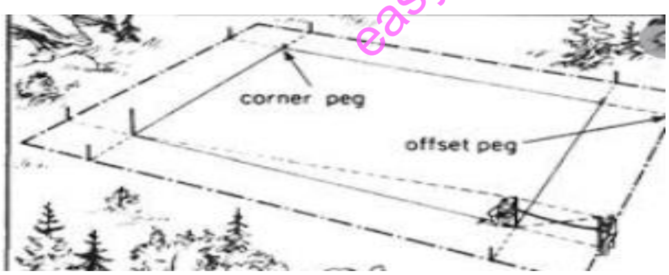

Figure 113 : Pegs used in a site for layout
Source: www.theconstructor.org

- **Ranging Rods**; these are tools used to mark the position of the survey stations and the viewing of those stations as well as the range of straight lines. They are used where the survey lines are long for proper boundary lines.

2.2 Calibrate levelling tools and equipment according to manufacturer's manual
To Calibrate is the process of relating readings of an instrument with those of standards to check the instrument's accuracy. Overtime levelling tools or any tool needs to be adjusted to try and bring it to its specification for it to give reliable data.

Calibration of tools & equipment

- If a piece of equipment has been subjected to an instance that would require the initiation of a new calibration, such a calibration shall be carried out;
- The recording of results used.
- To inform the project manager of any defective equipment and ensure that the equipment is labeled as "OUT of CALIBRATION" and is removed from service until it is restored/serviced.
- Consultation with the project manager or the employer on how to proceed in case of any doubt.
- Tools & any equipment should be calibrated as per the Instrument Manual.

Reasons why an equipment should be calibrated;

- Statutory as provided for in the Surveys Act or other relevant legislation
- Driven by event such as; damage of the equipment, new equipment, rental equipment.
- Driven by time events such as; heavily used equipment, un-used equipment for an extensive period of time, prescribed calibration schedules.

When calibrating the following should be taken note of;

- The person performing the calibration should be conversant with the calibration procedure for that particular piece of equipment.
- Equipment owner's manual should be reviewed with the respect to the procedure.
- The company policy should be reviewed and understood if available.
- All proper forms should be in hand and kept where easily available.

When to calibrate;

- In case of equipment damage.
- When equipment is subjected to shock.
- Equipment has been repaired.
- New equipment.
- Expiry of the stated time limit

2.3 Set road levels according to the design data

Road level is set through profile levelling, which is determination of elevation of points measured along a fixed line such as centreline line of rails, sewer line or roads.

Field procedure for levelling

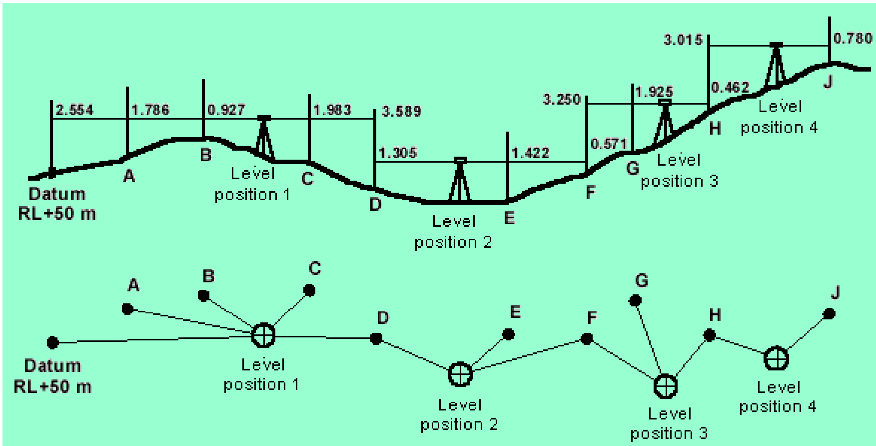

Figure 114: Sketch to guide in levelling
Source: www.geomag.nrcan.gc.ca

i. Levelling instrument is set at position 1.
ii. The staff is held at (RL+50M) and reading taken, this is taken as the Back Sight since is the first reading after the intermediate sight.
iii. Move the staff to A to take reading, this would be Intermediate Sight.
iv. Move the staff to B, take the reading, this point is taken as Intermediate Sight.
v. Move the staff to C to take the reading for another Intermediate Sight.
vi. Move staff to D take the reading, this is taken as Foresight, the level.
vii. The distance between two station should measure and data recorded in field book.
viii. Level is set at level 2 and leave the staff at D on the change plate. Turn out the staff so that it faces the level & take the reading, and this should be your back sight.
ix. Move staff to the point E and take the reading, this point is an intermediate sight.
x. Move the staff to point F and take the reading, this is your foresight since after taking the reading the levelled is moved.
xi. Move the level to level position 3, leave the staff at F on the change plate.
xii. Repeat the stated process from **i** to **k** until the last point at J.

NOTE: All the staff reading should be recorded in a field book; -Students are required to know how to feed the field book with, staff data.

- To eliminate errors resulting from line of sight also known as collimation back sight and should be equal in distance.

- Work usually commences from a known Bench Mark and close the level transverse. This facilates for level run to be checked.

Booking Levels

There are two methods of taking booking levels.

I. Rise and fall method

II. Height of collimation method.

I. Rise and fall Method

- In the appropriate columns on different lines, backsight, intermediate sight and foresight readings are entered. However, as shown in the fig below, if you adjust the level instrument, the back sights and foresights are put on the same side**.**
- The first lowered level is the datum height, baseline, or R.L.
- If an intermediate sight or foresight is lower than the read of the immediately preceding staff then the difference of the two readings is in the column of rise.
- If an intermediate sight or foresight is greater than the readings of the staff immediately preceding then the difference between two readings is in the fall column.
- The previous reduced level (RL) is increased in case there is a rise and a drop are subtracted from the previous RL.

NOTE; Arithmetic checks are run to check for any error, it only proves that the rise and fall is correctly in appropriate columns of rise & fall.

Checks

∑BS-∑FS

∑Rise-∑Fall

Last RL – first R

Table 24: A Worked Out Tabled Using the Rise and Fall Method

Back-sight	Inter-mediate	Fore-sight	Rise	Fall	Reduced level	Distance	Remarks
2.554					50.00	0	**Datum** RL+50 m
	1.783		0.771		50.771	14.990	**A**
	0.926		0.857		51.628	29.105	**B**
	1.963			1.037	50591	48.490	**C**
1.305		3.587		1.624	48.967	63.540	**D** / change point **1**
	1.432			0.127	48.840	87.665	**E**
3.250		0.573	0.859		49.699	102.050	**F** / change point **2**
	1.925		1.325		51.024	113.285	**G**
3.015		0.496	1.429		52.453	128.345	**H** / change point **3**
		0.780	2.235		54.688	150.460	**J**
10.124		**5.436**	**7.476**	**2.788**	**54.688**		Sum of B-sight & F-sight, Sum of Rise & Fall
-5.436			-2.788		-50.000		Take smaller from greater
4.688			**4.688**		**4.688**		Difference should be equal

Source: www.quora.com

II. Height of collimation

- Booking is similar to that of rise and fall method for back sight, fore-sight and intermediate sight. In place of rise and fall column is replaced with height of collimation.
- The first reading of back sight (datum, benchmark or RL staff) is added to the first RL which gives collimation height.
- The next reading of staff is entered in the corresponding column but on a new line. The station's RL is calculated by subtracting staff reading from the collimation height.
- Only when the level is moved to a new position will the collimation height change. The new collimation height is found by adding the back sight to the change point on the RL.
- It should be noted that the accuracy of intermediate RLs is not tested and errors cannot be detected.

  NB; Students should prefer to use rise and level method because it's easier to note errors, a check of all columns is run.

Table 25: A worked-out table using the height of collimation

Back-sight	Inter-mediate	Fore-sight	Height of collimation	Reduced level	Distance	Remarks
2.554			52.554	50.00	0	**Datum** RL+50 m
	1.783			50.771	14.990	**A**
	0.926			51.628	29.105	**B**
	1.963			50591	48.490	**C**
1.305		3.587	50.272	48.967	63.540	**D** / change point **1**
	1.432			48.840	87.665	**E**
3.250		0.573	52.949	49.699	102.050	**F** / change point **2**
	1.925			51.024	113.285	**G**
3.015		0.496	55.468	52.453	128.345	**H** / change point **3**
		0.780		54.688	150.460	**J**
10.124		**5.436**		**54.688**		Sum of B-sight & F-sight, Difference between RL's
-5.436				-50.000		Take smaller from greater
4.688				**4.688**		Difference should be equal

2.4 Carry out monitoring and control of road levels as per the standard construction requirements

- Plans, processes, tools and organization carried out by professional design are required to track the quality of the contract document and ensure compliance with the standard construction specifications applicable.
- Monitoring and quality control includes observation, inspection, tests, documentation that checks the quality process such as road level.Monitoring and control of road levels is necessary to ensure the project meets the requirements of the contract.
- Monitoring is described as data gathering prior to and during implementation of the project. Upon analysis, these data identify progress or constraints as soon as possible, allowing project managers to modify project activities as needed. It also provides the basis for evaluating commitments. It is the duty of the contractor to ensure the desired quality is achieved. By ensure that construction materials are supplied according to contract requirements the overseeing body should ensure the supplied materials and process of construction is within the required standards. This is achieved by regular visit by the third party.

