SURVEYOR

NSQF LEVEL - 5

2nd Year (Volume I of II)

TRADE THEORY

SECTOR : Construction

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : Construction

Duration : 2 Year

Trade : Surveyor - 2nd Year (Volume I of II) Trade - Theory NSQF (Level - 5)

Developed & Printed by

National Instructional Media Institute
Post Box No.3142
Guindy, Chennai - 600032
INDIA
Email: chennai-nimi@nic.in
Website: www.nimi.gov.in

Printed by
National Instructional Media Institute
Chennai - 600 032

First Edition : February 2020 Copies : 1000

Rs.90/-

FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Mentor Councils comprising various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, an autonomous body under Ministry of Skill Development & Entrepreneurship is entrusted with developing producing and disseminating Instructional Media Packages (IMPs) required for ITIs and other related institutions.

The institute has now come up with instructional material to suit the revised curriculum for **Surveyor 2nd Year (Volume I of II) Trade - Theory NSQF (Level - 5) Construction Sector** under annual pattern. The NSQF Level - 5 Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 5 trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 5 the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

Director General/ Addl. Secretary
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

R. P. DHINGRA
EXECUTIVE DIRECTOR

Chennai - 600 032

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Surveyor 2^{2d} Year (Volume I of II) NSQF (Level - 5)** under **Construction** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

Shri. V. Dhanasekaran	_	Assistant Director of Training (Retd) MDC Member, NIMI, Chennai - 32
Shri. G. Jayaraman	_	Assistant Training Officer (Retd) MDC Member, NIMI, Chennai - 32

NIMI - COORDINATORS

Shri.Nirmalya Nath	_	Deputy Director NIMI- Chennai - 32.
Shri. S. Gopalakrishnan	_	Assistant Manager, NIMI, Chennai - 32

NIMI records its appreciation for the Data Entry, CAD, DTP operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks the invaluable efforts rendered by all other NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

INTRODUCTION

TRADE THEORY

The manual of trade theory consists of theoretical information for the 2nd year (Volume I of II) Course of the Surveyor Trade. The contents are sequenced according to the practical exercise contained in NSQF (LEVEL - 5) syllabus on Trade practical. Attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The Trade Theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise atleast one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self learning and should be considered as supplementary to class room instruction.

TRADE PRACTICAL

The trade practical manual is intented to be used in practical workshop . It consists of a series of practical exercises to be completed by the trainees during the course. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 5 syllabus are covered.

This manual is divided into Five modules. The Five modules are given below.

Module 1 - Contour survey

Module 2 - Curves

Module 3 - Total station

Module 4 - Cadastral survey

Module 5 - Road project in survey

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

CONTENTS

Lesson No.	Title of the Lesson	Learning Outcome	Page. No.
	Module 1 : Contour survey		
3.1.67	Introduction to contouring		1
	Characteristics of contours		2
	Uses of contours		3
	Indirect method of contouring		4
3.1.68 - 69	Interpolation of contour and drawing	1	5
3.1.70	Locating contour gradient		6
3.1.71	Contour map		7
3.1.72	Tracing of grade of contour		8
3.1.73	Establishment of gradient by ABNEY level, boning rod and sight rail		10
	Problems on computation of earth work		11
3.1.74	Topograpy map with contour		17
	Module 2 : Curves		
3.2.75	Introduction to curves		18
3.2.76	Setting of simple curve by linear method		23
3.2.77	Setting out curves by instrumental methods (angular)		25
3.2.78	Geometric of compound curves	2	28
3.2.79	Reverse curve		29
3.2.80	Transition curve		31
3.2.81	Vertical curve		34
	Module 3 : Total station		
3.3.82	Introduction to total station		36
3.3.83	Measurement with total station	3	40
3.3.84	Open and closed traverse		43
3.3.85	Types of total station		45
	Module 4 : Cadastral survey		
3.4.86	Preliminary knowledge for prepare a site plan	4	46
3.4.87	Digital planimeter		47
	Module 5 : Road project in survey		
3.5.88	Principles of road alignment and classification of roads		48
3.5.89	Reconnaissance survey in road project		50
3.5.90-91	Computation of earth work in embankment and cutting	5, 6 &7	52
3.5.92	Preparation of topographic map		55
3.5.93	Preparation of cadastral map		58
3.5.94	Prepare a road map for 1 km showing details on both sides (Open traversing)		60
3.5.95	Use auto cad command survey software for survey drawing		61

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 112 hrs; Professional Knowledge 32 hrs.	Make topography map using level instrument with contours.	67. Prepare contour (direct/indirect method) (20hrs.) 68. Interpolation of contour.(15 hrs.) 69. Draw contour lines. (12hrs.) 70. Locating contourgradients. (10hrs.) 71. Preparation of section from contour map. (15hrs.) 72. Computation of volume(prismoidal trapezoidal)formula. (10hrs.) 73. Establishment of gradientby abney level. (10hrs.) 74. Make a topography map with contours. (indirect method) (20hrs.)	Contouring, contour interval selection of contour interval, characteristics of contour, uses of contour contouring by various method. Interpolation of contour by various methods, drawing of contours, computation of volume establishment of gradient by abney level. (32 hrs.)
Professional Skill 112 hrs. Professional Knowledge 32 hrs.	Concept & set out of curves	75. Computation of elementsof simple curve. (20 hrs.) 76. Set out of simple curve by linear method. (15 hrs.) 77. Set out of simple curve by instrument method. (17hrs.) 78. Set out of compoundcurve by instrument method. (15hrs.) 79. Set out of reverse curve by instrument method. (15hrs.) 80. Set out of transition curve by instrument method.(15hrs.) 81. Set out of vertical curve by instrument method. (15hrs.)	Curves, Purpose, Types of curves – simple, compound, reverse, transition, vertical. Elements of simple curve, computation of elements of simple curve. Various methods for setting out simple, compound, reverse, transition & vertical curve. (32 hrs.)
Professional Skill 112 hrs. Professional Knowledge 32 hrs.	Perform survey work using modern survey instruments (Total station) for prepare a map	82. Temporary adjustment of Total station. (20hrs.) 83. Measurement of angle & coordinates and heights. (27hrs.) 84. Traversing using Total station. (40hrs.) 85. Download survey data and Plotting. (25hrs.)	Familiarization with modern survey instruments. Parts of Total station, temporary adjustment of T.S, working procedure of T.S. (32 hrs.)
Professional Skill 28 hrs. Professional Knowledge 08 hrs.	Concept of cadastral survey & make a site plan	86. Prepare a site plan by the help of mouza map. (16 hrs.) 87. Calculate the plot area by digital planimeter. (12 hrs.)	Familiarisation with cadastral map, term used in cadastral survey, preliminary knowledge for prepare a site plan. Calculation of area by digital planimeter. (08 hrs.)
Professional Skill 84 hrs. Professional Knowledge 24 hrs.	Performing a road project survey.	88. Road project reconnaissance. (10 hrs) 89. Preliminary survey. (18 hrs) 90. Final location survey including preparation of route map. (36 hrs)	Types of surveys for location of a road. Points to be considered during reconnaissance survey. Classification of roads and terms used in road engineering, alignment

		91. Profile or longitudinal & cross sectional levelling & plotting. (20 hrs)	of roads relative importance of length of road, height of embankment depth of cutting & filling, road gradients super elevation etc. (24 hrs.)
Professional Skill 84 Hrs. Professional Knowledge 24 Hrs.	Perform survey work for prepare a topographical map ,cadastral map (mouza map), road project (survey camp in a suitable hilly / undulated area)	92. Prepare topographical map (direct & indirect method). (28 hrs) 93. Make a cadastral/ mouza map & calculate the plot area. (28 hrs) 94. Prepare a detail road project more than 1KM. (28 hrs)	Details knowledge for preparation of topographical map. Details knowledge for preparation of cadastral map. Details knowledge for preparation of a road project. (24 hrs.)
Professional Skill 28Hrs. Professional Knowledge 08Hrs.	Perform AutoCAD drawing from field survey data.	95. Survey drawing practice using Auto CAD commands (28 hrs)	Use auto cad command survey software for survey drawing.(08hrs.)

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No	Learning Outcome	Lesson No.
1	**Make topography map using level instrument with contours.**	**3.1.67 to 74**
2	**Concept and set out of curves.**	**3.2.75 to 81**
3	**Perform survey work using modern survey instruments (total station) for prepare a map.**	**3.3.82 to 85**
4	**Concept of cadastral survey and make a site plan.**	**3.4.86 to 87**
5	**Perform a road project survey.**	**3.5.88 to 89**
6	**Perform survey work for prepare a topographical map, cadastral map, road project (Survey camp in a suitable hilly/undulated area).**	**3.5.90 to 93**
7	**Perform Auto CAD drawing field survey data. (Module 5)**	**3.5.94 to 95**

Introduction to contouring

Objectives: At the end of this lesson you shall be able to
- **define contouring**
- **explain the terms used in contouring**
- **narrate the characteristics of contour.**

Introduction

Relief

The topographical map showing the configuration of the earth's surface by the use of suitable symbols is called relief. Contour lines are used for representing relief.

Contour line

A contour line is an imaginary line of constant elevation on the ground surface. It may be the line of intersection of level surface with ground surface.

E.g: show line of still pond or a lake.

Contouring

The process of locating the contour lines on the surface of the earth or on the plan or map is known as contouring.

Contour interval

The vertical distance between two consecutive contours is called contour interval. It is kept constant for a contour plan to correctly represent the topography of the terrain.

Horizontal equivalent

The least horizontal distance between two consecutive contours is called horizontal equivalent. It is different at different part of the contours and it depends upon the slope of the ground. It is usually less in hills than in plains.

Factors for deciding contour interval

Contour interval on a map is decided on the following considerations.

Scale of the map

The contour interval is kept inversely proportional to the scale of the map. Smaller the scale of map, larger the contour interval. On the other hand, if the scale of the map is large, the contour interval should be small.

Purpose of map & extent of survey

For small extent of survey and for detailed design work contour interval should be small. For large extent of survey, the contour interval shall be large. For the survey of canal, railway, road etc, if the work is very important, contour interval should be less and vice versa.

Nature of the ground

The contour interval generally depends upon the topography of the terrain. In flat ground contour interval is small so that it will be suitable to depict the general nature of the ground. Whereas in hilly areas it can be depicted with contours at larger interval.

Availability of time and fund

If the time and fund available is less, large contour interval is adopted or vice versa. This is due to the fact that the greater the interval, the smaller is the amount of field work, reduction and plotting required in the preparation of the plan.

The contour interval for general topographical may be computed by the following rule.

$$\text{Contour interval} = \frac{25}{\text{Number of cm per km}} \text{ m}$$

Considering the above factors the contour intervals recommended for the contour plans for various purposes are as follows.

Contour intervals

Type of ground	Scale of map	contour intervals in (M)
Flat rolling Hilly	Large 1Cm = 10m or less	0.2 to 0.5, 0.5 to 1.01, 1.5 or 2 meters
Flat rolling hilly	Intermediate 1cm = 10 to 100m	0.5, 1 or 1.51, 1.5 or 2 2, 2.5 or 3 meters
Flat rolling hilly mountainous	Small 1cm = 100m.	1,2 or 3, 2 to 5, 5 to 10, 10, 25 or 30 meters

Sl.No	Purpose of survey	Scale	Contour interval in metre
1	Building site	1 cm = 10 m or less	0.2 to 0.5
2	Town planning schemes, reservoirs landscape grading	1cm =50m to 100 m landscape grading	0.5 to 2
3	Location surveying	1 cm = 50 m to 200 m	2 to 3
4	For general topographical work	1 cm = 100 m or more	3m & above

Characteristics of contours

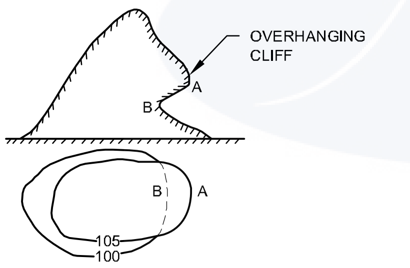
Objective: At the end of this lesson you shall be able to
- **explain characteristics of contours.**

Characteristics of contours

For the preparation of contour plan, it is essential to have a clear knowledge of the important qualities of the contours. Following are the important characteristics or peculiarities of the contours which are kept in mind while plotting.

- All the points lying on one contour line have same elevation.
- Two contours of different elevations do not cross each other except in the case of overhanging cliff. (Fig 1)

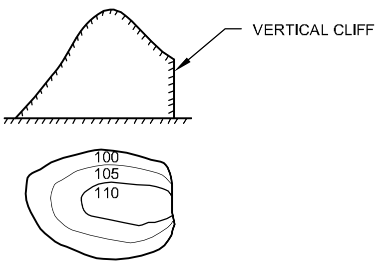
Fig 1



OVERHANGING CLIFF

- Contours of different elevations do not unite to form one contour except in case of vertical cliff. (Fig 2)

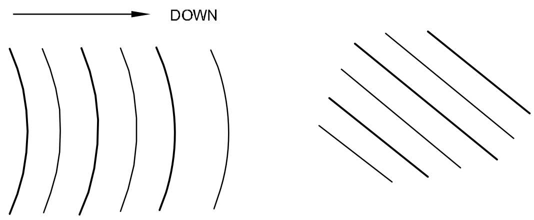
Fig 2



VERTICAL CLIFF

- Contours drawn closer represent a steep slope and if they are drawn far apart, represent a gentle slope. (Fig 3)
- Contours equally spaced represent a uniform slope. When contours are parallel, equidistant and straight they represent a plane area.

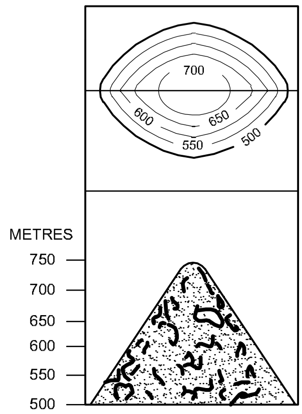
Fig 3



UNIFORM,GENTLE SLOPE

- The steepest direction through a point on the contour line is indicated by the perpendicular direction through that point.
- Contour line must close itself but not necessarily within the limits of the map.
- A set of closed contours with lower values inside indicates a pond or depression.
- A set of closed contours with higher values inside indicates a hill.(Fig 4)

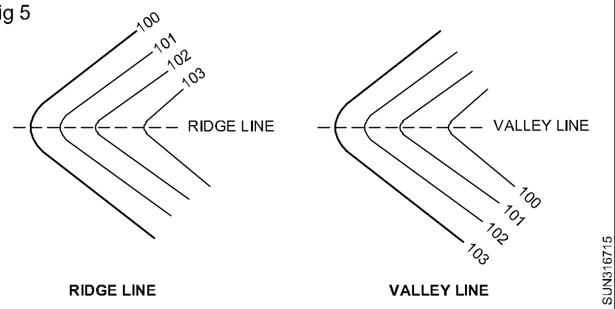
Fig 4



A HILL

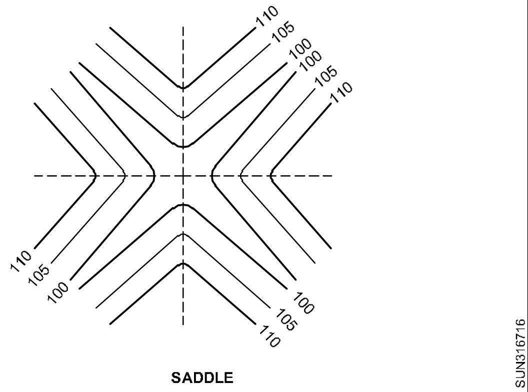
- Contours do not have sharp turnings.
- A set of 'V' shaped contours crosses the ridge line and valley line at 90°. If the higher value contours are inside the bent or loop, it represents a ridge line. V shaped contours represent a valley line, if the lower values are inside the bent or loop.
- The same contour must appear on both the sides of the ridge or valley line. (Fig. 5)

Fig 5



- Depression between summits are called saddles. (Fig. 6)

Fig 6



Uses of contours

Objectives: At the end of this lesson you shall be able to
- **explain the uses of contour**
- **explain the methods of contouring.**

Uses of contour maps

- To study the general character of a tract of land without visiting the ground if the contour map of the area is available.
- To decide the most economical and suitable site for engineering works such as canals, sewers, reservoirs, roads, railway etc.
- To determine the capacity of the reservoirs and the catchment area of drainage basins.
- To compute quantity of earth work required for filling or cutting along the proposed alignment of the project such as canals, roads etc.
- To ascertain the indivisibility of points.
- To trace gradient for the road alignment.
- To draw longitudinal section and cross section to ascertain the nature of the ground in any desired direction.
- To decide the best positions for the guns, the line of march and campaigning grounds by the army commanders during wars.

Locating contours

The location of contour on a map can be plotted only after knowing the horizontal position and vertical elevation of the points consisting of the contours. The fixing of the horizontal position of points is known as horizontal control and it depends upon the size, shape and importance of work. It may be carried out either by chain surveying or compass survey or plane table survey. For small areas, chain survey is adopted and for large areas traversing is adopted.

The fixing of the vertical height of points is known as vertical control and it is carried out by the process of levelling.

Methods of contouring

The method of locating contours may be classified into two. Direct method and indirect method.

Direct method

In this method, the contours to be located are directly traced out in the field with a level or hand level by marking various points along a contour. These points are then surveyed and whose positions are plotted. The line joining these points gives the required contour.

This method is very slow and tedious, but it gives very accurate results. It is used for small areas and for works of high precision.

In this method, first a temporary BM is established in the area where contouring is to be done by running fly levels from a permanent BM. Then the level is set up at a position from where maximum area can be visible. for A BS reading is taken on the BM. From that calculate the height of instrument. To locate the points along a particular contour, required staff reading is calculated by subtracting the reduced level from the height of instrument.

Then contour points are located by moving the staff up and down along the slope until the desired staff reading is obtained. The points are surveyed and whose positions are plotted on the plan.