Actions to ensure monitoring and control of road levels

- Ensure adherence to the established standards and description of methods.
- A maintenance standard with defined levels for monitored parameters e.g. cut & fill levels.

- A common system of coordinates which supports connection and Database synchronization.
- Methods of control of the received data.

Checking and maintenance

In road levels precise rods are used in matched pairs. Test the rods regularly to verify that vary in index stays constant. The index is checked using comparison High and low measurements done on the same rod Item. If index has changed, it is either the tape guides are fouled or the rod is broken. If a tape gets damaged badly, replace the rod. Tape replacements are not available. The guides are carefully disassembled and washed if the tape guides are fouled.

Conclusion

The leaner covered levelling tools and equipment, calibrate levelling tools, set, monitor and control of road levels per the standard construction requirements.

Further Reading

Read further on how to monitor and control road levels

11.3.3.3 Self-Assessment

Written Assessment

1. A staff intercepts.
    a) Maximum if the staff is kept to the line of sight truly normal
    b) Is minimum if the staff holds the line of sight truly normal
    c) Decreases when staff are tilted away from normal
    d) Increases if the staff is tilted towards normal
2. Pick the correct statement from the following:
    a) The tangent screw allows for small movement in smooth and positive control conditions
    b) The levelling screws are used to tilt the instrument, so that its angle of inclination is vertical
    c) The levelling head or tribrach needs to stand on a tripod
    d) All of the above

3. Closed contours of falling values to their center represent.
    a) Depression
    b) A Hill
    c) Bed of a river
    d) Saddle or a pass
4. When conducing survey works, what name is given to an imaginary line that joins the points of equal elevation on the earth's surface?
    a) Contour line
    b) Surface contour
    c) Level line
    d) None of the above
5. Explain the sensitivity of bubble tube in levelling and state its effect on accuracy of levelling.
6. Explain levelling and distinguish the tools used.
7. Evaluate the term calibration as used in levelling and it importance.
8. Writes short notes on dumpy level as used in levelling.
9. Complete the levelling table given below. If a gradient of 1 vertical in every 7 horizontal starts at 1 m above the peg 0, what is the height of gradient above or its peg below peg 7. (I.C.E London)

Table 26: levelling table

Station	Dist.	Back-sight	Inter-sight	Fore-sight	Rise	Fall	R.L.
B.M		3.10					193.62
0	0		2.56				
1	20		1.07				
2	40	1.92		3.96			
3	60	1.20		0.67			
4	80		4.24				
5	100	0.22		1.87			
6	120		3.03				
7	140			1.41			

Essay questions

1. Sketch the modern tilting level and name its main part. Describe step by step how it is used and its advantage over the dumpy level.
2. Draw a neat sketch of dumpy level and name its parts.

Oral Assessment

1 Briefly discuss rise and fall method for booking levels. Why would you prefer this method compared to Height of collimation?

2 Elabourate the importance of arithmetic checks booking levels?

Practical Assessment

PRACTICAL 1; LEVEL REDUCED BY RISE AND FALL METHOD

Equipment: Dumpy level, Leveling staff

Procedure: The field procedure and staff reading booking is done in the same way as explained in the instrument method height (each reading is entered on a different line in the corresponding column, except at a change point, where an FS and BS hold the same line).

Tabulation Format;

Table 27: Tabulation

STATION	READINGS			RISE	FALL	REDUCED LEVEL	REMARKS
	B.S	I.S	F.S				

Calculations:

1. The elevation difference between any two successive points (say, A and B) may be calculated as;

Difference in elevation between A and B = first reading in A-second reading in B

2. **NOTE:** For every 2 sequential readings by staff:
   - A rise is represented if the second reading is of a smaller value than the first reading. (rep.by a positive sign).
   - A fall is represented if the second reading is f a greater value than the first reading. (rep. by a negative sign).
3. If the elevation of the first is known the second elevation can be calculated as;

   Height of B=Height of A + (rise) or Height of B= Height of A- (fall)

4. The following arithmetic checks are performed on the booking levels;
    A. Number of BS readings=No of FS readings
    B. ∑BS-∑FS=∑Rise-∑Fall=RL of last point-RL of first point.

Project Assessment

Carry out a closed levelling of your school flower bed

11.3.3.4 Tools, Equipment, Supplies and Materials

- Surveying tools and equipment
- Computers
- CAD & GIS Software
- Construction manuals and guidelines
- Projectors
- Flip charts
- Calculators
- Stationery
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos
- Printers
- Workstation
- Standard of specifications

11.3.3.5 References

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11.3.4 Learning Outcome No 3: Conduct Tacheometry Works

11.3.4.1 Learning Activities

Learning Outcome No 3: Conduct Tacheometry Works	
Learning Activities	**Special Instructions**
3.1 Identify and select ***tacheometry tools and equipment*** 3.2 Carry out calibration of tools and equipment 3.3 Determine horizontal distances 3.4 Determine vertical distances 3.5 Collected tacheometry data is 3.6 Document data collected	• Written tests • Observation • Oral questioning • Third party report

11.3.4.2 Information Sheet No11/LO3: Conduct Tacheometry Works

Introduction to learning outcome

The student is expected to cover tacheometry tools, horizontal and vertical distances as well as data collection by the end of the topic.

Definition of key terms

Tacheometry:

Tacheometry is a surveying branch in which the horizontal and vertical distances are obtained by optical means in contrast to the ordinary chain and tape processes. This is do ne with the aid of two special types of instruments: a theodolite and stadia rod.

Horizontal distance

On a horizontal plane the distance between two points is the horizontal distance.

Vertical distance

The elevation of a point above a reference level surface (datum) is its vertical distance.

Content/Procedures/Methods/Illustrations

3.1 Identify and select *tacheometry tools and equipment* (Theodolite, levelling staff, Total station and accessories, cutting tools, driving tools) according to contract document

This involves the process of establishing the different types of tacheometry tools available. In identification of these tools, a clear description of the tools is required.

Theodolite: A theodolite is a precision measurement device in horizontal and vertical planes for calculating angles. A modern theodolite is a movable telescope that is positioned between the horizontal axis and the vertical axis. The angle of each of these axes can be determined with great accuracy when the telescope is pointed towards a target object.

Levelling staff: A levelling staff is a wooden or aluminium rectangular rod with graduations. The staff has metal shoes at the bottom to withstand wear and tear.

Total station: The instrument is a mixture of electronic theodolite and electromagnetic distance measurement (EDM). It also consists of a micro-processor with a memory unit that deals with records, readings and the simple measurement calculation. It is designed to measure horizontal and vertical angles, including measurement of object sloping distance to instrument.

Cutting tools: These tools are important for site clearing, which is normally the first operation to be performed once alignment is established. Examples of these tools are grass slashers and crosscut saws. The kind of cutting tools required depend on the nature of the site. A site containing grass will require a slasher, while a site requiring tree felling will require a crosscut saw.

Driving tools: The most common driving tool used in tacheometry is a hammer. The hammer consists of a metal head and a wooden handle. It is used to drive in pins and probes into the ground.

3.2 Carry out calibration of tools and equipment according to manufacturer's manual

This is the process of comparing a known measurement (the standard) and the measurement using your instrument. Calibration defines the accuracy and quality of measurements recorded using a piece of equipment. Overtime there is a tendency for results and accuracy to 'drift' when using particular equipment. To be confident in the results being measured, there is an ongoing need to maintain the calibration of equipment throughout its lifetime for reliable, accurate and repeatable measurements.

Reference Standards

- Whenever possible, reference standards traceable to SI units (International System of Units) shall be used. In situations where SI units cannot be used, certified reference material provided by a competent supplier shall be used if available.
- Reference standards shall be calibrated by an accredited organization or vendor that can provide proof of traceability. These typically would include, but not be limited to, ISO certified companies.

- Reference standards shall only be handled by employees authorized by the Quality Assurance manager/supervisor and shall be stored to prevent contamination and/or deterioration.
- Reference standards shall be calibrated before and after any adjustment. All reference standards, certified reference materials, or reference materials used for calibration shall be uniquely identified. A certificate of traceability, if applicable, shall be retained to ensure traceability.

3.3 Determine horizontal distances based on datum coordinates

Determination of horizontal distance is done using the stadia method. While finding the horizontal distance between an instrument station and a point and the elevation of a point with respect to the instrument station, the line of sight is horizontal.

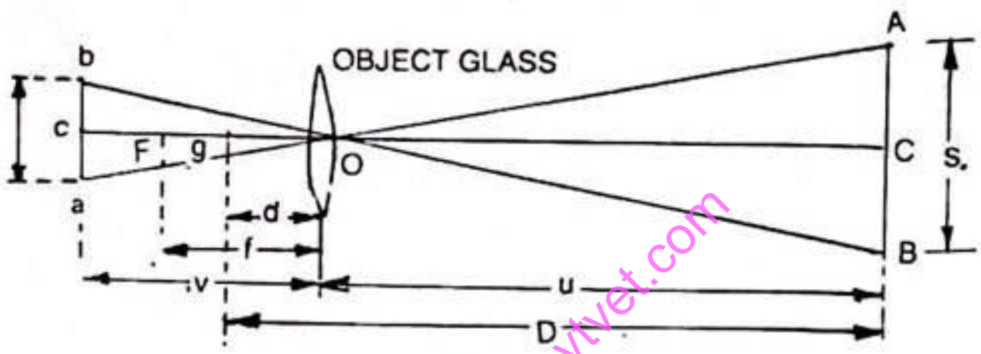

Figure 115: object glass
Source: www.slideshare.com

When the line of sight is horizontal and the staff is held vertical, in this case the horizontal distance from the axis of the instrument to the staff station is:

$D = \frac{f}{i} S + (f + d)$

Staff intercept, S is found by subtracting the reading of the upper and lower stadia reading. The constant K = f/i is called the stadia interval factor and the constant (f + d) =C is known as the additive constant of the tacheometer. These constant values are supplied by the manufacturer.

3.4 Determine vertical distances based on datum coordinates

This is the process of determining the elevation of a point with respect to a particular datum.

Procedure to determine vertical distance

i. Choose a benchmark, with a known elevation. This is the backsight.
ii. Choose the point that you require the elevation. It should be no more than 100 meters away from the instrument. This is the foresight.
iii. Set up the level in a position that is equidistant from the backsight and foresight. Ensure that from this position, a staff held on either point is visible.
iv. Sight at the backsight, and take a reading. Ensure that the readings obtained are correct.
v. Add the backsight reading to the backsight elevation. This gives you the Height of Instrument HI.
vi. Sight to the foresight, and carefully take a reading.
vii. Subtract the foresight reading from the H.I. This gives you the elevation of the foresight.

3.5 Collected tacheometry data is based on standard procedures

Data collection in tacheometry refers to the process of obtaining information regarding to vertical and horizontal distances and levels.

Data collection requirements

- The surveyor should include raw values and only use initial entries. They should include data that is the basis for calculations. These data include coordinates for inversed distances and bearings for calculated angles and azimuths or bearings.
- The surveyor should write true, comprehensive explanations of all record points, in particular points of origin and closing points and, lastly, cite references for all record points used.

3.6 Document data collected based on standard road construction procedures

Documentation of tacheometric data is the process of organisation of data collected in the field.

Procedure for documentation of data

i. All details are booked in either level books or levelling sheets
ii. These level books or loose-leaf levelling sheets must be numbered and indexed in a ledger in order to be listed in the history and inspection forms of the station.
iii. The surveyor must enter details of the location, job, date, observer, chainman, booker, weather, wind, instrument and any other related item.
iv. The surveyor must ensure neatness of records which will be used as referrals.
v. These documents should also be stored in fireproof space.

Conclusion

This learning outcome covered on how to conduct tacheometry works such as data collection, determination of vertical and horizontal distances and calibration of tools.

Further Reading

Refer to Schofield, W. (1984). Engineering surveying. London: Butterworths. for further reading on tacheometry.

11.3.4.3 Self-Assessment

Written Assessment

1. Stadia method can also be known as __________
    a) Fixed hair method
    b) Sub tense method
    c) Tangential method
    d) Movable hair method
2. The value of multiplying constant is generally taken as _________
    a) 60
    b) 80
    c) 90
    d) 100
3. Summarize tacheometric methods used in engineering survey.
4. Distance and elevation formulae for fixed hair method assuming line of sight as horizontal and considering an external focusing type telescope is D = Ks + C. where K is _______
    a) f/i
    b) i/f
    c) f + c
    d) f – c
5. Which among the following represents stadia interval factor?
    a) f + d
    b) f – d
    c) f / i
    d) i/ f
6. Define the stadia interval factor

7. Differentiate between a backsight and a foresight?
8. Differentiate between a theodolite and a total station
9. Elabourate the tacheometry?
10. Discuss how to determine horizontal distance between two points

Oral Assessment

1. Categorize the importance of tacheometry?

Practical Assessment

Using the knowledge gathered in class. Conduct an exercise to measure horizontal and vertical distances between two points.

Oral Assessment

1. What was observed as the difference in measuring horizontal and vertical distances in tacheometry?

11.3.4.4 Tools, Equipment, Supplies and Materials

- Surveying tools and equipment
- Construction manuals and guidelines
- Projectors
- Flip charts
- Calculators
- Stationery
- Charts with presentations of data
- Drawing sheets
- Relevant videos
- Printers
- Workstation
- Standard of specifications

11.3.4.5 References

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11.3.5 Learning Outcome No 4: Draft Road Cross-Sections

11.3.5.1 Learning Activities

Learning Outcome No 4: Draft Road Cross-Sections	
Learning Activities	**Special Instructions**
4.1 Compute and record road levels 4.2 Produce reduced levels 4.3 Draft ***road cross-sections*** (Cut and fill) 4.4 Interprets road cross-sections 4.5 Establish road designs	• Written tests • Observation • Oral questions • Third party report

11.3.5.2 Information Sheet No11/LO4: Draft Road Cross-Sections

Introduction to learning outcome

At the end of this topic, the leaner is expected to have a clear understanding on road-levels as well as road cross-sections.

Definition of key terms

Drafting

Drafting, otherwise known as scientific drawing, is the development of accurate representations of artifacts, structures, or houses for academic, architectural or engineering uses.

Cross-sections

This is a depiction of the element under construction, from the structure's side. A cross section's simplest explanation is to assume that the part of the structure was cut across its centre. That would allow the viewer to see all the different components that make up the entire item being drawn.

Content/Procedures/Methods/Illustrations

4.1 Compute and record road levels based on SOPs

Computation and recording of road levels is an essential process that involves the use of levelling methods. There are two methods of booking levels taken in the field: Height of Collimation Method or Rise and fall Method.

Procedure for computation of road levels using Rise and fall method

Table 28: Procedure for computation of road levels using Rise and fall method

Backsight	Intermediate sight	Foresight	Rise	Fall	Remarks
2.554					Datum RL + 50m
	1.783		0.771		A
	0.926		0.857		B
	1.963			1.037	C
1.305		3.587		1.624	D/change point 1

i. Backsight, intermediate sight and foresight readings are entered in the appropriate columns on different lines. However, as shown in the table above backsights and foresights are placed on the same line in the case of a change point.
ii. The first reduced level is the height of the datum, benchmark or reduced level.
iii. If an intermediate sight or foresight is smaller than the immediately preceding staff reading, then the difference between the two readings is placed in the rise column.
iv. If an intermediate sight or foresight is larger than the immediately preceding staff reading, then the difference between the two readings is placed in the fall column.

Procedure for computation of road levels using Height of Collimation method

Table 29: Procedure for computation of road levels using Height of Collimation method

Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
2.554			52.554	50.000	Datum RL + 50m
	1.783			50.771	A
	0.926			51.628	B
	1.963			50.591	C
1.305		3.587	50.272	48.967	D/change point 1

i. Booking is the same as the rise and fall method for back, intermediate and foresights. There is no rise or fall columns, but instead a height of collimation column.
ii. The first backsight reading (staff on datum, benchmark or reduced level) is added to the first R.L giving the height of collimation.
iii. The next staff reading is entered in the appropriate column but on a new line.

iv. The height of collimation changes only when the level is moved to a new position. The new height of collimation is found by adding the backsight to the RL at the change point.

4.2 Produce reduced levels based on computed road levels

Computation of reduced levels using Rise and fall method

Table 30: Computation of reduced levels using Rise and fall method

Backsight	Intermediate sight	Foresight	Rise	Fall	Reduced level	Remarks
2.554					50.000	Datum RL + 50m
	1.783		0.771		50.771	A
	0.926		0.857		51.628	B
	1.963			1.037	50.591	C
1.305		3.587		1.624	48.967	D/change point 1

For computation of R.L using the rise and fall method, A rise is added to the preceding RL and fall is subtracted from the preceding RL

Computation of reduced levels using Height of Collimation method

Table 31: Computation of reduced levels using Height of Collimation method

Backsight	Intermediate sight	Foresight	Height of collimation	Reduced level	Remarks
2.554			52.554	50.000	Datum RL + 50m
	1.783			50.771	A
	0.926			51.628	B
	1.963			50.591	C
1.305		3.587	50.272	48.967	D/change point 1

For computation of R.L using the Height of collimation method, the new RL is obtained by subtracting staff readings from the height of collimation.