Direct method by radial line

In this method, contour points are located along the radial lines from a common point at the centre.

Select a point at the centre of the area to be surveyed so that all the points can be commanded from that point and their relative positions are fixed by measuring the horizontal angles or bearings. Place the levelling instrument over the selected point and find the height of instrument with reference to the temporary BM established on the contour site. Calculate the staff readings required, to locate the points along various contours of different reduced levels.

Hold the staff vertically and move up and down along these radial lines until desired staff readings for their respective contours are obtained. The positions of these points obtained are located by measuring their distances from centre point. Join the points of same elevations to get the required contours.

Indirect method of contouring

Objectives: At the end of this lesson you shall be able to
- **explain the indirect method by squares**
- **explain the indirect method by cross section**
- **explain the indirect method by tacheometric.**

Indirect method

This method of contouring is commonly used because it is simple, quick and cheaper. In this method spot levels are taken along a series of lines laid over the area. The positions of these points are then plotted on the plan already prepared by other method of surveying and the contours of required reduced levels are drawn by interpolation. This method is also known as contouring by spot levels. This is done by any one of the following methods.

1) by squares

2) by cross section

3) by tacheometric

1 By squares

This method is suitable for small & low undulating area. In this method the area to be surveyed is divided into a network of squares by running a serious of lines at right angles. The corners of these squares are marked with pegs or arrows. Depending upon the nature of ground, the sides of squares may be uniform or varying. The reduced levels of the corners of the squares are determined by levelling. If required, reduced level of salient positions within the squares are also taken and are located.

The squares are plotted to the desired scale on the plan and reduced levels of the corners as well as salient points are entered. The contours of desired values are then interpolated.

2 By cross section

This method is suitable for long and narrow strips of land such as road or canal or railway. A centre line is laid down through the centre of the area to be contoured. Cross sections perpendicular to the centre line are erected at regular intervals.

The spacing of the cross section depends up on the nature of the ground, contour interval and scale of plan. Usually the interval being 20m in hilly area and 100m in flat country. Then, points at an interval of 5m or 10m are marked along the cross section lines. Points of salient features along the centre line and cross section line are also located.

The layout of the cross sections need not be at right angles to the centre line. They may be inclined at suitable angles to the centre line. The reduced levels of the points are determined. The contours of required reduced level are plotted by interpolation.

3 By tacheometric method

This method is suitable for the contouring of hilly areas. An instrument station is chosen at the peak of area. Set up the tacheometer over that point and a number of radial lines at known angular interval are drawn on the ground. The interval may vary from 10° to 30° depending upon the nature of ground.

Number of representative points are chosen along these radial lines. These points are located by observing the vertical angles and the staff readings of the bottom, middle and top wires. The horizontal distance of these points from instrument station and reduced levels are calculated by using the tacheometric formula.

The radial lines and the positions of the points on each line are plotted to the desired scale and their elevations are also noted. Then the contour lines are drawn by interpolation.

Comparison between direct and indirect method

Direct method	Indirect method
It is the most accurate method. But it is slow and tedious.	This method is cheaper and rapid and less tedious. But not very accurate.
It is used for small areas, where great accuracy is desired	It is used for large area where great accuracy is not the main consideration.
It is not suitable in hilly areas	The tacheometric method of contouring is particularly used for hilly areas. The indirect method by cross section is used in route surveys such as road, canal etc.
The calculation work of reducing the level is comparatively more, since the number of points in command from one set of the level is very less.	Area command from one set up of the tacheometer is more, therefore the calculation work is less.

Interpolation of contour and drawing

Objectives: At the end of this lesson you shall be able to

- **explain the term interpolation**
- **explain the various methods of interpolation of contours.**
- **drawing of contours.**

Interpolation of contours

The process of placing or spacing the contour lines proportionally between the plotted ground points is known as interpolation of contours. It is based on the assumption that the slope of ground between two points is uniform.

Contours may be interpolated by the following methods.

1) By estimation

2) By arithmetical calculation

3) By graphical method.

1) By estimation

In this method the position of contour point is judged by estimation. The method is rapid. But it gives approximate results. It is used for small scale map.

2) By arithmetical calculation

In this method of interpolation, the portion of contour points in between the plotted ground points are located by calculating their distance accurately based on their ratios of distance and level difference. This method is laborious and tedious. But it is the most accurate method.

E.g. let A and B are two points at a distance of 10m and have reduced levels 41.3 and 43.8m respectively. Assuming 1m contour interval, contours of 42m and 43m may be plotted between A and B.

Difference in level between A and B = 43.8 - 41.3 = 2.5 m

Distance between A and B = 10 m

Difference in level between A and B 42m contour = 42 - 41.3 = 0.7m.

Difference in level between A and B 43m contour = 43 - 41.3 = 1.7m.

Distance of A and 42m contour = 10 x 0.7/2.5 = 2.8 m

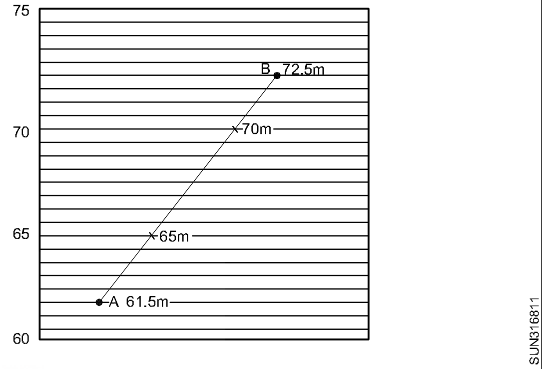
Distance of A and 43m contour $= 10 \times \frac{1.7}{2.5} = 6.8\text{m}$

Hence the points of reduced levels 42m and 43m are 2.8mm and 6.8m distance away from A. The contour points are then plotted, by scaling these distances to the scale of the map.

3) By graphical method

By graphical method. Graphical method of interpolation are simpler as compared to arithmetical methods and also the results obtained are accurate. Out of several graphical methods, the one in common use is explained below.

Fig 1



Suppose the contour interval is 5m, then on a piece of tracing cloth, a number of parallel lines spaced at 0.5m (usually one tenth of the contour interval) are drawn, every tenth line being made thick (Fig 1). Suppose it is required to interpolate contours between two points A and B of elevations 61.5 m and 72.5m respectively.

If the bottom line represents an elevation of 60m, then the successive thick lines will represent 65m, 70m and 75m etc. Place the tracing cloth so that the point A is on the third line from the bottom. Now, move the tracing cloth until B is on the fifth line above the 70m thick line. The intersections of the thick lines 1 and 2 representing elevations of 65m and 70m contours respectively and are pricked through on the plan with a pin.

Drawing of contours

After establishing points on the various contours, contour lines are drawn as fine and smooth freehand curved lines of uniform thickness. They may also be represented by broken lines. The line should be inked either in black or brown. Red or crimson lake may be also used for inking in special cases. Curves may be drawn with French curves as far as possible.

Usually every fifth contour is thicker than the rest. Elevations are in the uniform manner. The figures indicating the elevation of contour are written at the beginning, middle and at end of the contour lines. The figures should be normal to the contours and they should be placed uniformly in such way, that they can be read from one or two ends on the contour map.

Locating contour gradient

Objectives: At the end of this lesson you shall be able to
- **describe the term contour gradient**
- **explain the method of locating contour gradient**
- **explain the method of erecting grade stake.**

Contour gradient : Contour gradient may be defined as a line lying on the surface of the ground with uniform inclination to the horizontal at all points on it.

Locating a contour gradient on a contour plan : While locating a highway or railway or canal on a contour map a controlling factor is the gradient line. In portions of the location, the grade line ascends or descends at a uniform rate. At some places the grade line may be at the maximum gradient permissible. A uniform grade line can be drawn on the map by first calculating the horizontal distance corresponding to the contour interval and the given gradient.

Let A be the point on a contour line of RL 60.00m from which it is required to trace the contour gradient with ruling gradient of 1 in 30 (falling).

In the contour plan contour lines are drawn with a contour interval of 2m. Since the contour interval is 2m and the gradient is 1 in 30, the horizontal distance required between successive points on consecutive contours is 60m (30 x 2m). With A as centre and the horizontal distance 60m to the scale of the drawing as radius, draw an arc cutting 58m contour at B and B'.

Considering the point lying nearer to the progressive direction of the centre route, the point is selected. Let it be B. Then B as centre and with the same radius draw another arc cutting the 56m contour at C. Select the suitable point and repeat the same process up to the last contour. The line joining the points A, B, C, D etc gives the alignment for the given gradient.

The contour gradient thus established on the contour map can be then transferred to the field by the use of suitable surveying instrument.

Grade stakes : Stakes or pegs erected in ground in such a way that their top is at the formation level or their top at any whole number of metres above or below the formation level.

Setting grade stake : It is the process of erecting the stakes at a given elevation or gradient. They indicate cut or fill required to bring the surface of the ground to a given grade. Knowing the formation level at each change from the profile and height of instrument calculate the staff reading required to set a given grade. Staff reading may be calculated by subtracting the formation level from the height of instrument. This staff reading is called grade rod.

Stake may be set out in several methods.

Let us consider the following cases.

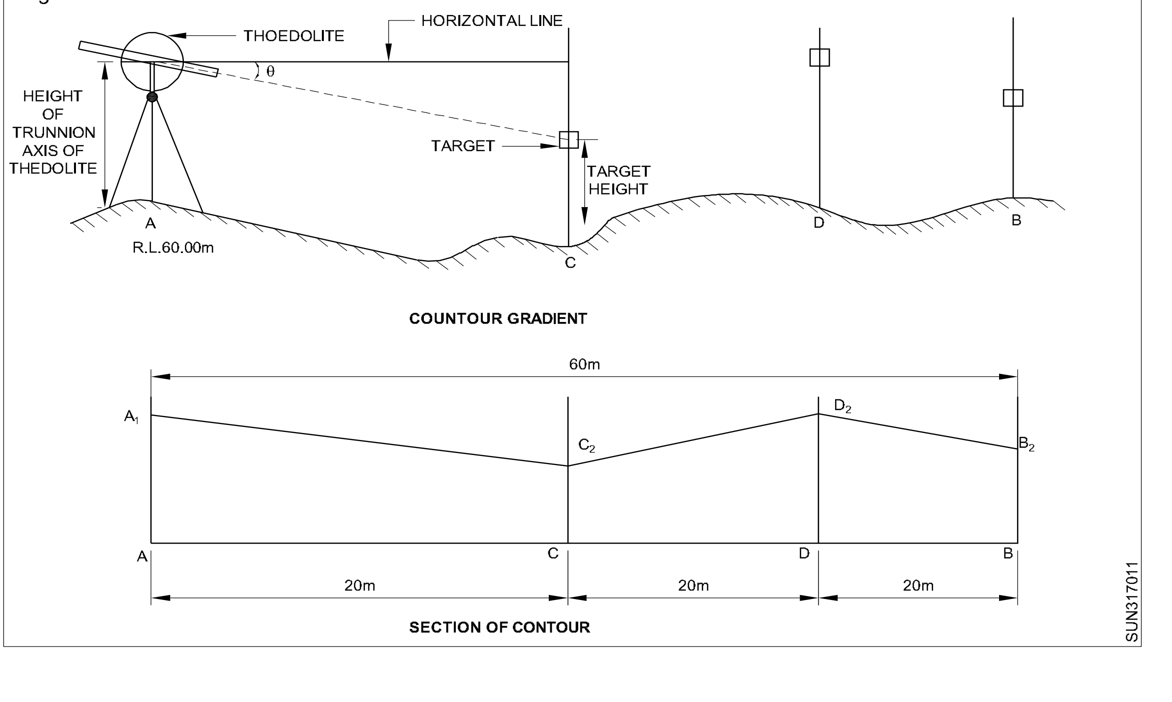
Method:1

The formation level of point A = 100.500

Height of instrument = 102.705

Ground level at A = 100.250

Fig 1



Now the grade rod = HI - the elevation of A.

= 102.705 - 100.500 = 2.205 m.

Erect a stake at A and take a staff reading on the top of the stake. If the staff reading differs from the grade rod, drive the staff until the desired reading 2.205 is obtained.

Method 2

Each stake may be driven so that its top is any whole numbers of metres above or below grade or formation level.

Suppose the formation level of the point 130.000m and the ground level at that point is 132.265m. The height of instrument has been found to be 134.255.

The grade rod or staff reading required = Hi - formation level.

= 134.255 - 130.000 = 4.255m.

The surface of ground is raised by = GL - formation level.

= 132.265 - 130.000

= 2.265m above ground.

As the ground is above the formation level we cannot erect the pegs at formation level A. So it may be erected at some whole numbers of metres above formation. Let the stake may be erected 2.5m above the formation level.

The staff reading required to establish the stake 2.5m above grade or formation level.

= grade rod - formation vertical distance

= 4.255 - 2.500

= 1.755 m

The stake is driven into the point A until its top staff reading obtained is 1.755m. The stake is then marked out 2.500 with crayon.

Method 3

Stake may be driven so that a mark may be made across one side of the stake either at the desired formation level or some whole number of metres above or below the formation level.

Stakes should be marked with crayon which will not be washed by rain or nail may be driven at the mark.

Contour map

Objectives: At the end of this lesson you shall be able to
- **prepare contour layout**
- **show the section of contour layout.**

Drawing of contour layout section: To study the general character of land area and shape with out visiting the land. We can able to know from the contour maps and their sections.

For calculating the earth work such section are more important. This process/earth work is carried out most in road. Railway, canal, projects. After taking out the levels of contour of a certain area. The contour levels are plotted in the drawing sheet in any one of method. It better have a some larger scale. Therefore the land areas undulations can be shown easily in detail. Give the contour levels properly in contour lines.

After completion of plotting the contour map draw the section line to the required direction (say here in horizontal direction).

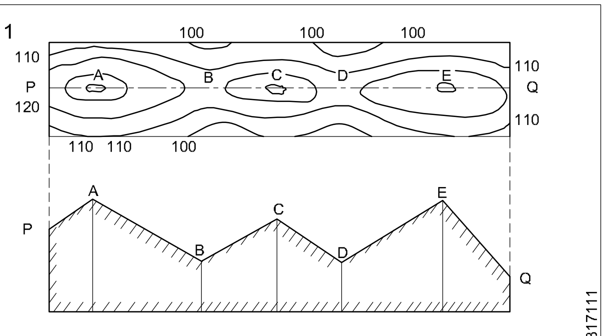
The cutting plane line section line should be drawn via either height level points or low level points. The cutting plane line drawn to the required length of project work. The cutting plane may be drawn at various area according to the project.

Below section line draw the projection lines of the intersecting points between contour lines and projection lines.

The cutting plane line/section line should be drawn either high level points or low level points. The cutting plane line drawn to the required length of the project. The cutting plane may be drawn of various areas according to the project

The section is drawn in graph paper with respect to levels (height) and horizontal distance to a suitable scale. As shown in (Fig 1)

Fig 1



SECTIONS OF CONTOUR MAP

Tracing of grade of contour

Objectives: At the end of this lesson you shall be able to
- **trace the contour gradient for alignment of roads, railways etc.,**
- **determine the volume of earth work and capacity of reservoir.**

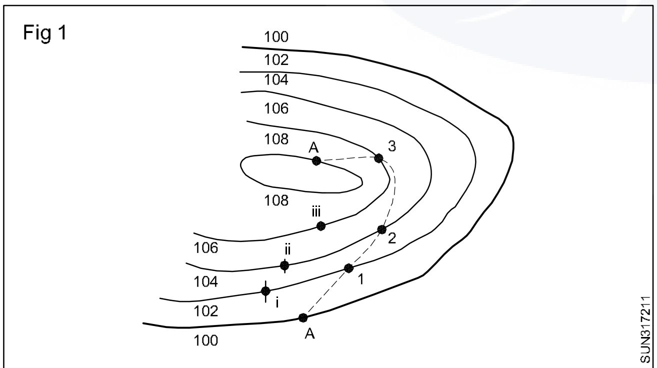
Tracing the contour gradient for alignment of roads, railways and canals etc.

A contour gradient may be defined as a line joining the points on different contours along the same gradient.

Fig 1. Shows a contour map on which the contour lines are at 2m intervals. The ground is sloping in an upward direction from A to B. supposing it is required to trace the path of a road with a ruling gradient of 1 in 30 from the starting point A on the 80m contour line since the contour intervals is 2m and the gradient 1 in 30, the horizontal distance between successive points on consecutive contours is 60m (2 x 30).

With A as centre and radius equal to 60m draw an arc cutting the 82m contour at 1. With 1 as centre and the same radius, draw an arc intersecting the 84m contour at 2 and so on for successive contours. Join these points which lie on the desired gradient. It may be noted that each of the arcs described will intersect the next contour at two points viz 1 and i, 2 and ii, 3 and iii etc. at 82, 84, 86. metre contour etc. and the points following the desired route such as 1,2,3, etc. should be joined.

Fig 1



Finding volume of earth and capacity of a reservoir from contour lines.

The volume of earth work and capacity of a reservoir may be calculated by treatment of contour lines. This method is only approximate as in dealing with contour lines we have to assume that the surface of the ground slopes uniformly form one contour to the next and in most cases this assumption is incorrect. However sufficient accuracy can be attained if the contours are located with an interval small enough to record mirror features of the ground.

After preparation of the contour plan of the particular site, the area enclosed by each contour line is measured by a planimeter, knowing the vertical distance between the first and the second contour lines (the contour interval) and their areas, Volume of earth work or water between them may be calculated either by trapezoidal formula or by some other formula.

Let A_1, A_2, A_3 etc., = The area within successive contour in sq metres.

d = the contour interval in metres

Then volume of the earth work or water between two adjacent contours:-

By trapezoid formula $= \frac{d}{2}(A_1 + A_2)$cu.metres

And more accurately $= \frac{d}{2}(A_1 + A_2 + \sqrt{A_1 A_2})$ cu.metres

Similarly cubic contents between successive contours may be found out, which when added together gives the required total cubical contents. This may be well understood by the following example.