4.3 Draft road cross-sections (Cut and fill) based on road levels

Drafting of road sections involves the use of design software that utilize survey data on road levels to come up with cross sections of the road. Such software includes CAD software such as civil 3D. These cross-sections allow for calculation of the areas of cut and fill once the sections have been plotted.

Plotting of cross-section

Cross sections are run at right angles to the longitudinal profile and on either side of it for the purpose of lateral outline of the ground surface. They provide the data for estimating quantities for earthworks and other purposes. The cross sections are numbered consecutively from the commencement of the centreline and are set out at right angles to the main line of the section which the chain and tape, the cross staff or the optical square and distances are measured left and right from the centre peg cross section may be taken at each chain. The length of cross-section depends upon the nature of work

4.4 Interpret road cross-sections as per standard procedures

Interpretation of road cross sections involves explaining what the cross sections are trying to convey.

Ways of interpreting road cross sections

Cross-sections display a right-angled vertical section of the ground or structure to the centreline of the roadway. There may be hundreds of cross-sections depending on the length and topographical complexity of the route. Each cross-section is linked to a station. Material can either be excavated or filled depending on the position of the proposed road and the natural ground line. These levels of the proposed route and ground levels are determined by cross- sections. Cross-sections show the slope gradients proposed for cutting and filling and provide the designer with a means to determine slope steepness.

4.5 Establish road designs based on interpreted road cross-sections and profiles

Most road designs are based on the particular cross-sections provided. Cross-section selection is key to finding a cost-effective approach to meet traffic needs.

Ways to establish road designs

The cross section displays the location and number of lanes and sidewalks for vehicles and bicycles, along with their cross slope or banking. The cross-sections also show drainage features, surface layout and other elements beyond the geometric style group. Depending on the kind of cross-section, the road design may require additional material to fill in so as to attain the desirable levels of the proposed route, the cross sections also affect road designs in terms of cost. Generally, a road should be designed in such a way that it is economical and guarantees proper performance, depending on the type of cross section and profile present.

Conclusion

This learning outcome covered on road cross-sections, reduced levels as well as road designs.

Further Reading

Refer to Ritter, L., Paquette, R., & Wright, P. (1987). Highway engineering. Chichester: Wiley for further reading on highway construction

11.3.5.3 Self-Assessment

Written Assessment

1. What is the creation of accurate representations of objects, buildings or houses for technical, architectural or engineering purposes?
    a) Drafting
    b) Drawing
    c) Sketching
    d) Plotting
2. Compare and contrast between the following methods of computing and recording road level
    a) Height of Collimation
    b) Rise and fall
3. Elabourate with a sketch how cross-sections help define cut and fills on a slope
4. Elabourate the use of a cross-section in design of economical and high performance road.
5. Categorize the step taken when reducing level.
6. Elabourate the steps taken when conducting a draft.
7. Using a sketch explain the term cross-section
8. Classify the methodes used in computing road level.
9. Explain the effects of cross-section on road design.
10. Discuss how road cross sections affect cut and fill.

Oral Assessment

Explain the importance of drafting of road sections.

Practical Assessment

Using the knowledge gathered in class. Ask the students to measure levels and compute road levels using either method.

Oral Assessment

Did the two methods of computation yield the same results?

11.3.5.4 Tools, Equipment, Supplies and Materials

- Surveying tools and equipment
- Computers
- CAD & GIS Software
- Construction manuals and guidelines
- Projectors
- Flip charts
- Calculators
- Stationery
- Internet
- Printers
- Workstation
- Standard of specifications

11.3.5.5 References

Kutz, M. (2013). Handbook of transportation engineering. New York: McGraw-Hill.
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11.3.6 Learning Outcome No 5: Carry out Setting out Activities

11.3.6.1 Learning Activities

Learning Outcome No 5: Carry out Setting out Activities	
Learning Activities	**Special Instructions**
5.1 Identify and select s***etting out tools and equipment*** 5.2 Carry out calibrations of equipment 5.3 Determine proposed alignment 5.4 Horizontal alignment is set out 5.5 Vertical alignment is set out 5.6 Book and compute Alignment data is	• Written tests • Observation • Oral questioning • Third party report

11.3.6.2 Information Sheet No11/LO5: Carry out Setting out Activities

Introduction to learning outcome

This learning outcome deals with setting out tools as well as equipment's. It includes making calibrations on alignment tools and being able to book and compute alignment data.

Definition of key terms

Alignments: This refers to the placing of survey points along a line. There are two types of alignments, vertical alignment and horizontal alignment

Setting out: This is the creation of a mark and a line to show levels and specific location of the elements for the construction work, so that the work can continue with respect to them.

Content/Procedures/Methods/Illustrations

5.1 Identify and select s*etting out tools and equipment* (Strings, Tape measures, ranging rods, Pegs, cutting tools, driving tools, Angle measuring tools, Plumb bob, marking tools and equipment) according to contract documents

Setting out tools and equipment are the tools used to create marks and measuring boundaries in order to describe a particular location or given alignment of a highway. The tools and equipment must be correctly identified and they must also be in good working condition for the correct setting out to be carried out.

Factors to be considered when identifying and selecting setting out tools and equipment

- **Quality;** Choose tools and equipment that are made of high-quality materials so they have the ability to withstand the deterioration caused by exposure to harsh environments and the punishment of environmental elements. In addition, you will save maintenance and repair costs. Please test the quality and Strength of the equipment before you purchase it.
- **Availability of spare parts**
- **Knowledge of using the equipment;** Ensure that only skilled and qualified technicians are responsible for using these tools and equipment to improve the efficiency and to keep the workplace healthy and avoid injuries.
- **Its availability in the vicinity to the work site**
- **Cost and reliability**

Considerations to be made when using the tools and equipment

- Check the condition of all tools before work begins
- Never use defective equipment when setting out, report any of those that you notice.
- Read the manufacturer's instructions on any devices, appliances and products you are using that you are not familiar with.
- Use tools for their intended use only.

How to identify and select setting out tools and equipment

- **Strings:** These are tools commonly made of a hard-thin linen that are used to indicate the alignment and levels during road surveys
- **Tape measures:** Different types of tape measures exist in the market. The most commonly used tape measure for setting out has a length of 30m and the tapes are usually made of steel or linen. The numbers on the tape must be legible.
- **Ranging rods:** These are sticks or steel rods which are commonly 2.5m-3.0m long with approximately 25mm. Are made of different types of materials such as steel, wood or plastic and are commonly provided with a pointed metal head.
- **Pegs:** These are used to mark levels and alignment of the road and are commonly made of wood. Examples are survey pegs, reference pegs and multi-purpose pegs. Reference pegs should have a length of 400mm and a cross section of 50mm round. Reference pegs are commonly used to show road chainages
- **Cutting tools:** These are tools such as hacksaws which are used to cut material that are used for setting out purposes
- **Driving tools:** These are tools that are used to drive other tools into the ground such as driving pegs into the ground.

- **Angle measuring tools:** These tools are used for different purposes such as setting out a right angle to a centerline and estimating or controlling the steepness of gradients. Are commonly manufactured from 3 wooden laths or steel.
- **Plumb bob:** This is a weight or bob lead that has a pointed end attached to the end of a string and is used to indicate the plumb or what is vertical with reference to the element being studied.
- **Marking tools and equipment:** These are tools such as chalk, paint, road marking crayons and survey nails that are used to indicate the boundaries of the given alignment

5.2 Carry out calibrations of equipment according to manufacturer's manual

Calibration is the process of checking or adjusting equipment and tools by comparing with standard specifications.

Reasons for Carrying out Calibration of equipment

- When an instrument is new
- When observations begin to appear questionable
- If the equipment usage/operating time has elapsed.
- When an instrument has had a shock or vibration that may have put it out of calibration

Calibration is taken as the process of modifying the final output on an equipment in order to agree with a value of the Standard specification. This is an important step when setting out of a highway since the number of errors are minimized. Different equipment have different procedures for calibration. It should be ensured that the calibration activity is done as per the equipment or instruments' manual and as per the contract terms.

5.3 Determine proposed alignment is in accordance with preliminary survey report

This process determines where the road will be placed. A preliminary survey serves the following purposes:

- To survey the various different alignments proposed after the recognition and gather all the necessary basic information on topography, soil data and drainage
- Comparing the various ideas in light of the successful alignment criteria.
- To estimate the quantity of earthworks and other building elements, and to assess the expense of alternative proposals

How to determine proposed alignments

The alignment of the highways is influenced by terrain. The landscape or topography of a region is usually categorized as flat, rolling, or mountainous. In level terrain, the selection of an alignment is affected by factors such as right-of - way costs, land use, rivers that may require costly bridging, existing roads, railroads and underlying conditions. A number of factors must be considered in rolling terrain, including: grade and curvature, cut depths and fill heights, drainage structures and number of bridges. Grades in mountainous country are the biggest challenge. Many approximate maps are usually drawn, showing various alignments. Selecting an alignment is a trial and error process, because the proposed alignments are tested for compliance with the requirements for horizontal and vertical power. The final alignment selection is based on a cost assessment and the environmental and social impacts.

5.4 Horizontal alignment is set out based on OGL

A horizontal alignment deals with the configuration of the lateral shift of the Highway on a horizontal line (original ground level). It consists of a horizontal arc and two transition curves that create a curve that joins two straights. Under certain circumstances, the transition curve may have zero length.

A horizontal alignment should be built to the highest standard in line with the topography and carefully chosen to ensure good drainage and reduce earthworks.

How to set out horizontal alignment based on OGL

Step 1: setting out of straight lines

Set out the centerline of the road on flat ground as a series of straight lines. For this, ranging rods and pegs are used. The distance between the pegs of the centerline should not exceed 20000mm.

Step 2: Setting out of curves

It is the process of defining on the ground the centerline of the curve by pegs at intervals of 10m to 30m. The points of tangent and intersection are first be set in the field, in their correct location.

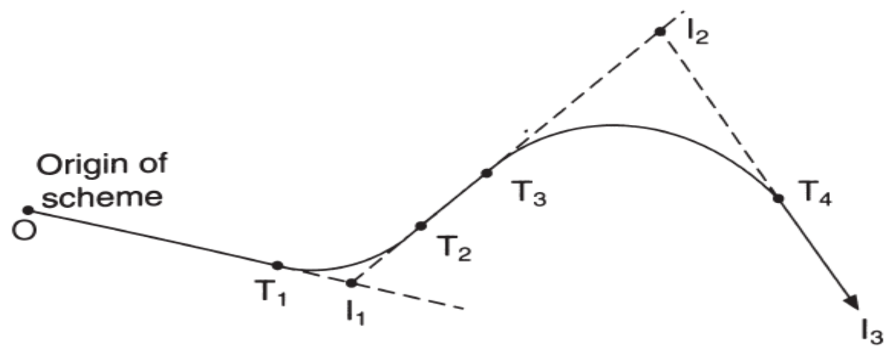

Fig. 10.3 *Through chainage*

Figure 116: Defining on the ground the centerline

The straights OI1, I1I2, I2I3 etc. are built in the plan. Appropriate curves will then be constructed using railway curves to link the straight lines. The tangent points of these curves will then be set, making sure that the tangent lengths are equal, i.e. T1I1 = T2I1, T3I2 = T4I2; The origin coordinates, point O, and all the intersection points will now only be carefully scaled from the plan. Using these coordinates, the straight bearings are measured, and even the coordinates of the tangent points are determined using the tangent lengths on these bearings. The difference of the straight bearings provides the deflection angles (almost) of the curves which, in combination with the tangent length, allows the radius of the curve to be calculated by means of chaining and all set-out data. The tangent and intersection points are now calculated from existing survey stations, and the curves distributed between them using the following methods:

- Using coordinates
- Using theodolite and tape
- Setting out using EDM

5.5 Vertical alignment is set out based on OGL

The vertical alignment shows the level of the road and are used to link vertical plane intersection gradients. It consists of a set of straight-line gradients connected by curves, typically parabolic in form. Therefore, such vertical parabolic curves must be given at all gradient shifts. The curvature will be determined by the speed of the design, which is sufficient to provide adequate driver comfort with reasonable stop sight distances. They are normally set out after the horizontal alignment has been set out.

How to set out Vertical alignment based on OGL

Vertical alignment of a road in rugged terrain takes a lot of practice. Following the terrains contours can lead to less earthworks. The largest allowable gradients will not be reached.

- Survey pegs are set out to indicate future levels of the road
- The supervisor of the road then places the pegs at least 0.5m away from the area to be excavated.
- Multi-purpose pegs are placed to direct the workers at the position where the earthworks will begin. Then, these pegs are linked to strings.
- Whenever "cuts" or "fills" are needed, the pegs must be marked to show how much will have to be produced or filled. When measurement rates are inscribed on the peg, always measure from the top of the peg.
- Set out outside the area to be excavated to avoid the loss of the pegs during construction.

5.6 Book and compute Alignment data as per the standard construction procedures

This is the process of recording alignment data for storage and for the computation of alignment data. Once observations are made from the setting out of alignments, the data is booked. Booking data takes various forms, and the format will be shared by your lecturer and it can also be found from different references. Procedure for booking alignment data and computation:

- Carry out the survey as per the standard operating procedures.
- Book the data as shown by your lecturer
- Carry out computations from the booked data.

Conclusion

This learning outcome covered: alignment, calibration of equipment as well as setting out of tools and equipment's.

Further Reading

Watch a video on how setting out is done. You can google it or watch from You Tube

11.3.6.3 Self-Assessment

Written Assessment

1. Select the best answer for the definition of an alignment from the following choices.
    a) Setting out using EDM
    b) Use tools for their intended use only.
    c) placing of survey points along a line
    d) The centerline of a road
2. All the following are setting out tools and equipment except?
    a) Strings
    b) Tape measures
    c) Phone
    d) ranging rods
3. The following are all factors considered when selecting setting out tools except?
    a) Quality
    b) Availability of spare parts
    c) Knowledge of using the equipment
    d) Tools for their intended use only
4. The procedure of setting out horizontal curves is? Select the best answer from the following choices
    a) Setting out of straight lines, setting out of curves
    b) Setting out of curves, setting out of straight lines
    c) Setting out of straight lines, placing of survey points along a line
    d) Setting out of curves, setting out of straight lines
5. Differentiate between horizontal alignment and vertical alignment
6. Level pegs are needed when a road passes through a flat terrain. True or false?
7. Summarize reasons for carrying out calibration of tools and equipment
8. Explain the purpose of carrying out setting out?
9. Elabourate the steps taken in carrying out the calibration of an equipment

Case Study Assessment

Visit a road construction site and note down the setting out activities.

Practical Assessment

With the help of your lecturer, carry out a survey of a flexible pavement in your school and determine its horizontal and vertical alignment.

Oral Assessment

Explain to your teacher or friend the procedure you used for carrying out vertical and horizontal alignment.

11.3.6.4 Tools, Equipment, Supplies and Materials

- Surveying tools and equipment
- Computers
- CAD & GIS Software
- Construction manuals and guidelines
- Projectors
- Flip charts
- Calculators
- Stationery
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos
- Printers
- Workstation
- Standard of specifications

11.3.6.5 References

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Us. Department of Transportation (2015). *Standard highway signs* 2004 edition. Create space Publishers

11.3.7 Learning Outcome No 6: Perform Traversing Works

11.3.7.1 Learning Activities

Learning Outcome No 6: Perform Traversing Works	
Learning Activities	**Special Instructions**
6.1 Identify and select t***raversing tools and equipment*** 6.2 Calibrate tools and equipment 6.3 Determine horizontal and vertical angles 6.4 Bearings and datum coordinates respectively. 6.5 Determine bearings 6.6 Measure distances 6.7 Plot traverses	• Written tests • Observation • Oral questions • Third party report

11.3.7.2 Information Sheet No11/LO6: Perform Traversing Works

Introduction to learning outcome

This learning outcome deals mainly with traversing activities such as traversing tools and calibration of the tools. It also elabourates on standard procedures for bearings and distances.

Definition of key terms

Theodolite: This is a surveying instrument used in measuring horizontal and vertical angles.

Traversing: This is a method in surveying, used in the establishment of control networks.

Data collection: In field survey, data collection is the process of measuring angles in various planes and recording the results obtained, in reference to some datum.

Content/Procedures/Methods/Illustrations

6.1 Identify and select t*raversing tools and equipment* (Traverse kits, Compass, GPS Survey equipment) according to contract documents

Traversing tools and Equipment

Traverse kits

This is a package containing tripods, tribrach, carrier, prisms along with protective container to carry the total station.

Figure 117: Traverse kits
Source: www.civiljungle.com

Compass

This is a navigation tool used in field survey to determining the bearing of traversing including the angles between waypoints and direction.

Figure 118: Compass
Source: www.civiljungle.com

GPS Survey equipment

These are tools and machines used to determine the position of objects on the surface on the earth by using signals from satellites.

Figure 119: GPS Survey equipment
Source: www.civiljungle.com

6.2 Calibrate tools and equipment according to manufacturer's manual

Calibration: This is the act of eliminating or reducing bias in an instrument's readings by adjusting the precision and accuracy of the measuring equipment using a standard equipment with the assigned correctness.

Methods used in the calibration of traverse equipment and tools.