Example: The area within contour lines at the site of a reservoir and the face of the proposed dam are as follows:

Contour in metres	Area in sq. metres
441	270
444	10,440
447	75,600
450	1,44,000
453	2,70,000
456	4,14,500
459	4,60,800
462	5,86,800
465	6,39,900

Taking 441 as the bottom level of the reservoir and 465 as the water level, find the volume of water in the reservoir in cubic metres.

Solution:

(i) By trapezoidal formula:

Volume of water between 441 and 465m contours,

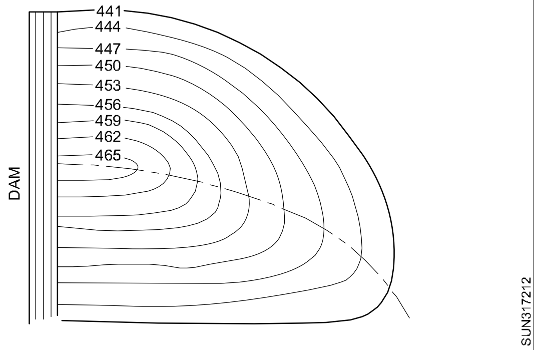
= Common vertical distance between consecutive contours or contour interval

$$\left\{\frac{\text{Sum of Area of End Contours}}{2} + \text{the sum of the remaining contours}\right\}$$

$$V = h\left\{\frac{A_{441} + A_{465}}{2} + A_{444} + \ldots.. + A_{462}\right\}$$

$$= 3\left\{\frac{270 + 639900}{2} + 10440 + 75600 + 144000 + 270000 + 414500 + 460800 + 586800\right\}$$

Fig 2



= 68,46,675 cu. metres

= 6.847 million cu. metres (Ans)

Solution:

(ii) By prismoidal formula:

Volume of a prismoid = height/6 [sum of the area of the ends + 4 X area of the mid - section]

The volume between three contours will be takes as that of a prismoid the bottom and top contours will give the area of its ends and the central contour, the area of the mid - section.

The given contours are grouped into different sets each having three contours viz 441,444, 447; 447, 450, 453; 453 456; 459; and 459, 462,465. Volume of each set is found separately and added together to find the total volume.

a) Volume between 441, 444 and 447 contours

$$= \frac{6}{6}(270 + 75600 + 4 \times 10440) = 1{,}17{,}630 \text{ cu. m}$$

b) Volume between 447, 450 and 453 contours

$$= \frac{6}{6}(75600 + 270000 + 4 \times 144000) = 9{,}21{,}600 \text{ cu.m}$$

c) Volume between 453, 456 and 459 contours

$$= \frac{6}{6}(270000 + 460800 + 4 \times 414500) = 23{,}88{,}800 \text{ cu.m}$$

d) Volume between 459, 461 and 465 contours

$$= \frac{6}{6}(460800 = 639900 + 4 \times 586800) = 34{,}47{,}900 \text{ cu. m}$$

Total volume = 1,17,630 + 9,21,600 + 23,88,800 + 34,47,900

= 68,75,930 cu.m

= 6.875 million cu. metres (Ans).

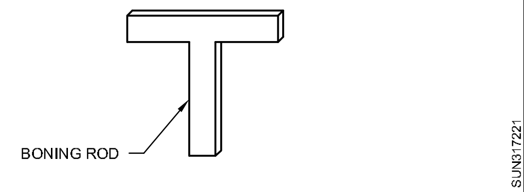
Establishment of gradient by ABNEY level, boning rod and sight rail.

Objectives: At the end of this lesson you shall be able to
- **explain the construction of boning rod & sight rail**
- **explain the method of setting out grade for sewer**
- **explain the method of setting out grade using (i) abney level (ii) ceylon ghat tracer (iii) level..**

Boning Rods (Fig 1)

The wooden T shaped rods used for setting out grade are known as boning rods. It consists of a cross piece and long vertical piece. The long piece is also provided with the same cross section but its length varies.

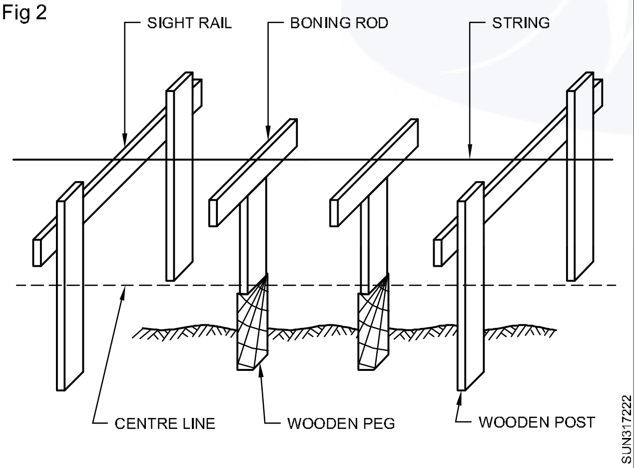
Fig 1



Sight rail & boning rod (Fig 2)

Boning rod or sight rail is a horizontal strip of wood 15cm wide and 5cm thick set across the trench and nailed to two vertical posts of 1 or 1.5m long, firmly embedded into ground on either side of the trench.

Fig 2



Setting out gradient for sewer

The inverts (the inside bottom surface level of sewer) of sewers and pipe line are set out to the proper gradient by means of sight rails and the boning rods.

The following procedure is adopted for the lying of the new sewer.

- The centre line of the proposed sewer line is first staked out on the ground at 20m interval.
- An offset line is set out on one side of the centre line at a convenient distance for locating the centre line, when excavation is carried out for laying the sewer. The offset line is marked on the ground by driving stakes on soft ground or by driving spikes in hard surface flush with the ground level.
- Then sight nails are erected across the trench at 30m interval and at the points where the change of gradient and direction occurs. The first sight rail is erected at the lowest end, working upwards. The top of each sight rail may be adjusted maintaining a fixed whole number of meter (say 3, 4, 5m) with the invert level.
- For setting out gradient, boning rod of the same length is also prepared.
- A chord is stretched between the nails erected on the top of two consecutive sight rails, which has the same gradient as that of the invert of the sewer.
- The excavation of trench for laying the sewer line is started. If necessary, timbering to protect the sides may be made.
- After preparing the bed, sewers are laid in the trench. In order to check the invert level of sewers, the boning rods may be used. The boning rod is placed vertically with its bottom touching the invert of sewer and if the top of the boning rod touches the string, the sewer is at proper gradient. But if it is above or below the string, excavation or filling is required to bring the top of the boning rod in level with the string to maintain the gradient.
- The refilling of the trenches started after the sewer line is properly laid in position. Earth should be laid equally on either side of sewer and filling should be carried out in layers of 15cm thickness. Each layer should be well watered and rammed.

Shooting in gradient

The method used to establish grade stakes when grade is uniform for a considerable distance is known as shooting in grade.

Establishing grade contour or contour grade

These can be established by using any one of the following methods:

Using abney level

The vernier of the abney level is set to read the given grade. The instrument is placed over the starting point at a known height (1.5m) above the point by supporting it against a pole. Another pole, on which the vane is fixed at same height, is held over the next point at some distance apart. The rod is then moved up or down until the vane is bisected and the bubble is centered. The line joining the instrument station to the point on which the rod is placed parallel to the line of sight and is in the given grade. The point so obtained is then pegged and is used as the next instrument station. The successive points are marked in the same manner.

Using ceylon ghat tracer

The instrument is placed over the starting point with the help of the upright staff. Move the weight along the rack by means of the milled headed screw until the index reads the given grade on the scale. Send an assistant to hold the sight vane along the required direction and direct him to raise or lower the sight vane until the cross wires bisect the centre of the sight vane. Then the bottom of the sight vane is the required point. The line from the instrument station to this point is parallel to the line of sight and is in the given gradient.

Using level

It is an accurate method. In this method the reduced levels of the pegs to be erected on the given grade are calculated from the given gradient, distance and reduced level of the starting point.

Then the staff reading which is to be read on each peg is calculated from the height of instruments and the reduced levels of each peg at the known distances. The pegs are erected on the ground until the required.

Staff readings at known distances are obtained. Then the top of these pegs are in the given grade.

Problems on computation of earth work

Objective: At the end of this lesson you shall be able to
- **compute volume of earth work by various methods.**

Example 1.1

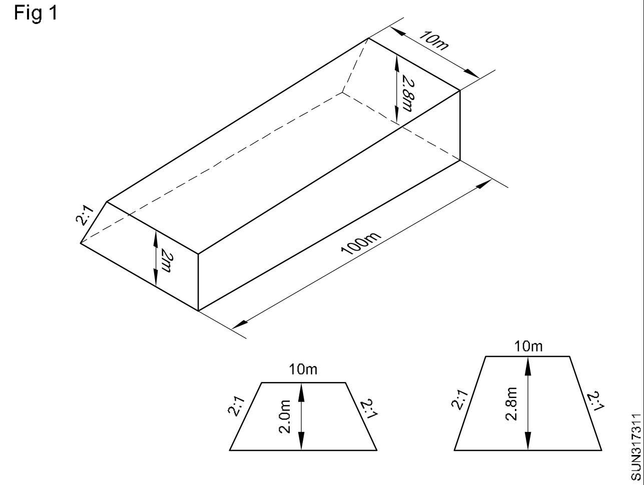
Calculate the quantity of the earthwork for 100 m length for a portion of an embankment in a uniform ground, with no transverse slope, the heights of the embankment at the ends beings 2.0 m and 2.8 m. The formation width is 10 metres and side slope 2: 1 (horizontal : vertical)

Solution

We shall calculate the volume by three different methods.

Average height method (Fig 1)

Fig 1



Given = B = 10 m ; L = 100 m ; S = 2

The height at section 1 = 2.0 m

The height of section 2 = 2.8 m

$\therefore$ The mean height, $d = \dfrac{2.0 + 2.8}{2} = 2.4\text{m}$

We know that the quantity of the earth work

$$V = (Bd + Sd^2) \times L$$

Substituting the values in eqn. (i) we get

$V = (10 \times 2.4 + 2 \times 2.4^2) \times 100$

$= (24 + 11.52) \times 100$

or Volume $V = 3552\ \text{m}^3$, Ans

Average cross sectional area method

Let A_1 = Cross - sectional area at section 1

A_2 = Cross - sectional area at section 2

$A_1 = Bd1 + Sd_1^{\,2} + 10 \times 2 + 2 \times 2^2 = 28\text{m}^2$

$A_2 = Bd_2 + Sd^2_{\,2} = 10 \times 2.8 + 2 \times 2.8^2 = 43.68\text{m}^2$

$$\text{Mean sectional area } A = \frac{A_1 + A_2}{2}$$

$$= \frac{28 + 43.68}{2} = 35.84\text{m}^2$$

Now, total volume of earth work = sectional area length

$V = A \times L$

$= 35.84 \times 100$

$= 3584\ \text{m}^3$. Ans

Prismoidal formula method

Let A_1 = Cross sectional area at section 1

A_2 = Cross sectional area at section 2

A = Cross sectional area at mid section

d_1 = the height of embankment at section 1

d_2 = the height of embankment at section 2

d = the height of embankment at mid section

$\therefore$ A_1 = $A_1 = Bd_1 + Sd_1^2 + 10 \times 2 + 2 \times 2^2 = 28m^2$

$A_2 = Bd_2 + Sd_2^2 + 10 \times 2.8 + 2 \times 2.8^2 = 43.68m^2$

$A = Bd + Sd^2 = 10 \times 2.4 + 2 \times 2.4^2$

where $= \dfrac{d_1 + d_2}{2}$

$= \dfrac{2.0 + 2.8}{2} = 2.4m = 10 \times 2.4 + 2 \times 2.4^2 = 35.52m^2$

> From the prismoidal formula, we get
>
> $v = \dfrac{L}{6}$ (area of first section + 4 x area of mid section + area of last section)

$= \dfrac{100}{6}(28 + 4 \times 35.52 + 43.68)$

$= \dfrac{100 \times 213.76}{6} = 3562.67m^3$.Ans

Example 1.2

Calculate the quantity of the earthwork for 100 m length for a portion of a road, if the depth in cuttings at the ends are 2.4 m and 2.8 m. The formation width is 10 m and side slopes 1: 1 (1 horizontal : 1 vertical). Assume no transverse slope.(Fig 2.)

Solution. 1 Average depth method

Here b = 10 m ; l = 100 m, s; s = 1: 1

The depth of cutting at section I = 2.4 m

The depth of cutting at section II = 2.8 m

$\therefore$ Average depth of cuttings = $= \dfrac{2.4 + 2.8}{2} = 2.6m$

> We know, the volume of a portion
>
> $V = (bd + Sd^2) \times L$

$= (10 \times 2.6 + 1 \times 2.6^2) \times 100$

$= (26 + 6.76) \times 100$

$\therefore$ Volume = 3276 m^3. Ans

Average cross - sectional area method

Let A_1 = Cross sectional area at section 1

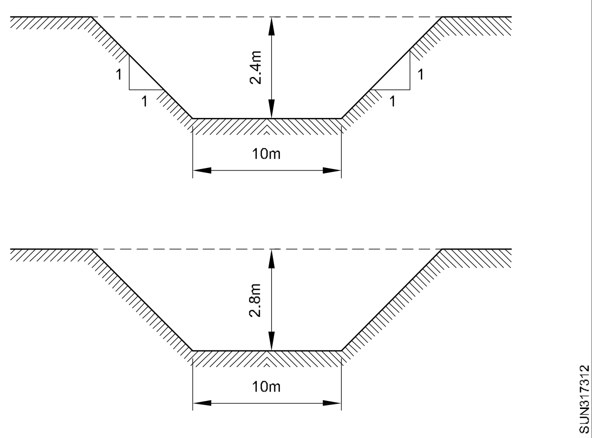
A_2 = Cross sectional area of section 2

$\therefore A_1 = Bd_1 + Sd_1^2 + 10 \times 2.4 + 2.4^2 = 29.76$

$A_2 = Bd_2 + Sd_2^2 + 10 \times 2.8 + 1 \times 2.8^2 = 35.84m^2$

Average cross sectional area A =

Fig 2



$\dfrac{29.76 + 35.84}{2} = 32.80m^2$

Volume = Average cross sectional area x length

$= 32.80 \times 100 = 3280$ m^2. Ans

Prismoidal formula method

Let A_1 = Cross sectional area at section 1

A_2 = Cross sectional area of section 2

A = Cross sectional area at mid section

d_1 = depth of cutting at section 1

d_2 = depth of cutting at section 2

d = average depth at the mid section

Here $A_1 = bd_1 + sd_1^2 = 10 \times 2.4 + 1 \times 2.4^2 = 29.76m^2$

$A = bd_2 + sd_2^2 = 10 \times 2.8 + 1 \times 2.8^2 = 35.84m^2$

But $d = \dfrac{d_1 + d_2}{2}$

$= \dfrac{2.4 + 2.8}{2} = 2.6m$

$\therefore$ $A = bd + sd^2$

$= 10 \times 2.6 + 1 \times 2.6^2 = 32.76$ m^2

Substituting the values in the prismoidal formula, we get.

$$V = \frac{100}{6}[29.76 + 4 \times 32.76 + 35.84]$$

$$\boxed{= \frac{100}{6}[29.76 + 4 \times 32.76 + 35.84]}$$

$$= \frac{196.64 \times 100}{6}$$

= 3277.333 m^3. Ans

Example 1.3

Work out the quantity of earth work for an earthen road for a length of 1.0 km, with the following data :

Width of formation = 5.00 m

Side slopes in banks = 1 : $1\frac{1}{2}$

Side slopes in cuttings = 1 : 2

The following are the ground levels at various reduced distances :

Reduced distance (1)	Ground Level (2)	Formation level (3)
0	100.00	100.00
100	98.56	-
200	95.37	-
400	99.35	-
500	102.67	-
600	110.52	-
700	105.62	-
800	101.70	-
900	102.28	-
1000	96.77	100.20

There is a uniform gradient from R.D 0 to R.D 1000

Solution

Rise per 100 m distance

$$= \frac{100.20 - 100}{1000} \times 100 = 0.02m$$

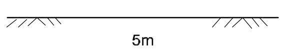
Formula used for calculating the cross sectional area

A = bd + sd^2

R.D. 0 m

Depth of cutting

= formation level - ground level



= 100 - 100 = 0

∴ Area = 0.000 sq.m

R.D 100 M (Fig 3)

Formation level

= 100.00 + 0.02 = 100.02 m

Ground level = 98.56 m

∴ Ht. of embankment

= 100.02 - 98.56 = 1.46 m

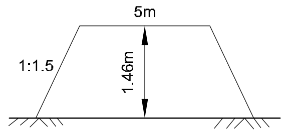


Fig 3

Area of cross section

= 5 x 1.46 + 1.5 x 1.46^2 = 10.50 m^2.

R. D 200 m (Fig 4)

Formation level

= 100.00 + 0.04 = 100.04 m

Ground level = 95.37 m

∴ Ht. of embankment

= 100.04 - 95.37

= 4.67 m

Area of cross section

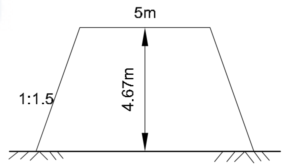


Fig 4

= 5 x 4.67 + 1.5 x 4.67^2

= 56.06 m^2

R. D 400 m (Fig 5)

Formation level

= 100.00 + 0.08 = 100.08 m

Ground level = 99.35 m

∴ Ht. of embankment

= 100.08 - 99.35

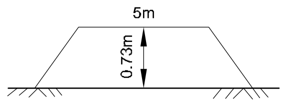


Fig 5

= 0.73 m

Area of cross section = 5 x 0.73 + 1.5 x 0.73^2 = 4.45 m^2

R. D 500 m (Fig 6)

Formation level

= 100.00 + 0.10 = 100.10 m

Ground level = 102.67m

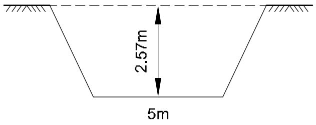


Fig 6

Depth of cutting

= 102.67 - 100.10 = 2.57

It is noted that road between R.D 400 m and R.D 500 m passes for banking to cutting. **(Fig 7)**

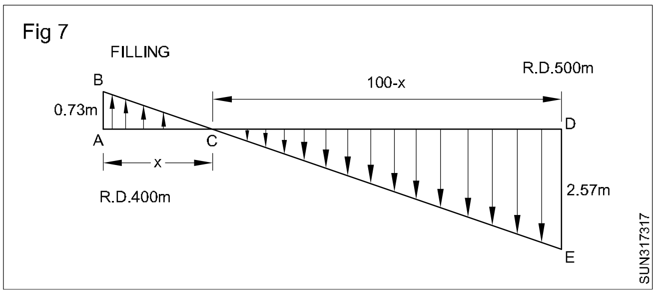


Fig 7

To locate the section having neither banking nor cutting, proceed as under :

Let C be the section having neither banking nor cutting.

Let AC = x

∴ CD = 100 - x

From similar Δs ABC and CDE, we get

$$\frac{x}{0.73} \times \frac{100 - X}{2.57}$$

2.57x = (100 - X) 0.73

2.57 x = 73 - 0.73 x

3.3 x = 73

$$x = \frac{73}{3.3} = 22.12\text{m}$$

Now, area of cross - section at R.D 500 m

= 5 x 2.57 + 2 x 2.57^2

= 26.06 m^2

R. D 600 m (Fig 8)

Formation level

= 100.00 + 0.12 = 100.12 m

Ground level = 110.52 m

Depth of cutting

= 110.52 - 100.12 = 10.40 m

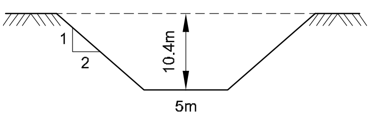


Fig 8

Area of cross - section

= 5 x 10.4 + 2 x 10.4^2

= 268.32 m^2

R. D 700 m (Fig 9)

Formation level

= 100.00 + 0.14 = 100.14 m

Ground level = 105.62 m

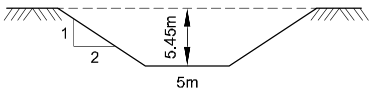


Fig 9

Depth of cutting

= 105.62 - 100.14 = 5.48 m

Area of cross - section = 5 x 5.48 + 2 x 5.48^2 = 87.46m.

R. D 800 m (Fig 10)

Formation level

= 100.00 + 0.16 = 100.16 m

Ground level = 101.70 m

Depth of cutting

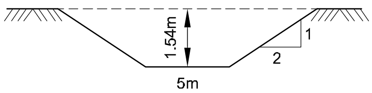


Fig 10

= 101.70 - 100.16 = 1.54 m

Area of cross - section

= 5 x 1.54 + 2 x 1.54^2 = 12.44 m^2.

R. D 900 m (Fig 11)

Formation level

= 100.00 + 0.18 = 100.18 m

Ground level = 102.28 m

Depth of cutting

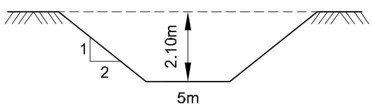


Fig 11

= 102.28 - 100.18 = 2.10 m^2.

Area of cross - section

= 5 x 2.10 + 2 x 2.10^2 = 19.32 m^2.

R. D 1000 m (Fig 12)

Formation level = 100.20 m

Ground level = 96. 77 m

Ht. of embankment

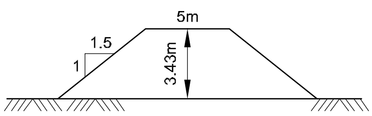


Fig 12

= 100.20 - 96.77 = 3.43 m

Area of cross - section

= 5 x 3.43 + 1.5 x 3.43^2 = 34.80 m^2

The road between R.D 900 m and R.D 1000 m again passes from cutting to banking. To locate the section having neither cutting nor banking, proceed as under.

Let AC = x

CE = 100 - x

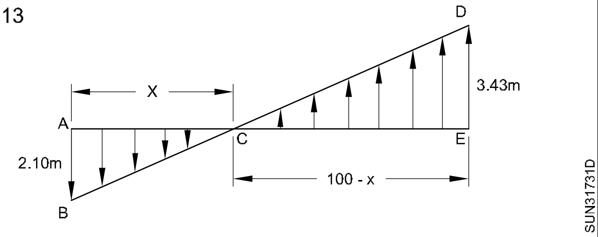
From similar triangles ABC and CDE (Fig 13)

$$\frac{x}{2.10} = \frac{100 - x}{3.43}$$

3.43x + 2.10x = 210

$$x = \frac{210}{5.53} = 37.97\text{m}$$

Fig 13



Calculation of the earthwork is done as tabulated here under :

R.D (m)	Cross section area	Mean Area		Length	Quantity	
		Cutting	Filling		Cutting	Filling
0	0	-	-	-	-	-
100	10.50	-	5.25	100	-	525.00
200	56.06	-	33.28	100	-	3328.00
400	4.45	-	30.25	200	-	6050.00
422.12	0.00	-	2.22	22.12	-	49.11
500	26.06	13.03	-	77.78	1013.47	-
600	268.32	147.19	-	100	14719.00	-
700	87.46	177.89	-	100	17789.00	-
800	12.44	49.95	-	100	4995.00	-
900	19.32	15.88	-	100	1588.00	-
937.97	0.00	9.66	-	37.97	366.79	-
1000	34.80	-	17.40	62.03	-	1079.32
			Total	999.90	40471.26	11031.43

Example 1.4

Estimate the quantities of earth work for an embankment to support a railway track at a uniform down gradient from stations A to I. The formation levels at stations A and I are R.L 218.90 and R.L 218.10 respectively. The ground levels at various stations 50 m apart are as under:

Table 1

Station :	A	B	C	D	E	F	G	H	I
GL (m)	220.50	220.10	219.70	219.20	218.50	218.20	217.70	217.30	217.50

The formation widths are 5.5 m in cutting and 6.0 m in banking. The side slopes are $1\frac{1}{2}:1$ in banking. There is no transverse slope of the ground. Apply prismoidal formula for computation.

Solution:

Total distance between stations A and I = 400 m

Difference in formation levels at stations A and I = 218.90 - 218.10 = 0.80 m

Difference in formation level at 50 m distance.

$$\frac{0.8}{400}\times 50.01\text{m}$$

Ground levels, formation levels and depth of cutting / filling at various sections are shown under :

Section	A	B	C	D	E	F	G	H	I
Ground level	220.50	220.10	219.70	219.20	218.50	218.20	217.70	217.30	217.50
Formation level	218.90	218.80	218.70	218.60	218.50	218.40	218.30	218.20	218.10
Cutting	1.60	1.30	1.00	0.60	0.00	-	-	-	-
Filling	-	-	-	-	-	0.20	0.60	0.90	0.60

Cross sectional area at different sections may be calculated from the formula .

Section A : (Fig 14)

Area = 5.5 x 1.6 + 1.5 x 1.6^2

= 12.64 m$^{2.}$

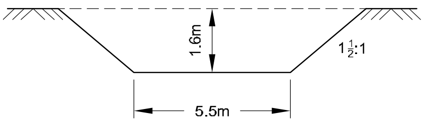


Fig 14

Section B : (Fig 15)

Area = 5.5 x 1.3 + 1.5 x 1.3^2

= 9.69 m^2

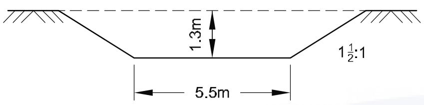


Fig 15

Section C : (Fig 16)

Area = 5.5 x 1.0 + 1.5 x 1.0^2

= 7.00 m^2

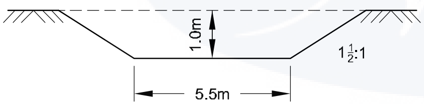


Fig 16

Section D : (Fig 17)

Area = 5.5 x 0.6 + 1.5 x 0.6^2

= 3.84 m^2

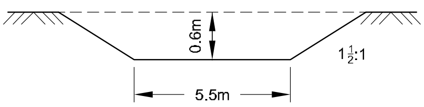


Fig 17

Section E : (Fig 18)

Area = zero = 0.00 m^2

= 3.84 m^2

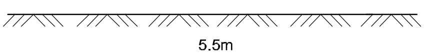


Fig 18

Section F : (Fig 19)

Area = 6 x 0.2 + 2 x (0.2)^2

= 1.28 m^2

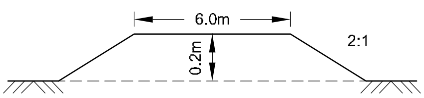


Fig 19

Section G : (Fig 20)

Area = 6 x 0.6 + 2 x 0.6^2

= 4.32 m^2

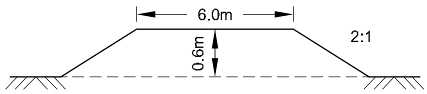


Fig 20

Section H : (Fig 21)

Area = 6 x 0.9 + 2 x 0.9^2

= 7.02 m^2

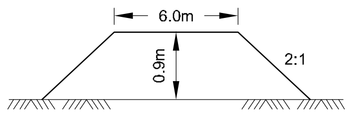


Fig 21

Section I : (Fig 22)

Area = 6 x 0.6 + 2 x 0.6^2

= 4.32 m^2

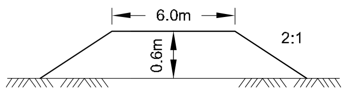


Fig 22

Applying the prismoidal formula :

Volume in cutting

$$= \frac{50}{3}\left[12.64 + 0 + 4\left(9.69 + 3.84\right) + 2 \times 7.0\right]$$

$$= \frac{50}{3}\left[12.64 + 4 \text{ x } 13.53 + 14.0\right]$$

$$= \frac{50}{3}\left[12.64 + 54.12 + 14.0\right]$$

$$= \frac{50}{3} \times 80.76$$

= 1346 m^3. Ans

Volume in filling

$$= \frac{50}{3}\left[0 + 4.32 + 4(1.28 + 7.02) + 2 \times 4.32\right]$$

$$= \frac{50}{3}\left[4.32 + 33.20 + 8.64\right]$$

$$= \frac{50}{3} \times 46.16$$

= 769.33 m^3. Ans

Topography map with contour

Objectives: At the end of this lesson you shall be able to
- **topographic survey in field work**
- **topographic surveying (vertical control system)**
- **locating details.**

Topography map with contour

The topographic survey field work consists of three parts.

1 Establishing horizontal control as well as vertical control

2 Locating the contours

3 Locating the details of rivers lakes, roads, railways, buildings, trees, etc,.

The establishment of horizontal and vertical control system is very essential from three co-ordinate of point (two co-ordinate in horizontal plane to locate the ordinate in horizontally and another one co-ordinate in vertical plane with respect to base line/datum line) can the obtained or measured only with respect to well connected horizontal and vertical control system.

Horizontal control: It forms a skeleton of survey from which contours and their details are located if the area to be surveyed is small, the horizontal control may consists of one/single station point and the direction and the distance of each point can be measured with respect to the station.

Horizontal control for large area

Topography map with contour:

It consists of traverse. Traverse may proceed with tape compass, plane table depending up on the extent of area. The length of traverse sides are may determined with the help of stadia measurements, it happen when land is uneven and for moderate size of land.

Topographic surveying (vertical control system)

The vertical control system is very important because of topographic map must indicate the third dimension (or) relief. It determines the elevations of primary control station or we have to establish bench marks near the station with a convenient intervals.

High order sprit level circuits are run to determine elevations accurately defining position of all control points. Trigonometric levelling in used to transfer elevation the precise levelling circuits to triangulation station then these station generally being located on high commanding point, when the levels are in so as for as possible over level, gently sloping terrain. Then the secondary vertical control is established by finalising elevation of traverse station points or bench mark near the station. By tachometric method this can be established. When level is used the elevation of the vertical control points can be established determined by running circuits of bench marks can be positioned such that the portions that can be seen from near by horizontal control points.

Locating detains

After having the located points by horizontal and vertical control system the measurement of distances and angles are help to complete the map.

The three co-ordinates of any can be determined by measurement of

(i) Direction (ii) Elevation of point (iii) Distance of point from control point. Angles may be measured with compass, transit or grafically by means of plane table. Distance can be measured with chain or tape. The elevation may be obtained by level. The map in prepared by plotting the control points and then the detail. The contour are drawn next and then only the relief depicted by means of contour conventional signs.

Method of locating contours:

Depending up on the instruments used locating contour is divided into two methods.

1 Direct method

2 Indirect method.

1 Direct method: Here the contour to be plotted is actually traced on ground. There points are surveyed which happen to be plotted. After surveying the points they are plotted, and contour are drawn through them. It is used for small areas where the accuracy in essential. This method is slow and tedious.

Direct method: the tracing contour field work has two fold.

(i) Vertical control

(ii) Horizontal control

2 Indirect method: Here some suitable girdle points are selected and surveyed. The points (which are guide) not necessary on contour lines. The guide points plotted serve as a base for the interpolation of contours. This method is used in engineering surveys.

Introduction to curves

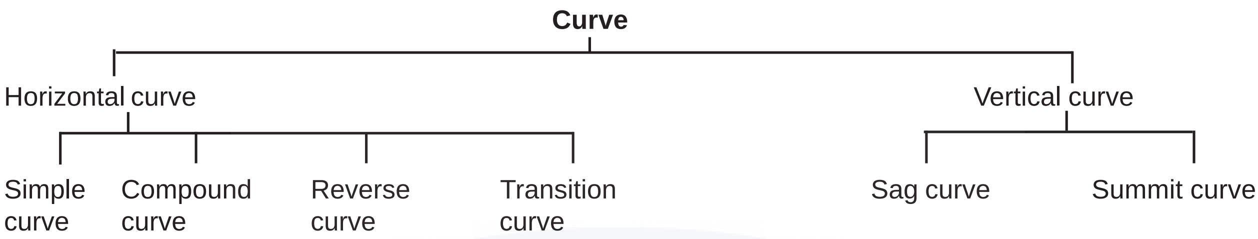
Objectives: At the end of this lesson you shall be able to
- **explain the necessity for the provision of curves on road and railway**
- **explain the classification of curves**
- **explain the different terms used in curve.**

Introduction

Initially the alignment of roads and railways are consisting of straight lines. But in actual practice it is not possible to construct them in this way as it is difficult to run the vehicles through them. This necessitates the provision of horizontal curves on roads and railways.

Again, along the alignment of roads and railways the nature of the ground may not be uniform and may consist of abrupt changes. It also makes difficulty for the easy movement of the vehicles. This also necessitates the provision of vertical curves.

Classification of curves



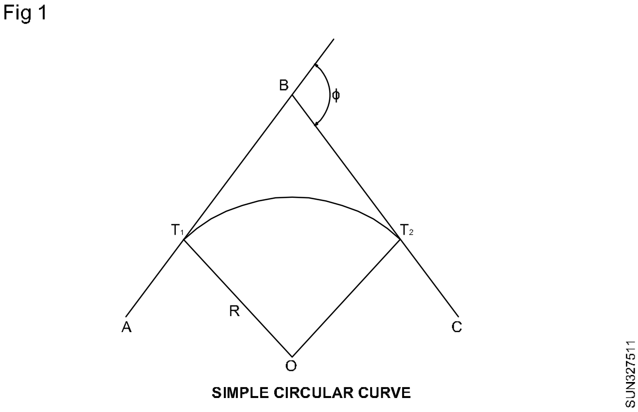
Curves are generally classified into two. They are horizontal and vertical.

Horizontal curves: Curves which are provided on roads or railways for the easy change of direction on the horizontal plane are called horizontal curves.

Horizontal curves may be further divided into four.

Simple circular curve: It is a curve of single radius connecting two straight lines. (Fig 1)

Fig 1

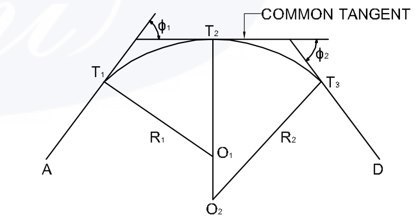


SIMPLE CIRCULAR CURVE

Compound curve: Curve which are consists of two or more arcs of different radii is called compound curve. (Fig 2)

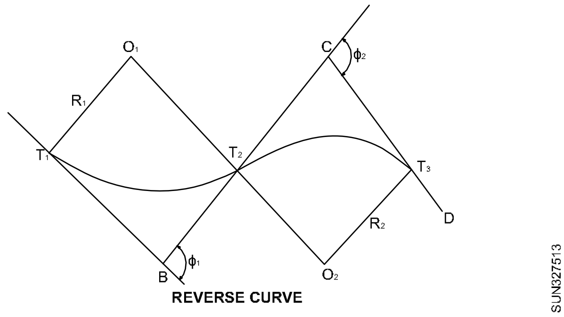
Reverse curve: Curve which are consists of two arcs of same or different radii bending in opposite directions is called reverse curve. (Fig 3)

Fig 2



COMPOUND CURVE

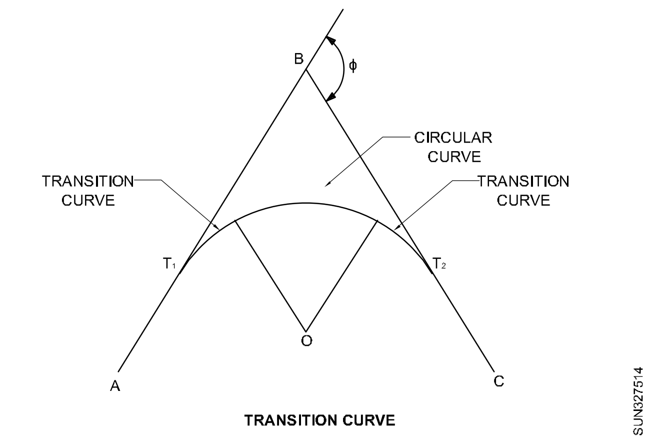
Fig 3



REVERSE CURVE

Transition curve: A curve of varying radius, ie infinite at straight and definite value at an arc or vice versa is called transition curve. (Fig 4)

Fig 4



TRANSITION CURVE

Vertical curves: Curves which are provided on roads or railways for easy change of grade called vertical curves.