Table 32: Methods used in the calibration of traverse equipment and tools

EQUIPMENT	TESTED AGAINST	CONDITIONS	COMMENTS
Prisms	Baseline test	Done on unknown baseline	
Prism poles	Test for vertical with a total station	The bubble should be tested in the office bracket	Adjust bubble as required
Steel tape	Approved tape	Tapes to be at similar temperatures	Tension handles are used
Level rods	Tested steel tape		
Tribrach	Test and adjust in office bracket	Ensure that all screws are tight	
Thermometer	A correct thermometer	Permit enough time for the thermometers to acclimatize	
Total stations	Check horizontal angles and adjust as per the user's manual		Always double critical angles

Rod bubbles	Known vertical		Testing item should be vertical
Levels	Two peg test and adjust	Test as required	Set up a baseline on larger projects

Reasons for equipment calibration

- Statutory as provided for in the Surveys Act or other relevant legislation
- Driven by event such as; damage of the equipment, new equipment, rental equipment.
- Driven by time events such as; heavily used equipment, un-used equipment for an extensive period of time, prescribed calibration schedules.

When calibrating the following should be taken note of

- The person performing the calibration should be conversant with the calibration procedure for that particular piece of equipment.
- Equipment owner's manual should be reviewed with the respect to the procedure.
- The company policy should be reviewed and understood if available.
- All proper forms should be in hand and kept where easily available.

When to calibrate

- In the event of equipment damage.
- When equipment is subjected to shock.
- After equipment has been repaired.
- When dealing with new equipment.
- Expiry of the stated time limit of equipment useful life

6.3 Determine horizontal and vertical angles based on datum bearings and datum coordinates respectively

Horizontal angle: A horizontal angle is formed when two lines intersect in the horizontal plane.

Vertical angle: A vertical line is formed when two lines intersect in the vertical plane.

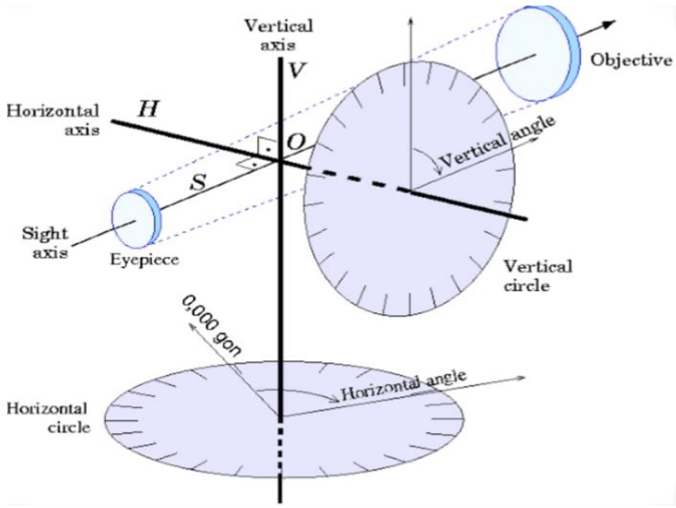


Figure 120: Vertical angle
Source: www.civiljungle.com

Determining Horizontal angles

In determining the horizontal angles, measurement between three survey points A, B and C is considered as follows;

i. The instrument is set up, centered and leveled on survey point B. Parallax is then removed.
ii. Begin on, 'face left', this carefully bisects the target set at survey point A and the horizontal scale reading of 25^o is noted.
iii. The instrument rotated to survey point C which is bisected. The horizontal scale reading is noted as 145◦.
iv. The horizontal angle is the difference of the two directions. Forward Station (C) minus Back Station (A), (FS − BS) = (145◦ − 25◦) = 120◦.
v. Change face and then observe survey point C on 'face right'. The reading is then noted as 325◦.
vi. Swing to point A, and the reading of 205◦ is noted.
vii. The readings or directions are subtracted in the same order as in, C − A. Therefore, (325◦ − 205◦) = 120◦

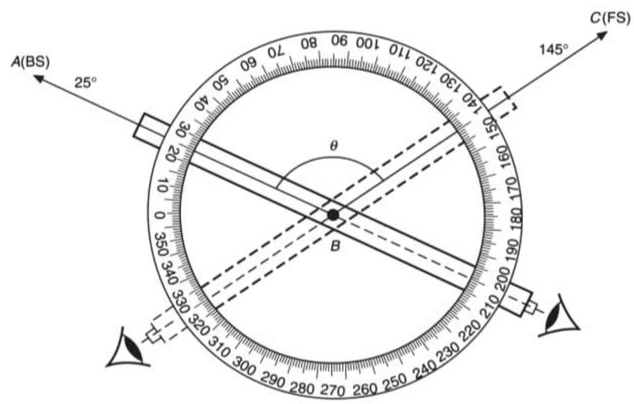


Figure 121: Readings or directions
Source: Text book, Engineering Survey by W. Schofildmark.

Determining Vertical Angles

In the case of determining vertical angles, the protractor moves relative to a fixed horizontal index.

i. Figure (a) below, shows the telescope horizontal and reading 90◦, changing face would result in a reading of 270◦ being realized.
ii. In Figure (b) below, the vertical circle index remains horizontal whilst the protractor rotates along with the telescope, as the top of the spire is observed.
iii. The vertical circle reading of 65◦ is the zenith angle, equivalent to a vertical angle of (90◦ − 65◦) = +25◦ = α.
iv. This illustrates the basic concept of vertical angle measurement.

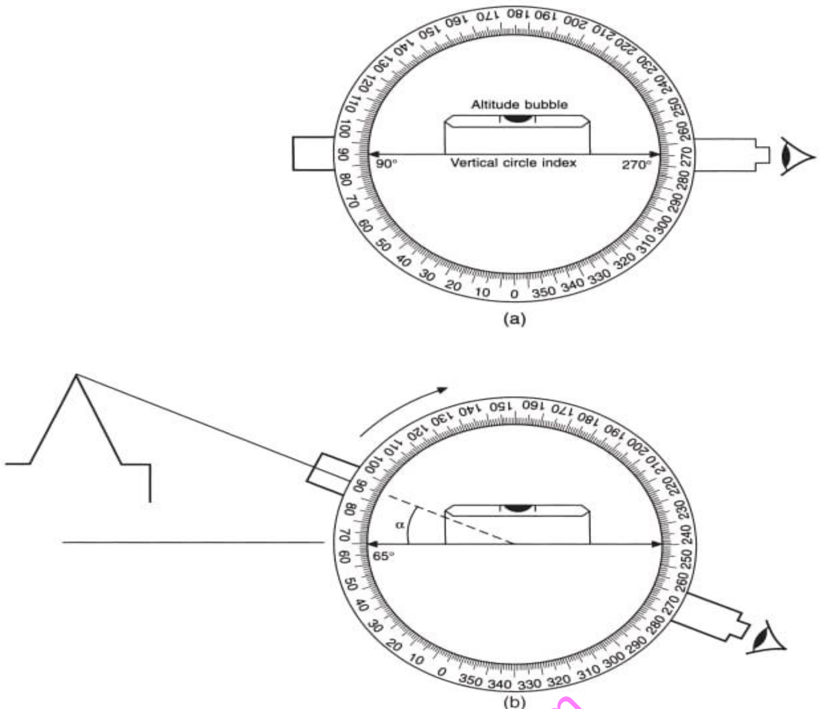


Figure 122: Vertical angle measurement
Source: Text book, Engineering Survey by W. Schofildmark.

6.4 Determine bearings according to standard procedures

Bearing of a line is the direction of the line.

Bearings are of two types; quadrantal and whole-circle bearing.

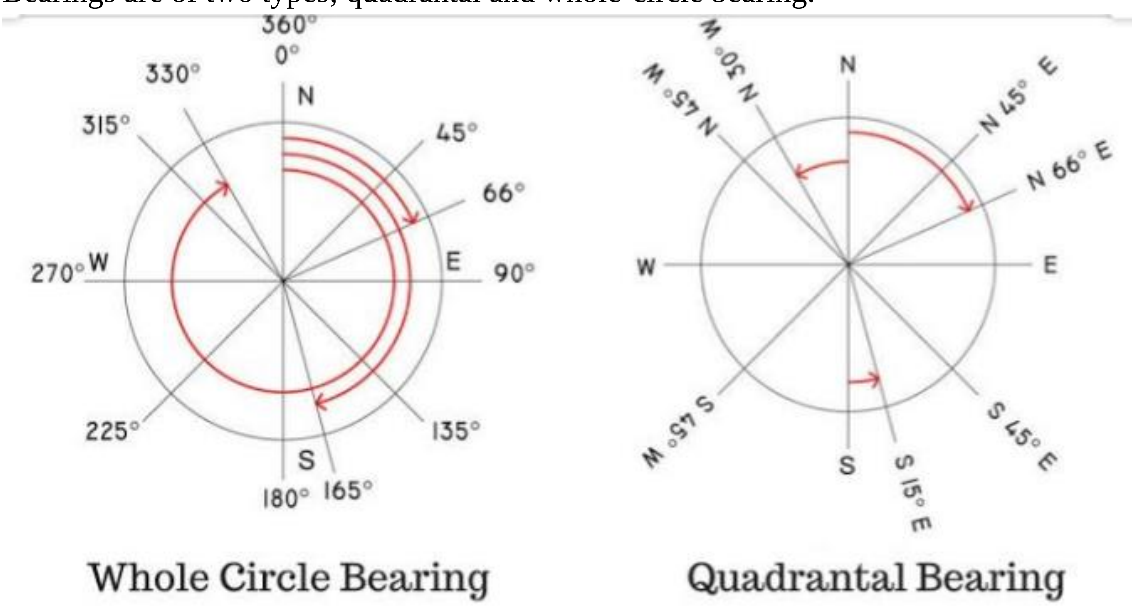


Figure 123: Quadrantal and whole-circle bearing.
Source: https://www.google.com/civilsnapshot.whole-circle-bearing-quadrantal-bearing

Quadrantal Bearing

This is whereby bearings are measured either from the north or from the south towards the east or west. For every quadrant the values range from 0 to 90 degrees.

Whole-circle bearing

This is whereby bearings are measured in a clockwise direction from north and range from 0^0 to 360^0.

6.5 Measure distances according to standard procedures

In performing traverse works, the main objective of determining distance is to establish the horizontal distance between two points. The methods involved in determining distance include; tape and plumb bob, tape and calculation

The method used to determine horizontal distance depends on the following factors;

- Accuracy needed
- Available equipment
- Type of terrain

Procedure for measuring horizontal distance using tape is whereby the horizontal distance is directly measured.

6.6 Plot traverses according to bearings and distance

Traversing is a method in surveying, for the establishment of control networks.

Advantages of Traverse Networks

- Very little pre-sit visit is required compared with that needed for an interconnected network of points.
- Observations only involve three stations at a time therefore planning the task is simple.
- Traversing permits the control to follow the route of a highway, pipeline or tunnel, with the minimum number of stations.

Types of Traverses

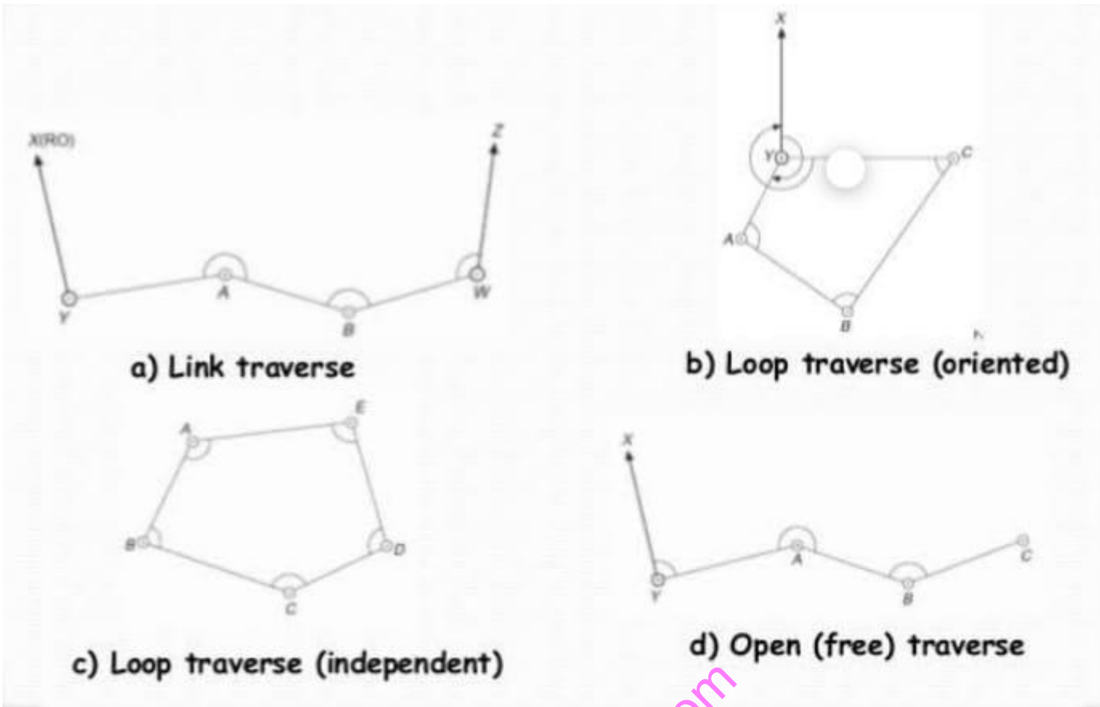


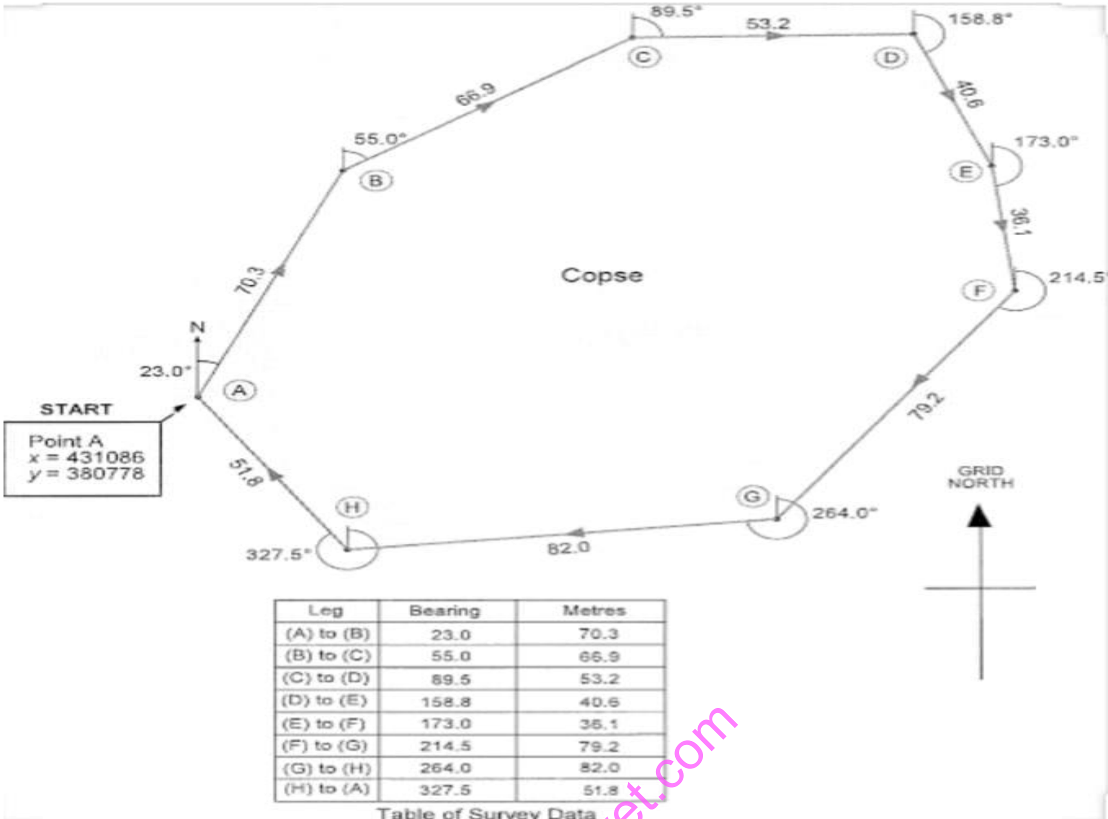
Figure 124: Types of Traverses
Source: www.engineersdaily.com

Methods used in plotting a traverse

- By using bearings through Each Station
- By quadrants or reduced bearing
- By using a central bearing or Paper Protractor
- By using Rectangular Co-Ordinates:
- Using Chords

Traverse plotted using Bearing method follows the following procedure;

- Having the position of the starting point at a given point A, draw a line representing the true north.
- With a protractor, plot the bearing of line AB (θ1), and ensure it is according to the scale.
- Then at point B, draw a line parallel to the previous line representing the meridian and plot the bearing of BC (θ2) then measure its length with the scale.
- Repeat the whole process until all the lines are drawn.
- If the type of traverse is a closed one, the last line should end at the starting point. If it does not, discrepancy is said to be the closing error.



Leg	Bearing	Metres
(A) to (B)	23.0	70.3
(B) to (C)	55.0	66.9
(C) to (D)	89.5	53.2
(D) to (E)	158.8	40.6
(E) to (F)	173.0	36.1
(F) to (G)	214.5	79.2
(G) to (H)	264.0	82.0
(H) to (A)	327.5	51.8

Table of Survey Data

Figure 125: Closed traverse
Source: www.engineersdaily.com

Conclusion

This learning outcome covered performance of traversing works. Which included traversing tools and equipment's as well as bearings and distance measurements.

Further Reading

Read further on how to plot traverses using the Bodwitch method.