Vertical curves are divided into two.

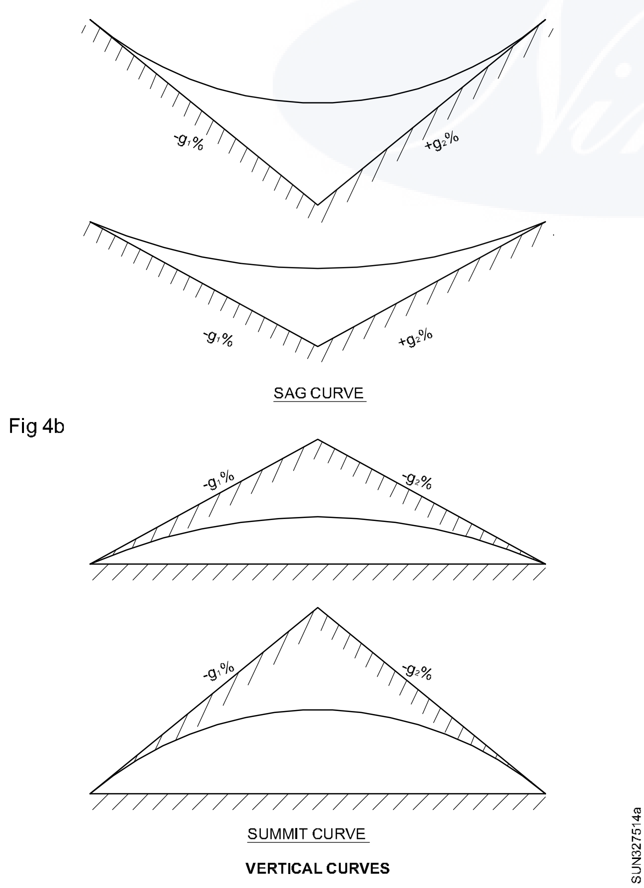
Sag curve or valley curve: (Fig 4a)

Vertical curve formed by

(i) a down grade followed by an equal or different up grade or (ii) a down grade followed by a flatter down grade.

Summit curve:(Fig 4b)

Fig 4a



VERTICAL CURVES

Vertical curve formed by (i) an upgrade followed by an equal or different downgrade or (ii) an up grade followed by a flatter upgrade or (iii) by down grade followed by a steeper down grade.

Element of a circular curve and notations

Fig 5 shown a simple circular curve of radius R with its centre at O. A curve has the following element.

Back tangent: The tangent AT_1 at the point of commencement T_1 of the curve, is the back tangent.

Forward tangent: The tangent T_2B at the end point T_2 of the curve, is the forward tangent.

Point of intersection (P.I.): The point I where the back tangent when produced forward and forward tangent when produced backward meet, is called the point of intersection.

Intersection angle: The angle φ between the back tangent AT_1 and the forward tangent T_2B at I, is called the intersection angle.

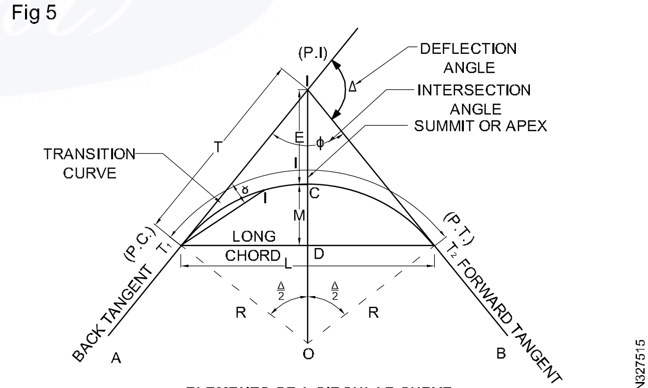
Deflection angle of the curve: The angle **Δ** through which the forward tangent deflects, is called deflection angle of the curve. It may be either to the left or the right.

Point of commencement (P.C.): The point T_1 where the curve commences is called the point of commencement of the curve. It is also called point of the curve.

Point of tangency (P.T.): The point T_2 where the curve joins the forward tangent, is called point of tangency.

Deflection angle to any point on the curve: The deflection angle δ to any point 1 on the curve is the angle at P.C. between the back tangent and the chord $T_1 1$ from P.C. to the point on the curve.

Fig 5



ELEMENTS OF A CIRCULAR CURVE

Tangent distance (T): It is the distance between P.C. to P.I. (or P.I. to P.T.)

External distance (E): It is the distance from the midpoint of the curve to P.I. It is also known as the apex distance.

Length of curve (l): It is the total length of the curve from P.C. to P.T.

Long chord (L): It is the chord joining P.C. and P.T.

Mid - ordinate (M): It is the ordinate from the midpoint of the long chord to the midpoint of the curve. It is also called the versine of the curve.

Normal chord (C): A chord between two successive regular pegs on the curve, is called a normal chord.

Sub -chord (C): When the chord is shorter than the normal chord, it is called a sub-chord. These generally occur at the beginning and end of the curve. These will be designated Cf and Cl, respectively.

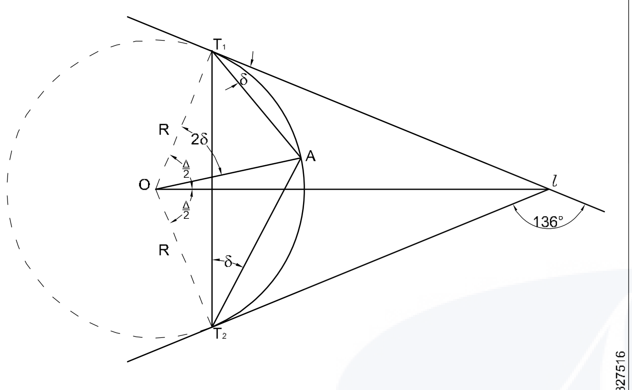
Right - hand curve: If the curve deflects to the right of the direction of the progress of survey it is called the right - hand curve.

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

Geometrics of a circle:

Some of the important properties of a circle used in the computations for curve ranging, are given below (Fig. 6).

Fig 6



GEOMETRICS OF A CIRCLE

$$\text{Length of tangents } T_1 I = IT_2 = T = R \tan \frac{\Delta}{2}$$

$$\text{Long chord } T_1 T_2 = 2 R \sin \frac{\Delta}{2}$$

The angle subtended by any chord at the centre is twice the angle between the chord and the tangent, i.e.,

$$\angle IT_1A = \frac{1}{2}\angle T_1OA$$

The angle subtended by a chord at any point on the circumference is equal to the angle between the chord and the tangent, i.e.

$\angle AT_2 T_1 = \angle IT_1A$

$$= \frac{15}{R}$$

$$\text{or } R = \frac{15}{\sin \frac{D_c}{2}} \text{(exact)}$$

Note that radius of curvature varies inversely as the degree of curve. A sharp curve has a large degree of curve whereas a flat curve has a small degree of curve.

To satisfy the requirements of safety at high speeds the curve should be as flat as economically feasible.

These days the curves are generally designated by the radius of curve as the calculations can be done conveniently with an electronic calculator.

Formulae for various elements of a circular curve

For the computation of the various elements of a curve, the following formulae may be used

Length of curve (l)

$L = T_1 CT_2$

$$= \frac{2\pi R}{360}\Delta$$

$$\frac{\pi R\Delta}{180}$$

Alternatively, from arc definition

$$\frac{Da}{30} = \frac{\Delta}{l}$$

$$= OT_1 \tan\frac{\Delta}{2}$$

$$= R\tan\frac{\Delta}{2}$$

This eq. uses for the specified length of the arc as 30 m and can be used if the curve is flat.

Tangent length (T)

$T = T_1I = IT_2$

$$= OT_1 \tan\frac{\Delta}{2}$$

$$R \tan\frac{\Delta}{2}$$

Horizontal and vertical curves

Chainage of tangent points

The chainage of P.I. is generally known and thus.

Chainage of T_1 = Chainage of I - T

Chainage of T_2 = Chainage of T_1+ l

Long chord (L)

$L = T_1T_2$

$$2OT_1 \sin\frac{\Delta}{2}$$

$$2R \sin\frac{\Delta}{2}$$

External distance (E)

E = IC

= OI - OC

$$= R \sec\frac{\Delta}{2} - R$$

$$= R\left[\sec\frac{\Delta}{2} - 1\right]$$

Mid - ordinate (M)

M = DC

= OC - OD

$$= R - R\cos\frac{\Delta}{2}$$

$$= R\left[1 - \cos\frac{\Delta}{2}\right]$$

$$= R \text{ versine } \frac{\Delta}{2}$$

The mid-ordinate of the curve is also known as the version of the curve.

Designation of a circular curve

The sharpness of curvature of a curve may be expressed in any of the following ways:

Radius of the curve.

Degree of the curve.

Radius of curve

The curvature is defined by stating the length of radius. This method is often employed in subdivision surveys and sometimes in highway work.

In highways, the minimum radius of the curve is determined from the following formula:

$$R_{min} = \frac{V^2}{127(e+f)}$$

Where

V = the speed of vehicles in km/h,

e = the maximum super elevation, and

f = the maximum friction (= 0.16).

In railways, R_{min} is determined using the following formula:

$$R_{min} = \frac{BV^2}{127e}$$

Where

B = the gauge of the railway track (B = 1.676 m for broad gauge and 100m for metre gauge), and

e = the maximum super elevation (e = 165 mm for broad gauge, and 90 mm for metre gauge).

Degree of curve

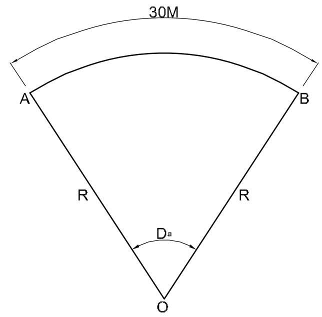
Here the curvature is expressed by stating the degree of curve D, which is traditionally defined as the angle subtended at the centre of the curve by an arc or a chord of specified length. Thus, there are two definitions of degree of curve. These are

Arc definition, and

Chord definition.

Arc definition (Fig 7)

Fig 7



ARC DEFINITION

Here the degree of curve is the central angle D_a that is subtended by an arc AB of 30 m length. The arc definition for degree of curve, is the method most frequently followed in highway practice.

If the degree of curve D_a is taken in degrees, for a curve of radius R, we have

$$\frac{Da}{30} = \frac{360°}{2\pi R}$$

$$\text{or } Da = \frac{10800}{2\pi R} \text{degrees}$$

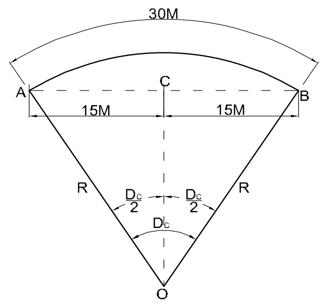
$$= \frac{1718.9}{R} \text{degrees(approximate)}$$

If the arc length is taken as 20 m then

$$D_a = \frac{1145.92}{R} \text{degrees(approximately)}$$

Chord definition (Fig 8)

Fig 8



CHORD DEFINITION

The degree of curve may also be defined as the central angle of the curve that is subtended by a chord AB of 30 m length (Fig 8). This definition is followed almost invariably in railway practice.

From fig 8. we have

$$\sin \frac{Dc}{2} = \frac{AC}{AO}$$

Elements of simple curve (Fig 9)

1 Length of curve (l)

Length = l = T_1 CT_2 = $R\Delta$

Where, Δ is in radians = $= \frac{\pi R}{180°} \Delta$

If the curve is designated by its degree of curvature. The length of curve depend upon the degree of curve.

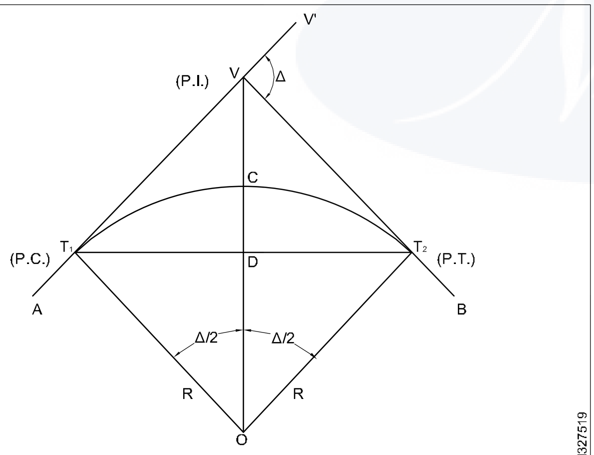
Arc definition:

Length of arc = 20m.

Any two central angles of the same circle are proportional to the corresponding intercepted ares or chords.

$$L = \frac{20\Delta}{D} \text{metres}$$

Fig 9



ELEMENTS OF SIMPLE CURVE

2 Tangent length (T)

Tangent length= T = T_1 V= VT_2 = OT, $\tan \frac{\Delta}{2} = R \tan \frac{\Delta}{2}$

3 Length of long chord (L) = l = T_1T_2 = 2

OT_1 $\text{Sin} \frac{\Delta}{2} = 2R \sin \frac{1}{2} \Delta$

4 Apex distance or external 1 distance (E)

E=CV = VO - CO =-R $\sec \frac{\Delta}{2} - R$

$$R = \left(\sec \frac{\Delta}{2} - 1 \right) = R \text{ exsec} \frac{\Delta}{2}$$

5 Mid ordinate (m)

M=CD = CO - DO $= R - R \cos \frac{\Delta}{2}$

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

The mid - ordinate of the curve is known as versed sine of the curve.

Setting of simple curve by linear method

Objectives: At the end of this lesson you shall be able to
- **determine the elements of curve**
- **determine the offsets from long chord**
- **explain the method of setting out curve by offsets from long chord.**

Simple curve setting by linear method

The following are the general methods employed for setting out curves by linear method:

Taking offsets or ordinates from the long chord

Taking offsets from the chord produced

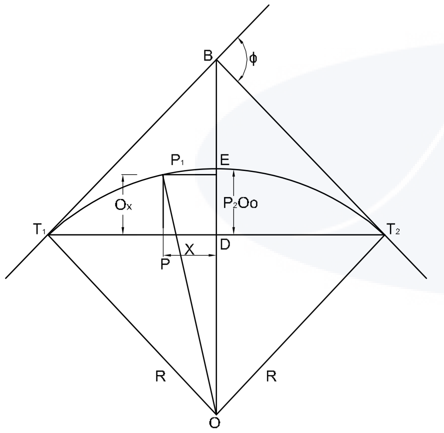
Successively bisecting the arcs

Taking offsets from the tangents

Offsets or ordinates from long chord

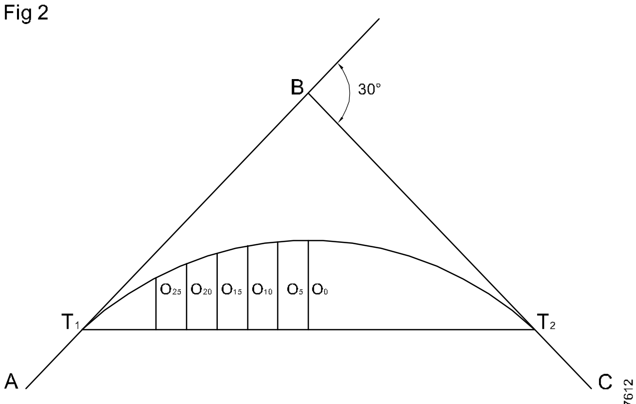
Let AB and BC be two tangents meeting at a point B, with a deflection angle φ. The following data are calculated for setting out the curve (Fig 1 & 2).

Fig 1



OFFSETS OR ORDINATES FROM LONG CHORD

Fig 2



OFFSETS OR ORDINATES FROM LONG CHORD

The tangent length is calculated according to the formula; TL = R tan $\phi/2$

Tangent points T_1 and T_2 are marked.

The length of the curve is calculated according to the formula:

$$= \frac{\pi R \varphi^{\circ}}{180^{\circ}}$$

The chain ages of T_1 and T_2 are found out.

The length of the long chord (L) is calculated from:

$L = 2R \sin \phi/2$

The long chord is divided into two equal halves the left half and the right half. Here the curve is symmetrical in both the halves.

The mid-ordinate O_0 is calculated as follows:

(a) O_0 = DE = versed sine of curve = R (1- cos $\phi/2$) (1)

(b) Again OX = R and OD = R - O_0

From triangle OT_1D, $OT_1^2 = OD^2 + T_1D^2$

(or) $$R^2 = (R - O_0)^2 + \left(\frac{L}{2}\right)^2$$

(or) $$R - O_0 = \sqrt{R^2 - (L/2)^2}$$

(or) $$O_0 = R - \sqrt{R^2 - (L/2)^2} \qquad (2)$$

Thus, the mid-ordinate O_0 can be calculated from Eq. (1) or (2).

considering the left half of the long chord, the ordinates O_1, O_2, ...are calculated distances X_1, X_2,.... taken from D towards the tangent point T_1.

The formula for the calculation of ordinates is deduced as follows.

Let P be a point at a distance x from D. Then PP_1 (O_x) is the required ordinate. A line P_1P_2 is drawn parallel to T_1T_2. From triangle OP_1P_2, $OP_1^2 = OP_2^2 + P_1P_2^2$

(or) $R^2 = \{(R-O_0) + O_x\}^2 + x^2$ [Where, $OP_2 = (R - O_0) + O_x$]

(or) $$R - O_0 + O_x = \sqrt{R^2 - X^2}$$

(or) $O_x = \sqrt{R^2 - X^2} - (R - O_0)$ (3)

The ordinates for the right half are similar to these obtained for the left half.

Example Two tangents AB and BC intersect at a point B at chainage 150.5 m. Calculate all the necessary data for setting out a circular curve of radius 100 m and deflection angle 30° by the method of offsets from the long chord.

Solution

tangent length = R tan $\frac{\phi}{2}$

= 100 x tan 15° = 26.79 m

Chainage of T_1 = 150.50 - 26.79 = 123.71 m

Curve length = $= \frac{\pi R \varphi^\circ}{2} = \frac{3.14 \times 100 \times 30^\circ}{180^\circ} = 52.36\text{m}$

Chainage of T_2 = 123.71+ 52.36 = 176.07 m

Length of long chord (L) = 2R sin $\phi/2$

= 2 x 100 x Sin 15° = 51.76 m

The long chord is divided into two equal halves.

Each half = 1/2 x 51.76 = 25.88 m

Mid-ordinate, $O_0 = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$

$= 100 - \sqrt{100^2 - 25.88^2} = 3.41\text{m}$

The ordinates are calculated at 5 m intervals starting from the centre towards T_1 for the left half.

$O_5 = \sqrt{R^2 - x^2} - (R - O_0)$

$\sqrt{(100^2 - 5^2)} - (100 - 3.41)$

= 99.87 - 96.59 = 3.28 m

$O_{10} = \sqrt{(100^2 - 10^2)} - 96.59$

= 99.50 - 96.59 = 2.91 m

$O_{15} = \sqrt{(100^2 - 15^2)} - 96.59$

= 98.87 - 96.59 = 2.28 m

$O_{20} = \sqrt{(100^2 - 20^2)} - 96.59$

= 97.98 - 96.59 = 1.39 m

$O_{25} = \sqrt{(100^2 - 25^2)} - 96.59$

= 96.82 - 96.59 = 0.23 m

$O_{25.88} = \sqrt{(100^2 - 25.88^{2)}} - 96.59 = 0(\text{checked})$

The ordinates for the right half are similar to those for the left half.

Exercise

Compute the offsets from long chord at 10m interval for a simple curve of radius 400m, length of long chord is 100 m.

Setting out curves by instrumental methods (angular)

Objectives: At the end of this lesson you shall be able to
- **determine the deflection angles of chords.**
- **narrate the procedure of setting out of simple curve by one theodolite and tape method.**

Angular methods: The following angular methods are commonly used for setting out curves.

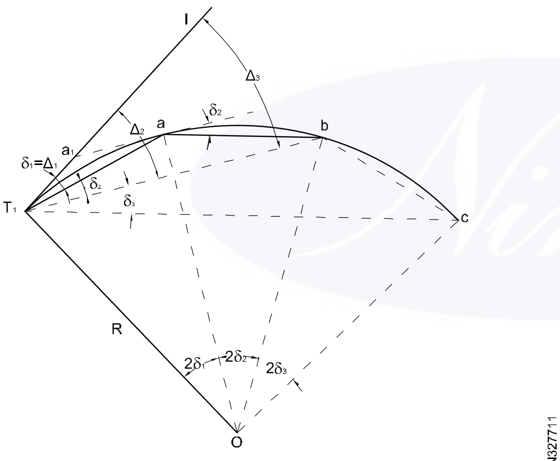
Rankine's method of deflection angle (one-theodolite method)

Two-theodolite method.

Tacheometric method.

Rankine's method of deflection angle (Fig 1): This method is useful for setting out a circular curve of long length and of large radius. It yields good results except when the chords are long as compared to the radius, so that the variation between the length of an arc and its chord becomes considerable. It is quite accurate and is frequently used on highways and railways.

Fig 1



RANKINE'S METHOD OF DEFLECTION ANGLE

A deflection angle to any point on the curve is the angle at P.C. between the tangent and the chord from P.C. to that point. According to Rankine's method, this deflection angle is equal to half the angle subtended by the arc at the centre.

In Fig T_1 is the P.C; a, b, c, etc. are the points on the curve; δ_1, δ_2, δ_3, etc. are the respective deflection angles between the chords and the respective tangents at T_1, a, b, etc.; Δ_1, Δ_2, Δ_3, etc. are the total deflection angles to the points a, b, c, etc.

From the property of a circle that the angle subtended by a chord at the centre is twice the angle between the tangent and the chord. Then,

$$\angle T_1 Oa = 2 \, x \, \angle \pi_1 a = 2\delta_1$$

Now R x $2\delta_1$= T_1a = C_1

$$\text{or } \delta_1 = \frac{C_1}{2R} \text{ radians}$$

$$\text{or } \delta_1 = \frac{C_1}{2R} \times \frac{180^\circ}{\pi} \text{ degrees}$$

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

$$\text{i.e.} \delta_1 = 1718.9 \frac{C_1}{R} \text{ minutes}$$

Similarly,

$$\delta_2 = 1718.9 \frac{C_2}{R} \text{ minutes}, \delta_3 = 1718.9 \frac{C_3}{R} \text{ minutes}$$

For the first chord T_1a, the deflection angle Δ_1 is its tangential angle δ_1. For the second point b on the curve, the deflection angle $\Delta_2 = \angle IT_1b$

Let the tangential angle for chord ab = δ_2, i.e. the angle between the tangent at a and chord ab.

The angle subtended by the chord ab at T_1 is $\angle aT_1b = \delta_2$, so that

$$\Delta_2 = \angle IT_1b = \angle IT_1a + \angle aT_1b$$

$$= \delta_1 + \delta_2 = \Delta_1 + \delta_2$$

Similarly, $\angle bT_1c = \delta_2$, so that

$$\text{Similarly}, \angle bTc = \delta_2,$$

$$\Delta_3 = \angle IT_1c = \angle IT_1b + \angle bT_1c$$

$$= \delta_1 + \delta_2 + \delta_3 = \Delta_2 + \delta_3$$

$$\text{and} \Delta_n = \delta_1 + \delta_2 + \ldots + \delta_n$$

$$= \Delta_n - 1 + \delta_n$$

Last point of the curve is T_2, so that

$$\Delta_n = \angle IT_1T_2 = \frac{\Delta}{2}$$

Check: sum of all the individual deflection angles is equal to half the deflection angle of the circular curve.

Field procedure:

Locate P.C. (T_1), P.T. (T_2) and P.I. (I).

Set up the theodolite exactly at T_1 and make its temporary adjustments.

Set the vernier A to zero and bisect the P.I. Clamp the lower plate.

Release the upper plate and set the vernier A to read Δ_1. The line of sight is thus directed along T_1a.

Hold the zero of the tape at T_1, take a distance C_1 (T_1a) and swing the tape with an arrow till it is bisected by the theodolite. This establishes the first point a on the curve.

set the second deflection angle Δ_2 on the scale so that the line of sight is set along T_1b.

With the zero of the tape held at a and an arrow at the other end (chord distance = ab), swing the tape about a, till the arrow is bisected by the theodolite at b. This establishes the second point b on the curve.

The same steps are repeated till the last point T_2 is reached.

Example Two tangents intersect at chainage 1,250 m. The angle or intersection is 150°. Calculate all data necessary for setting out a curve of radius 250 m by the deflection angle method. The peg intervals may be taken as 20 m. Prepare a setting out table when the least count of the vernier is 20″. Calculate the data for field checking.

Solution Given data:

Radius = 250 m

Deflection angle ϕ = 180°- 150° = 30°

Chainage of intersection point = 1,250 m

Peg interval = 20 m

LC of vernier = 20″

Tangent length = R tan $\phi/2$

= 250 x tan 15° = 67.0 m

$$\text{Curvelengh} = \frac{\pi R \text{ø}^\circ}{180^\circ} = \frac{\pi \times 250 \times 30^\circ}{180^\circ} = 130.89\text{m}$$

Chainage of first TP, T_1= 1,250.0 - 67.0 = 1,183.0 m

Chainage of second TP, T_2= 1,183.0 + 130.89 = 1313.89m

Length of initial sub-chord = 1,190.0 - 1,183.0 = 7.0 m

No. of full chords (20 m) = 6

Chainage covered = 1,190.0 + (6 x 20) = 1,310.00 m

Length of final sub-chord = 1,313.89 - 1,310.00 =3.89 m

Deflection angle for initial sub-chord,

$$\delta = \frac{1{,}718.9 \times 7.0}{250} \text{mins} = 0^\circ\ 48'\ 8''$$

Deflection angle for full chord,

$$\delta = \frac{1{,}718.9 \times 20}{250} \text{mins} = 2^\circ\ 17'\ 31''$$

Deflection angle for final sub-chord,

$$\delta_n = \frac{1{,}718.9 \times 3.89}{250} = 0^\circ 26' 45''$$

Arithmetical check:

Total deflection angle (Δ_n) = $\delta 1 + 6 \times \delta + \delta n$

$$\phi/2 = \frac{30^\circ}{2} = 15^\circ$$

Here,

Δ_n = 0°48′8″+ 6 x 2°17′31″+0°26′45″ = 14°59′59″

= 15° (approximately)

So, the calculated deflection angles are correct.

Data for field check:

(a) Apex distance = R (secϕ/2-1)

= 250 (sec 15°-1) = 8.82 m

(b) Versed sine of curve = R (1- cos ϕ/2)

= 250 (1-cos 15°) = 8.52 m

Setting out table

Point	Chainage	Chord length	Deflection angle for chord	Total deflection deflection angle (Δ)	Angle to be set	Remark
T1	1,183.0	-	-	-	-	Starting point of curve
P1	1,190.0	7.0	0°48' 8″	0°48' 8″	0°48' 0″	LC or vernier
P2	1,210.0	20.0	2°17' 31″	3°5' 39″	3°5 40″	= 20
P3	1,230.0	20.0	2°17' 31″	5°23'10″	5°23'0″	
P4	1,250.0	20.0	2°17' 31″	7°40'41″	7°40'40″	
P5	1,270.0	20.0	2°17' 31″	″9°58'12″	9°58'0″	
P6	1,290.0	20.0	2°17' 31″	12°15'43″	12°15'40″	
P7	1,310.0	20.0	2°17' 31″	14°33' 14″	14°33'20″	
T2	1,313.89	3.89	0°26' 45″	14°59' 59″	15°0'0″	Finishing point of curve

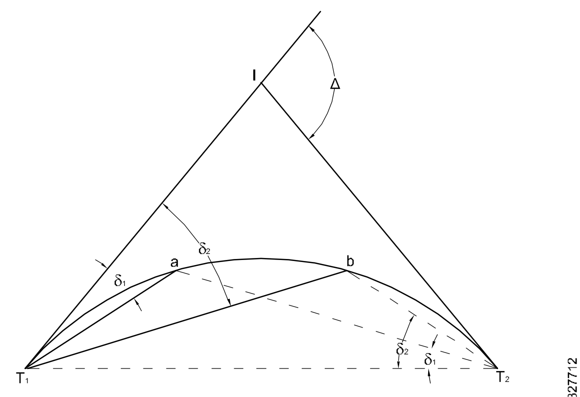
Exercise

Two straights AO and BO meet at chainage 3500 m, A right handed simple circular curve of 250 m radius join them. The deflection angle between the two straights is 50°. Compute and tabulate the necessary data required for layout the curve by rankine's method of deflection angle. Take the chord interval as 20 m.

Two theodolite method, this method is most convenient when the ground is undulating, rough and not suitable for linear measurements. In this method, two theodolites are used and linear measurements are completely eliminated. Hence, this is the most accurate method. It is a based on the principle that the angle between the tangent and the chord is equal to the angle subtended by the chord in the opposite segment.

Thus, in (Fig 2).

Fig 2



TWO-THEODOLITE METHOD

$$\ell IT_1a = \delta_1 \angle aT_2T_1 \text{ and} \angle IP_1b = \delta_2 = \angle bT_2T_1$$

Field procedure

Set up one theodolite at P.C. (T_1) and the other P.T. (T_2).

Set the vernier A of both the theodolites to zero.

Direct the theodolite at T_1 towards I, and the theodolite at T_2 towards T_1.

Set an angle δ_1 in both the theodolites so as to direct the line of sights towards T_1a and T_2a, thus the point a, the point of intersection of the two line of sights, is established on the curve.

Similarly, point b is established by setting δ_2 in both the theodolites and bisecting the ranging rod at b.

The same steps are repeated with different values of δ establish more points.

The method is expensive and time consuming, but most accurate. The various points are established independent of each other and thus the error in establishing a point is not transferred to the subsequent points.

Geometric of compound curves

Objectives: At the end of this lesson you shall be able to
- **define compound curve**
- **state the different part of curve**
- **explain the constructing curve.**

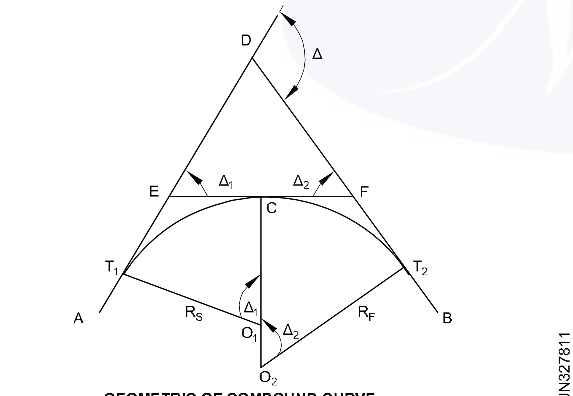
Introduction:

A compound curve consists of two or more arcs of circles of different radius. That deviate in the same direction and join at a common tangent point. These curves may be two centered, three cantered or so. According to the number of simple arcs these are composed of. To understanding the component parts of a compound curve a two centered compound curve is dealt with topic.

Two centered compound curve.

Two straight AD and BD when prolonged intersect at D. A two centered compound curve T_1 C T_2 is intersected between them. Two circular arcs T_1C, and C T_2 have O_1 and O_2 centres. T_1, T_2 are the points of the curve commencement the point of tangency of curve respectively (Fig 1)

Fig 1



GEOMETRIC OF COMPOUND CURVE

The essential components of a compound arc:

Δ = Total deflection angle

Δ_1 = deflection angle DEF

Δ_2 = deflection angle DFE

Rs = radius of small arc T_1 C

RL = radius of large arc T_2 C

Ts = total tangent length = T_1 D

TL = total tangent length (large) T_2 D

Angle = T_1 O_1 C = 180° - angle T_1EC

Angle = CO_2 T_2 = 180° - angle CFT_2

T_1E = CK = T_1 and CF = F T_2 = t_2

Applying sine rule to DEC we get

$$= \frac{ED}{\sin\Delta_2} = \frac{DF}{\sin\Delta_1} = \frac{EF}{(\sin 180° - \Delta)}$$

$$= EF = EF\frac{\sin\Delta_2}{\sin\Delta} = (t_1 + t_2)\frac{\sin\Delta_2}{\sin\Delta}$$

$$= DF = EF\frac{\sin\Delta i}{\sin\Delta} = (t1 + t2)\frac{\sin\Delta_1}{\sin\Delta}$$

Hence total tangent length Ts = T_1E + ED

$$= t_1 + (t_1 + t_2)\frac{\sin\Delta_2}{\sin\Delta}$$

Total tangent length = TL = T_2 F + DF

$$= t_2 + (t_1 + t_2)\frac{\sin\Delta_1}{\sin\Delta}$$

$$Ts = (R_s \tan\frac{\Delta_1}{2}) + \left[\frac{Rs\tan\Delta_1}{2} + R_L\frac{\tan\Delta_2}{2}\right]\frac{\sin\Delta_2}{\sin\Delta}$$

$$T_L = (R_L \tan\frac{\Delta_2}{2}) + \left[R_s\frac{\tan\Delta_1}{2} + R_L\frac{\tan\Delta_2}{2}\right]\frac{\sin\Delta_1}{\sin\Delta}$$

Checks on field work

To ascertain the accuracy of setting out the curve, the following two checks will use.

1 The point of tangency located from the point of common curvature should coincide with the location already fixed by measuring distance equal to the total tangent length from the point of intersection.

2 Angle

$$T_1 C\, T_2 = 180° - \left[\frac{\Delta_1}{2} + \frac{\Delta_2}{2}\right]$$

$$180 - \frac{\Delta_1 + \Delta_2}{2}$$

$$\therefore 180° \frac{-\Delta}{2}$$

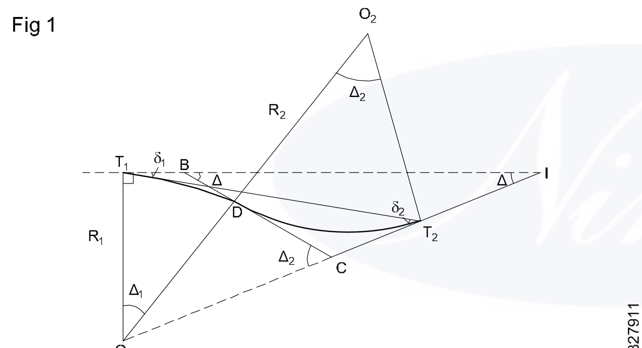
Reverse curve

Objectives: At the end of this lesson you shall be able to
- **define reverse curve**
- **describe need of providing reverse curve**
- **describe the elements of reverse curve**
- **state relationship between elements of reverse curve.**

Definition: A reverse curves consists of two circular arcs of same or different radii having their centres opposite sides of the common tangents at point of reverse curvature.

Need of providing reverse curve: reverse curves are generally provided when the straight line are either parallel or angle between them is too small. Road or Railway curves in mountainous regions are generally reverse curves. A loop of curve in a valley is followed immediately by another loop round. The shoulder of a ridge of opposite curvature. It occurs in road turn in different direction in successions or where road approach flyovers.