11.3.7.3 Self-Assessment

Written Assessment

1. The school's labouratory technician was asked to purchase a traverse kit. Which of the following was not in the package?
    a) Tripods
    b) Tribrach
    c) Prisms
    d) Stopwatch
2. A student was asked to construct a closed traverse in the School's hockey pitch. Which of the following was not a factor he should have considered when determining the method to use in determining the horizontal distance?
    a) Accuracy required
    b) Available equipment
    c) Topography of the field
    d) Day of the week
3. During a revision session with her classmates, Nancy was not sure about the types of bearing using in field survey. Which of the following should she have chosen as a type of bearing?
    a) Straight bearing
    b) Vertical bearing
    c) Whole circle bearing
    d) Diagonal bearing
4. Elabourate the term bearing
5. Distinguish between horizontal and vertical angles
6. Classify the different types of traversing
7. Using sketches, discuss the difference between whole circle bearing and quadrantal/reduced bearing.

Practical Assessment

Conduct a calibration check on the traversing tools and equipment present in your school's engineering labouratory

11.3.7.4 Tools, Equipment, Supplies and Materials

- Surveying tools and equipment
- Computers
- CAD & GIS Software
- Construction manuals and guidelines
- Projectors

- Flip charts
- Calculators
- Stationery
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos
- Printers
- Workstation
- Standard of specifications

11.3.7.5 References

J. Uren. (2010), Surveying for engineers, Fifth Edition Publishes by Palgrave Macmillan
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11.3.8 Learning Outcome No 7: Perform Traffic Engineering Survey

11.3.8.1 Learning Activities

Learning Outcome No 6: Perform Traffic Engineering Survey	
Learning Activities	**Special Instructions**
7.1 Identify pavement location 7.2 Prepare traffic survey for 7.3 Carry out traffic counts 7.4 Estimate traffic and road characteristics	• Written tests • Observation • Oral questions • Third party report

11.3.8.2 Information Sheet No11/LO7: Perform Traffic Engineering Survey

Introduction to learning outcome

This learning outcome tends to deal mainly with pavement survey. This entails pavement location as well as traffic and road characteristics that entail the analysis of traffic behaviour in order to come up with designs that will ensure economical, smooth and safe operations in the traffic sector. In order to come up with such a traffic sector, there is need to have vast and adequate knowledge on the nature of traffic flow by knowing the traffic stream parameters and the kind of mutual relationship that they have. This learning outcome will therefore equip the learner with the basic concept of performing a traffic engineering survey.

Definition of key terms

Traffic: This is a term that is mainly used in Civil Engineering to refer all the vehicles moving on a section of road or all the pedestrians or transportation vessels moving along a particular route at a given time.

Pavement: This is a structure with layers of processed materials that are superimposed on top of the natural soil sub grade with the aim of transmitting stresses brought about by wheel loads onto the sub grade to reduce them sufficiently.

Survey: This is a term used to refer to the analyzation/examination or inspection of the behaviour in a particular area while taking down records in order to ascertain a condition or come up with a plan, map or description of the area characteristics.

Content/Procedures/Methods/Illustrations

7.1 Identify pavement location

Before the construction of a pavement, there is usually need to first identify the most suitable route or section.

Steps undertaken in identifying a suitable location for pavement construction

i. There should to be a thorough examination of the existing records for that location.
ii. Subsurface explorations are conducted in order to establish the various engineering properties of the rock and soil that is present in that area.
iii. The relevant properties like durability, strength susceptibility to moisture and even durability is then determined either by empirical estimates as per the soil types, field tests or even by carrying out measurements in the labouratory.
iv. When carrying out the tests, the sample is first tested in its weakest expected state which is normally the materials most probable moisture content.
v. Its possible performance when subjected to various traffic conditions is then identified.
vi. After the tests have been completed, the soils found to be unsuitable for laying the final pavement are identified and removed then replaced with the most suitable materials.
vii. Finally, the degree of compaction that ought to be attained is identified together with the drainage requirements then the location can now be considered as the most suitable for the pavement construction.

7.2 Prepare traffic survey for as per SOPs

The section of the outcome tends to outline the steps to be followed in carrying out the traffic survey to data collection and recording.

Types of data and data sources

Various data/variables will be required in order carry out a successful study with the nits of analysis and units of observation classified.

a) Units of analysis include;
   - Means of transport and modal split/division
   - Road network and traffic route
   - Pedestrian routes
   - Transportation facilities
   - Road design and condition
   - Road user behavior
   - Traffic volumes and capacity
   - Conflict points and accident point

b) Units of observation include;
- Generators of traffic
- Land use
- Road user (pedestrians, Motorists, cyclists, motorcyclists,)

Population sampling

The population area should then be stratified with the required stratified random sampling in order to take into account data from the whole of the population subgroup using the road. The main sub-groups present will include private vehicle owners, public vehicle operator and even pedestrians. The samples will then be selected based on periods and areas of high traffic congestion and traffic conflict i.e. the points selected will have to be given ample time to fetch/collect qualitative data. From the first 2 strata, about 15 respondents can be requested to fill in a questionnaire with the questionnaires being availed to the motorist at the beginning of a jam density/congestion then collected at the other end of the jam density i.e. before vehicles left the jam. Interviews can be carried out for the pedestrians if necessary.

7.3 Carry out traffic counts

This is the section of the outcome that requires the student to do the actuals traffic count and data collection. When conducting the survey, data from primary and secondary sources will be required collection of data consisted of both qualitative and quantitative techniques. As discussed below;

i. Secondary data

This is the data sourced from literature review of the existing works by other scholars and researchers on vehicular and pedestrian traffic challenges as well as transportation planning. One could also use other source of secondary information like aerial photographs case studies, maps and other documents obtained from the library, government office or even media and the internet.

ii. Primary data

This will include data collected directly from the field through any of the following methods:

- Observation

It is a systematic selection, watching and recording of behaviour and characteristic of subject, object or phenomena that is related to the study. Variables are observable and can include pedestrians, motorist and other road users.

- Questionnaires

Written questionnaires that had been presented to respondents who were expected to answer the question in written form. The questions were both structured and open-ended questions with some having choices to choose from for precision purposes while others required full explanation.

- Interviews

Written interviews

Interview schedules can be drafted and prepared for the relevant stake holder in the traffic management sector which may include the Ministry of roads, ministry of transport, traffic personnel and the NCC (transportation section). The type of data to be collected from the mentioned sources include planning data on traffic patterns and management as well as the challenges and prospects of highway traffic

Oral interviews

This is part of the data collected through talking to respondent individually or as a group. It will mainly be used for complementing questionnaires especially where the sample characteristic did not understand the questionnaire. In such a case the questionnaire will have been converted into a discussion between the respondent and the interviewer with the most convenient language for both parties.

iii. Mapping and photography

For this section, existing maps can be used to map out the spatial traffic scenarios within the area under survey. Photographs can also be used to enhance the analysis of the existing traffic situation along the area under study.

7.4 Estimate traffic and road characteristics

This section of the outcomes deals with the data analysis, presentation and synthesis. The data which has been collected may be analysed using computer-based analysis and/or other various models by doing computer- based analysis with programs such as SPSS or other programs that help in solving theories and concepts such as the green shield model and green berg. The data synthesis can then be presented in the form of graphs, charts, tables, maps or diagrams that may help in interpret the data and aid in the estimation of the traffic and load characteristics.

Conclusion

By the completion of this section of the outcome, the student should be well equipped with the knowledge on performance of traffic engineering survey as this learning outcome covered traffic counts, traffic survey as well as determining pavement location. The outcome goes to elabourate on the steps required to effectively carry out the survey and even how to analyse and present the collected data.

Further Reading

Read on:

1. Highway traffic analysis and design by R. J salter.
2. Transportation Engineering by Alfredo Adkins
3. Watch videos on how to create traffic data reports

11.3.8.3 Self-Assessment

Written Assessment

1. All transport vessels moving along a particular route at a given time is referred to as?
    a) Transport
    b) Travel
    c) Traffic
    d) Survey
2. Which of the following is not a unit of analysis in traffic survey?
    a) Pedestrian routes
    b) Land use
    c) Transportation facilities
    d) Road design and condition
3. Differentiate between traffic and transportation?
4. Evaluate the of traffic data analysis
5. Differentiate between written and oral interviews
6. Classify methods of carrying out traffic data counts
7. Categorize the ways in which traffic and road characteristics can be estimated

Oral Assessment

1. Discuss units of observation under types of data and data sources
2. Outline the process of identifying pavement location

Case Study Assessment

Carry out a traffic survey on a section of a chosen road, collect the data, analyze it and present it in any relevant or suitable form.

Oral Assessment

What was the selected time intervals selected for carrying out the survey?

Practical Assessment

What tools or equipment are relevant when performing a traffic survey?

11.3.8.4 Tools, Equipment, Supplies and Materials

- Computers
- SPSS Software
- Traffic survey manuals and guidelines
- Projectors
- Calculators
- Stationery
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos
- Workstation

11.3.8.5 References

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