Fig 1



ELEMENTS OF A REVERSE CURVE

Elements of reverse curve: (FIg 1)

1 Radii R_1, R_2 are two circular arcs

2 Angles of total deflection (Δ) of the straights.

3 Angles of deflection (Δ_1, Δ_2) of common tangent

4 Angles (δ_1, δ_2) between the straights and the line joining the points of commencement and tangency

Here are some assumptions

1 $R_1 = R_2$

2 (Δ_1, Δ_2)

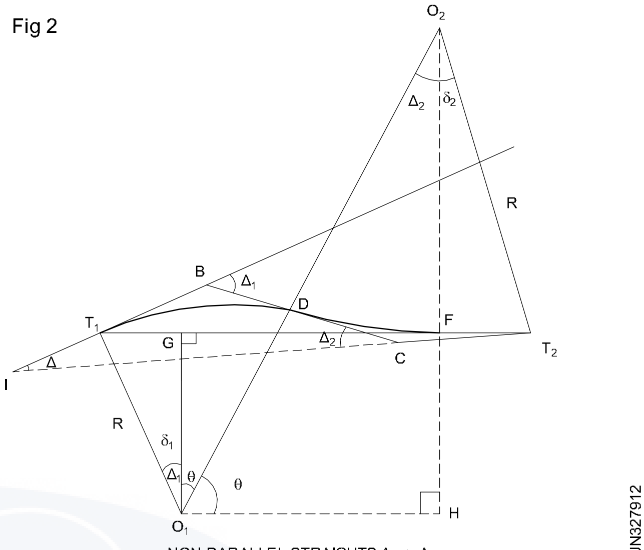
3 The length of tangent points are known.

Relationship between elements of a reverse curve

When the two straights are non-parallel and (Δ_1, Δ_2) **point of intersection:** This may obtained by producing the forward straight backward to intersect the back sight.

Given data: The length of the line jointing the tangent points T_1 and T_2. (Fig 2)

Fig 2



NON-PARALLEL STRAIGHTS $\Delta_1 > \Delta_2$

The angles δ1 and δ2 between the line T_1, T_2 and back straight. T, B and forward straight CT_2 respectively.

Required: To find, Common radius 'R'

Specified conditions: $R_1 = R_2 = R$

Say T_1 and T_2 be the two tangents points.

O1 and 02 are the centres of the circular arc and distance T_1 T_2 be equal to length 'L'

Construction: Draw O_1 g and O_2 F perpendicular to $T_{1,}$ T_2 and Q_1 H perpendicular to O_2 F

let the angle O_2, O_1 H b = ϕ

Now $T_1, T_2 = L = T_1$ G + G F + F T_2

Q, G = R Cos δ_1 = FH

O_2 F = R Cos δ_2

O_1 O_2 = 2R.

$$\sin\theta = \frac{0_2H}{0_1 0_2} = \frac{0_2F + FH}{0_1 0_2} = \frac{R\cos\delta_1 + R\cos\delta_2}{2R}$$

$$\theta = Sin^{-1} = \frac{Cos\delta_1 + Cos\delta_2}{2}$$

Again: F1G = R. Sin δ_1

G F = O_1H = 2R Cos θ

FT2 = R sin δ^2

Substitute values in

L = R Sin δ_1 + 2 R Cos $\theta + $R sin δ_2

$$R = \left(\frac{L}{\sin\delta_1 + 2\cos\text{ø} + \sin\delta_2}\right)$$

Central angle for the first arc $\Delta_1 = \delta_1 + (90\text{-}\theta)$

The central angle for second arc

$$\Delta_2 = \delta_2 + (90° - \theta)$$

Now the length of curve may be completed.

Transition curves

Objectives: At the end of this lesson you shall be able to
- **explain transition curve**
- **state super elevation**
- **state type of transition curve**
- **construction of transition curve.**

Definition: A non circular curve introduced between a straight and a circular curve (or) between two branches of a compound curve (or) reverse curve.

Types: 1

- Cubical spiral
- Cubic parabola
- The lemniscates curve

The transition curve introduced between the circular curve and the tangent shall satisfy the following conditions.

1 The transition curve tangential to straight
2 The transition curve meet curve tangentially
3 At the origin of on straight the curvature should be zero.
4 The curvature at the junction with the curve (circular) should be same as that of circular curve.
5 The rate of increase of curvature along the transition curve shall be the same as that of increase of cant or super elevation.
6 It length shall be such that full super elevation is attained of the junction with the circular curve.

Super-elevation (Fig 1)

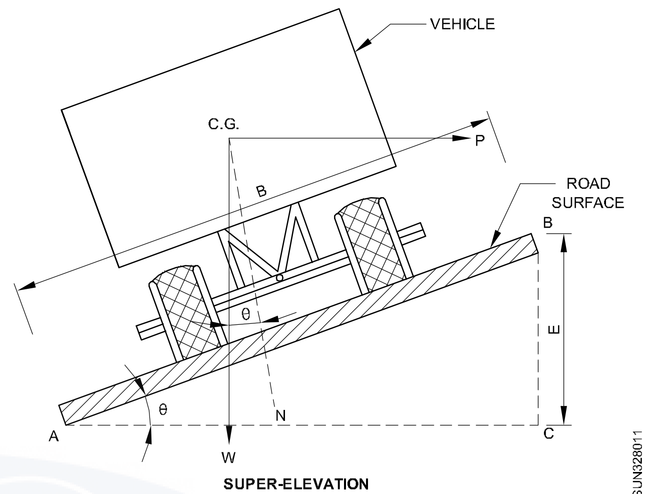
Super elevation: When a fast moving vehicles negotiates a horizontal curves the centrifugal force acts on the vehicle for inside towards the outside of the curve and hence the vehicles has a tendency to overturn and skid. In such situation the outer edge of the pavement is raised with respect to the inner edge.

Super elevation is the inward transverse slope provided throughout the length of horizontal curve by raising the outer edge of the pavement with respect to the inner edge. This is also called cant or banking and is generally denoted by 'e'.

It is provided to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn of skid, when it is moving on the horizontal curve.

The super elevation is expressed as the ratio of the height of outer edge with respect to the horizontal width of the pavement from Fig 1.

Fig 1



SUPER-ELEVATION

Super elevation $e = \frac{BC}{AC} = \tan\varphi$

In practice the value of **θ** is so small, then tan **θ** is equal to sin ø

Then e= tan ø= sin ø $= \frac{BC}{AB} = \frac{E}{B}$

Total super elevated height of outer edge for a pavement width 'B' is equal to 'eB'

E=eB

By analysis of super elevation, we get $e = \frac{V^2}{12TR}$

(Considering the co - efficient lateral friction as zero)

Where V = Speed of vehicle

R = Radius of curve

Types of transition curves

1 Cubical spiral: equation (Fig 2)

$$x = \frac{l^3}{6RL}$$

Where:

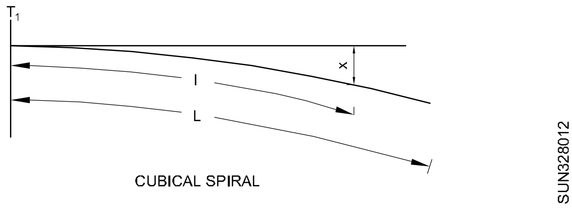
L: Total length of transition curve

R: Radius of circular curve

L: distance measured along curve

X= perpendicular offset form tangent

Fig 2



2 Cubic parabola equation (Fig 3)

$$x = 7^3 \big/ 6\,RL$$

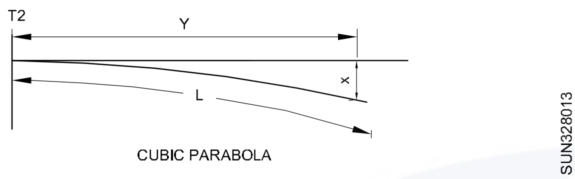
X = perpendicular offset from tangent

Y = Distance measured along the tangent

R = Radius of circular curve

L = Length of transition curve

Fig 3



3 Lemniscates curve equation (Fig 4)

$$r - \frac{P}{3\sin\propto}$$

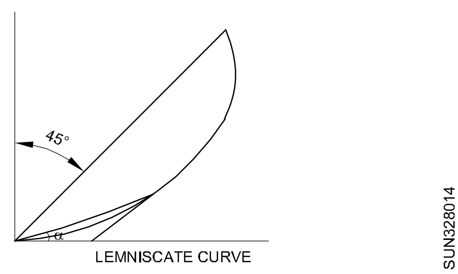
Where:

r = radium of curvature

p = polar ray of any point

$\propto$ = Polar deflection angle (angle between polar ray and straight)

Fig 4



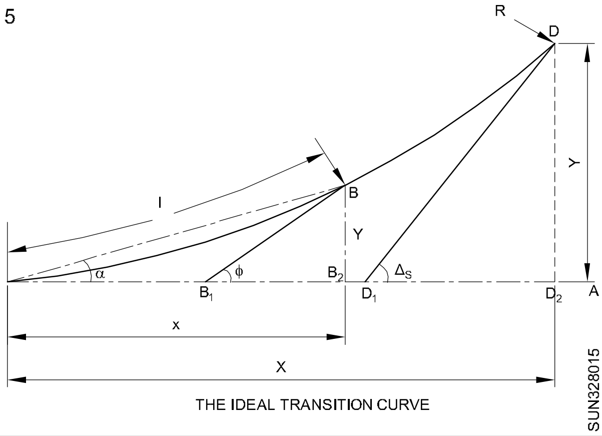
The ideal transition curve (Fig 5)

Centrifugal force action on a vehicle $p = \frac{Wv^2}{gr}$

r = radius of curvature at any point of curve if 'p' centrifugal force increased at a constant rate 'p' must differ with time.

T = Tangent point = beginning of trans curve.

Fig 5



TA= initial tangent

D = point of junction of the transition and circular curve.

B = Any point an curve at a distance of 'l' along the curve.

R = Radius of the curve at any point on B

ø = inclination of tangent to the curve at B to the initial tangent. TA.

Δ s Spiral angle.

l = Length of curve from T to B.

R = Radius of the circular curve

L = Total length of transition curve.

X = The 'x' co-ordinate of D.

Y = The 'y' co-ordinate of D.

x = TB2 = x co-ordinate of any point B on transition curve.

Y = BB2= y co-ordinate of any point B on transition curve.

$$\text{we know } l.r = L.R \therefore \frac{1}{r} = \frac{l}{RL}$$

$$\text{But } \frac{1}{r} = \text{curvature } \frac{d\text{ø}}{dl} = \frac{\ell}{RL}$$

$$\therefore d\,\text{ø} = \frac{\ell - dl}{RL}$$

$$\text{Integrating we get} = \text{ø} = \frac{l^2}{2RL} + C$$

$$\text{When } \ell = 0 \,\&\, \text{ø} = 0 \therefore C = 0$$

$\boxed{\therefore \varphi = l^2 \big/ 2\,RL}$ it is for intrinsic equation of the ideal

transition curve.

This equation also expressed in the form of

$$l = \sqrt{2\,RL\varphi} = k\sqrt{\varphi}$$

Where $K = \sqrt{2\,RL}$ Then

When $l = L, \varphi\, d = \Delta s = \frac{L^2}{2\,Rl} = \frac{L}{2R}$

Again if the speed of the vehicle is constant, the distance 'l' along the transition curve measured from the tangent point must vary with time.

$\therefore\ P \propto l = \frac{Wv^2}{gr}$ = But W,V,g are all constant.

$\therefore\ l = \frac{l}{r} =$ constant LR.

Total length of curve up to its end = L

R = Radius of the curve at its end (ie mini radius)

Also the super elevation from the equilibrium point of view given by $e = 1.18\frac{V^2}{r}$

Where : r = radius of curve

e = is to increase at constant rate it is proportional to 'l'

$$e \propto l \propto 1.18\frac{V^2}{r} \text{ or } l = \frac{1}{r}$$

Vertical curves

Objectives: At the end of this lesson you shall be able to
- **use of vertical curves**
- **types of vertical curves**
- **computation and setting out of vertical curve.**

Use of vertical curves: A vertical curves is used to join the intersecting surfaces/ grade lines of railway, roadways or other routes to smooth change of direction in vertical motion. Sudden /abrupt change of route/direction subject to a vehicle passing through over it to an impact that would be either injuries/dangerous.

The vertical curve thus contributes to safety. Comport vertical arc or parabola arc may be used.

The general Grade or gradient to railway or highway are 2% or 3% i.e in 50 or 1 in 30.

The rate of change of gradient given by equation for parabola curve with vertical axis

$Y = a x^2 + b x$

Slope of curve at any point $= \frac{dy}{dx} = 2ax + b$

Rate of change of slope = $r = \frac{d^2 y}{dx^2} = 2a$

For 1st class railways

The rate of change of gradient is 0.06% per 20m

Station at summit

Station at sag the gradient is 0.3% per 20m

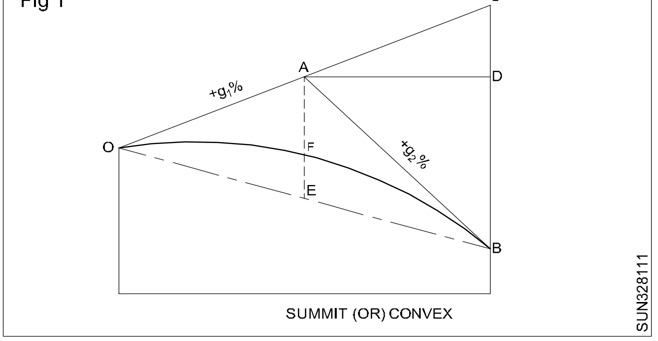
Beginning of curve in vertical summit 1%

Station	Distance from beginning (M)	gradient
0	0	1%
1	20	0.95%
2	40	0.90%
3	60	0.85%
4	80	0.80%
5	100	0.75%

Types of vertical curve – (6 Types)

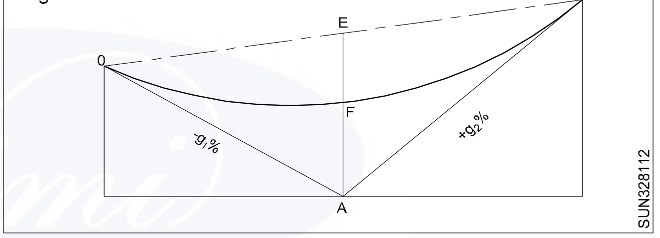
1 An upgrade (+ g 1%) followed by a down grade (- g_2 %) (Fig 1)

Fig 1



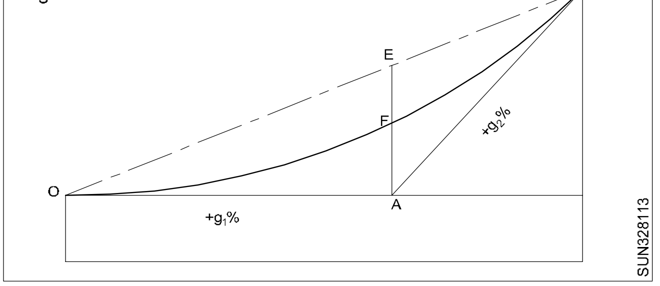
2 A down grade (-g %) followed by an upgrade grade (-g_1%) followed by an upgrade (+g_2%) (Fig 2)

Fig 2



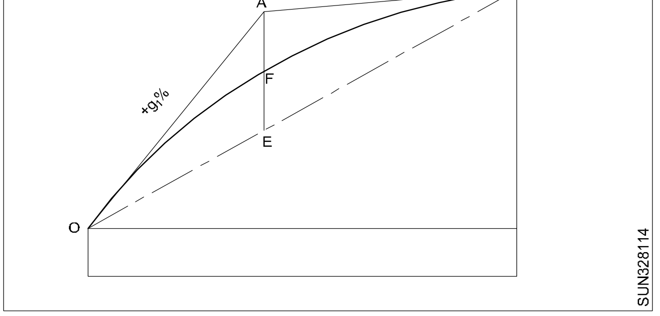
3 An upgrade (+g_1%) followed by another upgrade (+ g%) $g_2 > g_1$ (Fig 3)

Fig 3



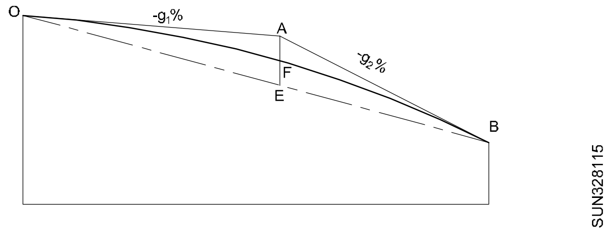
4 An upgrade (+g_1 %) followed by another grade (+g_2 %) ($g_1 > g_2$) (Fig 4)

Fig 4



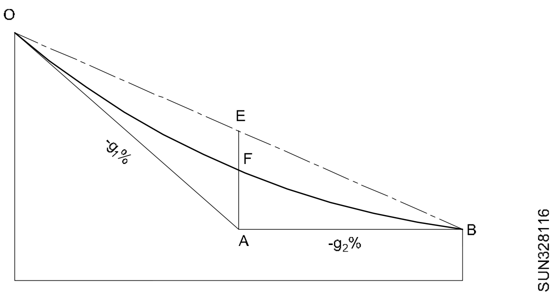
5 A down grade ($-g_1$%) followed by another downgrade ($-g_2$%) $g_2 > g_1$ (Fig 5)

Fig 5



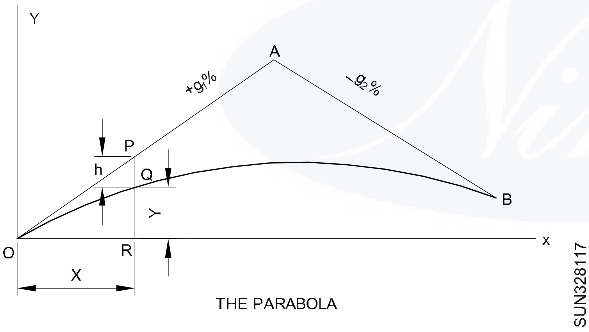
6 A down grade ($-g_1$%) followed by another down grade ($-g_2$%) ($g_1 > G_2$) (Fig 6)

Fig 6



Computation and setting out of vertical curve (Fig 7)

Fig 7



In vertical curves all distances along the curve are measured horizontally and all offsets from the tangents to the curve are measured vertically from the Fig 7

OY and Ox are ordinates begin from OY beginning curve in from 'O'

OA Tangent + g_1%

AB Tangent – g_2 % slope

Q. any point on curve having co-ordinates

Draw perpendicular Via Q to OX.

The equation of parabola = $Y = ax^2 + bx$

$$\therefore \frac{dy}{dx} = 2ox + b$$

$$\text{At } x = o \ \frac{dy}{dx} = +g_1$$

$$g_1 = 2a(0) + b/$$

$$\therefore b = g_1$$

Have equating of parabola $y = ax^2 + g_1$

Let PQ = h = Tangent correction

PQ = PR –QR = lent DR = g_1X

QR = Y

$\therefore$PQ = h = $g_1x - y$

but $g_1 x - y = -ax^2$ from Eqn

$\therefore h = g_1x - y = -ax^2$

$\therefore h = cx^2$

$\therefore h = kn^2$

'N' coincide from 'O' at the beginning of the curve. The difference in elevation between a vertical curve and a tangent it varies as the square of its horizontal distance from the point of tangency.

If the offsets are measured vertically downwards, through they should the measured parallel to the axis of the parabola for a true curve.

Due to the uneven values of g_1 and g_2 the axis is lightly tilted. Therefore by making offsets vertical (and not parallel to the tilted axis) the curve will be distorted from the parabolic form (negligible value for practical.)

The value of 'K' in Eqn ($h = KN^2$)

Can be found by the Fig 8.

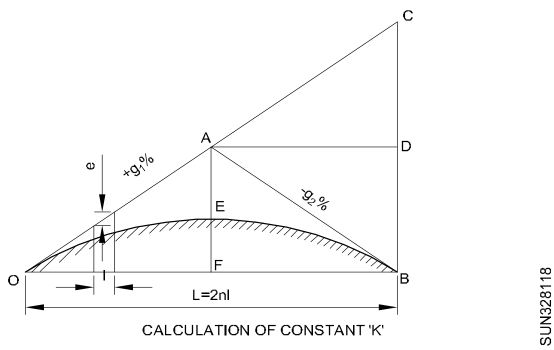
Produce 'OA' to 'C' a point vertically above 'B' through A draw AD. Horizontal to meet BC in D.

Let 2n = Total no of equal chords each length 'l' on each side of apex.

g_1, g_2 grade of the two tangents

e_1, e_2 corresponding rise or falls

Fig 8



Chord length 'L'

OA = AC

CD = ne_1

BD = $-ne_2$

CB = CD + DB = n (e_1-e_2)

From Eqn $h = kN^2$

Where N = 2n

$4K^2 = n (e_1-e_2)$

$$\therefore K = \frac{e_1 - e_2}{4n}$$

Introduction to total station

Objectives: At the end of this lesson you shall be able to
- **introduction to the total station**
- **purpose of total station**
- **explain the benefits and uses of total station.**

General

At present the analogue methods of recording data for conventional surveying is changed to digital data collection methods. Previously plane table is used as the best way to map a small area. But the output of a plane table is just a low precision analogue drawing in case of plane table the map is drawn directly on a sheet in a fixed scale, there was no way to plot the map to different scales and the quantity of topographic data collected was few. But these limitations can be overcome by the use of modern electronic total stations. With the use of total stations we can use fastest digital data collection methods.

Definition

Total station is an assembly of a short to medium range EDM instrument installed in the framework of an electronic theodolite with all components under the control of a built-in micro processor. This single instrument permits observing distances and directions from a single setup.

Important parts of total station (Fig 1,2)

- EDM with laser generator
- Endless drives
- Trigger keys
- Tribrach with foot screws
- Communication side cover
- Bluetooth
- Battery downloading port

Features of total station

1 The theodolite is offering a complete product family. It is easy for a user to switch between models without learning a new operation.

2 Absolute circle reading

3 Excellent hardware features, such as laser plummet, endless drives on both sides for Hz and V, brilliant optics with 30x magnification.

4 Dual-Axis compensation for reliable Hz and V reading

5 New and intuitive software

6 Unique levelling guidance for fast and convenient setup

7 High resolution LCD display

8 Audible notice for 900 turns and layout

9 Electronic laser distance measurement

10 Graphic sketches

11 Hassle-free EDM measurement with red laser on any target or on the flat-prism

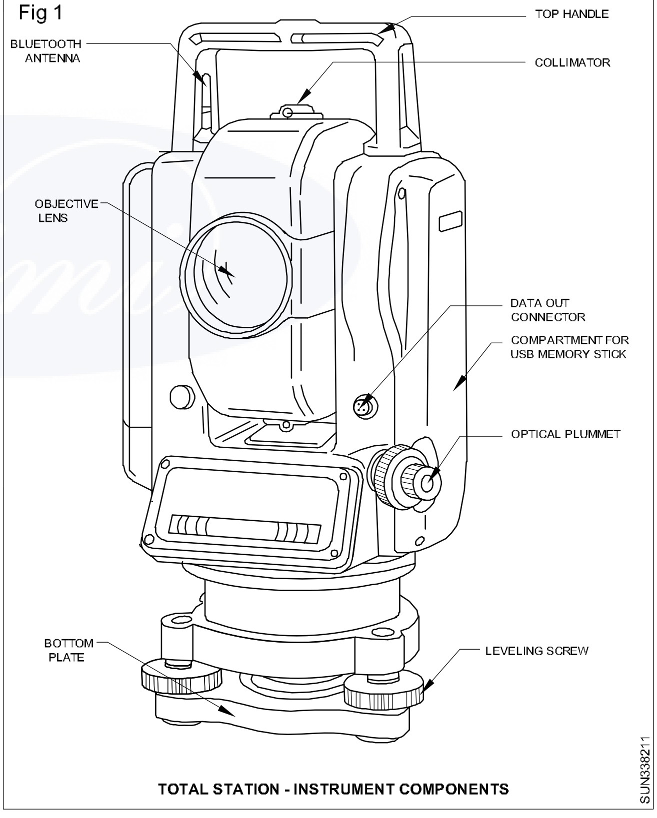
12 Enter the data at the office and simply call it up at the site

13 Upload and transfer data via on board data connection

14 Data editing and exchange in total stations

15 Connectivity to 3rd party devices

Fig 1



TOTAL STATION - INSTRUMENT COMPONENTS

Use of total station

The instrument is mounted on a tripod and is levelled by operating levelling screws.

Within a small range instrument is capable of adjusting itself to the level position. Then vertical and horizontal reference directions are indexed using onboard keys. It is possible to set required units for distance, temperature and pressure (FPS or SI).Surveyor can select measurement mode like fine, coarse, single or repeated. When target is sighted, horizontal and vertical angles as well as sloping distances are measured and by pressing appropriated keys they are recorded along with point number. Heights of instrument and targets can be keyed in after measuring them with tapes. Then processor computes various information about the point and displays on screen. This information is also stored in electronic note book. At the end of the day or whenever downloaded to computers, the point data downloaded to the computer can be used for further processing. There are software's like auto civil and auto plotter clubbed with AutoCAD which can be used for plotting contours at any specified interval and for plotting cross-section along any specified line.

Fig 2

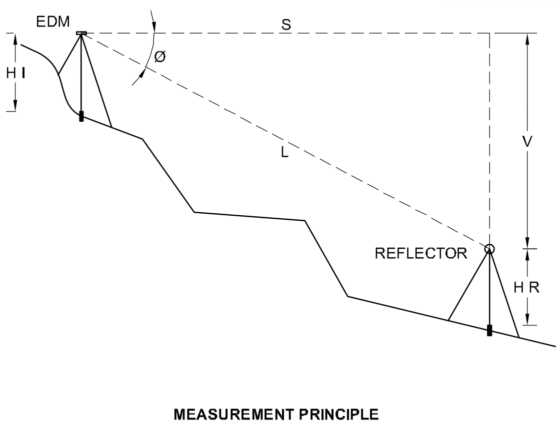
Accessories of total station

Total station definition

The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM), plus internal data storage and/or external data collector

EDM of total station

Fig 3

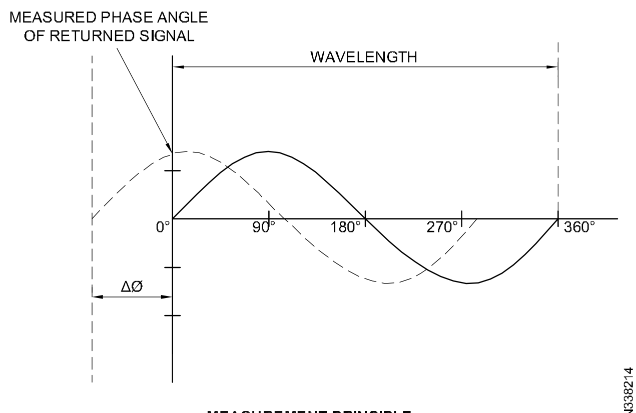


MEASUREMENT PRINCIPLE

Measurement of distance is accomplished with a modulated microwave or infrared carrier signal, generated by a small solid-state emitter within the instrument's optical path, and reflected by a prism reflector or the object under survey. The modulation pattern in the returning signal is read and interpreted by the onboard computer in the total station (Fig 3).

The distance is determined by emitting and receiving multiple frequencies, and determining the integer number of wavelengths to the target for each frequency. (Fig 4)

Fig 4



MEASUREMENT PRINCIPLE

Most total stations use purpose -built glass porro prism reflectors for the EDM signal, and can measure distances to a few kilometres. The typical total station can measure distances to about 3 millimetres or 1/1000 th of a foot.

EDMs measurement principle (Fig 3,4)

Angles and distances are measured from the total station to points under survey, and the coordinates (X,Y, and Z or northing, easting and elevation) of surveyed points relative to the total station position are calculated using trigonometry and triangulation.

Most modern total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar-codes etched on rotating glass cylinders or discs within the instrument. The best quality total stations are capable of measuring angles to 0.5 arc second. Inexpensive "construction grade" total stations can generally measure angles to 5 or 10 arc-seconds.

Total station- requires line of sight observations and must be set up over a known point or with line of sight to 2 or more points with known location.

Total station

Purpose satisfied by total station

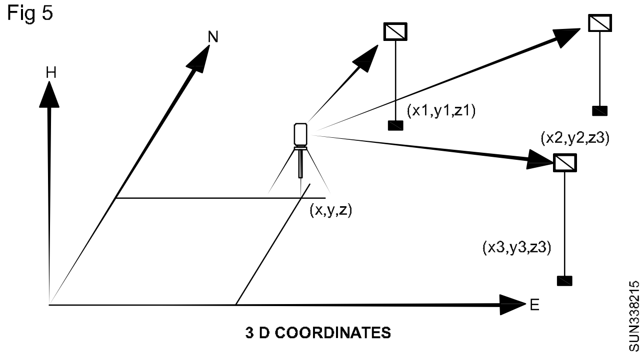
- Distance measurement
  - Electronic Distance Measurement
    - (EDM)
- Angle measurement
  - Absolute continuous Encoder
- Preparation of site plan
- Reduce level calculation
  - (Preparation of site plan and Reduce level calculation) → 3D coordinate system.

3D coordinates (Fig 5) :-

Refer the drawing.

- Where E & N gives the position and H gives the reduced level.
- Suppose we know, (x, y, z)
- We need an algorithm to calculate positions of (x1,y1,z1); (x2,y2,z2) & (x3,y3,z3) w.r.t to (x, y, z)

Fig 5



3 D COORDINATES

For this algorithm, we need the following inputs:

Inputs for the algorithm are:-

Coordinates at which the instrument stands.

- Height of the instrument.
- Orientation of the instrument (Hz = 0).
- Height of the reflector.
- Angle at which the prism is placed with respect to orientation.

  (or)

- 0°00'00".
- D°M'S"
- Hi.

Algorithm calculates (x1, y1, z1) etc.......

Computer interface (Fig 6) :

- Interfacing
- Data can be downloaded/uploaded from the total station to a computer and application software used to compute results and generate a map of the surveyed area.
- Each point has its own identifier.
- Identifiers can be manually altered according to user interest.
- On downloading and processing we get the output as below.

Field exercise for total station:

- Job creation
- Station set up
- Topo collection
- Change of station point
- Setting out
- COGO functions
- Downloading and post processing.

Total station initial setting (General setting required for all models) temporary adjustment.

The following are the steps for the initial setting of a total station:

1 Turn on the total station.

2 Release both horizontal and vertical locks.

3 Some total stations require rotating the telescope through 360° along the vertical and horizontal circles to initialize angles.

4 Adjust the telescope to best fit to the observer's eye. Using the inner ring of the eyepiece, make the image of the cross-hair sharp and clear.

5 Rotate the alidade until the HZ angle reading is equal to the azimuth to the back sight measured by the compass (for sokkia models only). Push the HOLD key once. The HZ angle will not change until the next hold.

6 Aim at the very centre of the prism at the back sight. For the coarse aiming, rotate the alidade and the telescope by hand using optical sight. Adjust focus using the outer ring of the eyepiece. When the prism comes into the sight and close to the center, lock the horizontal and vertical drives. Then use dials to aim at the exact centre of the prism.

7 For Sokkia models, push HOLD button again. The horizontal reading will now change according to the rotation of the telescope in the horizontal direction. For Leica models, input the azimuth of the back sight manually in the measurement setup window.

8 If a station ID and back sight ID are required, use a 2-digit or 3-digit serial number like 101, 102,....... for each reference point. Use a 4-digit number for unknown points.

9 Input station parameters like hi (height of the instrument). E0, N0, and H0 (easting, northing and RL of the instrument is setup). Use 1000, 1000 and 1000 for E0, N0 and H0 to avoid negative figures. If the Coordinates are known, manually input the date.

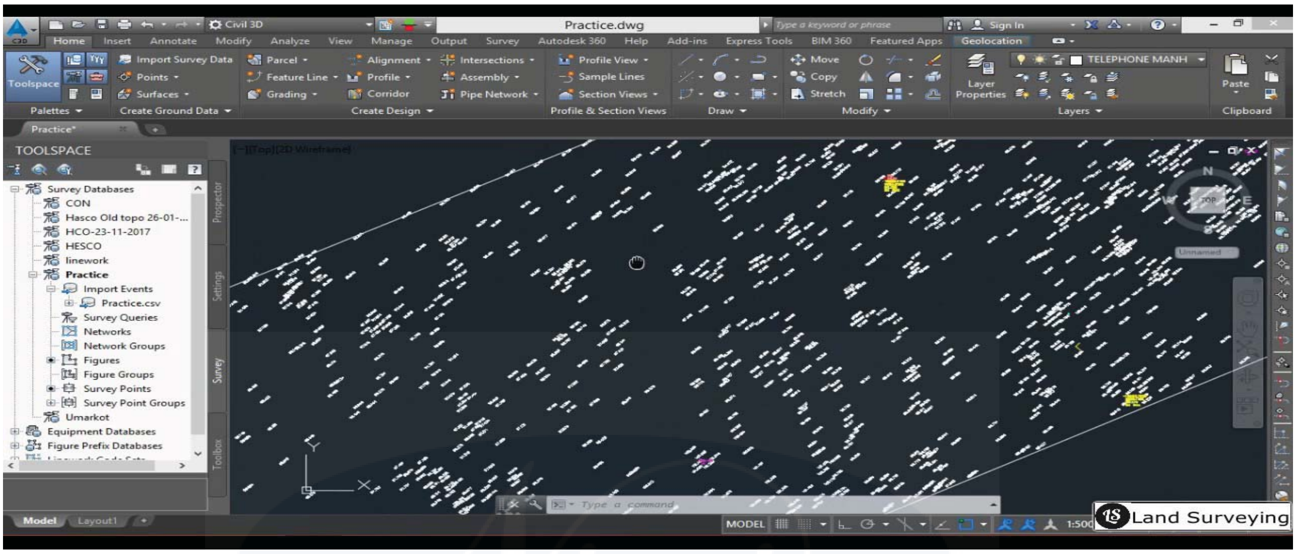
10 Input the target height (hr.)

11 Check the pointing at the prism again.

12 Using the distance calculation key, make the back sight measurement. From the LCD display of the total station, note the horizontal angle, the vertical angle slope distance, easting, northing and height, and record them in a field book with a sketch of the plan. Here the horizontal angle, vertical angle and the slope distance are the raw data.

13 Create a new job or open an existing job. A job is a block of data sets stored in the memory like a file. One can create new job or append data to an existing job, A job name is used as an output file name in a new Leica total station with gist extension.

Fig 6



Measurement with total station

Objectives: At the end of this lesson you shall be able to
- **explain the equipment required for total station surveying**
- **explain the procedure of measurement with total station.**

For using the modern electronic survey equipments, surveyors are need to be more maintenance conscious than they were in the past. They must have to thorough knowledge, about power sources, downloading data and the integrity of data.

For the survey of an area, the survey crew (two person crew, consisting of a party chief / ranging rod person and a note keeper / instrument person) need the following equipment inventory.

1 Total station set
   a Total station instrument in a hard case
   b Battery charger
   c Extra batteries
   d Memory module / card, serial cable
   e Rain cover
   f User manuals
   g Tripod
   h Measuring tape

2 Prism set
   a Prism
   b Prism holder
   c Cantering rod

3 Back sight set
   a Prism
   b Prism holder
   c Prism carrier (to be fixed to tribrach, with optical / laser plummet)
   d Tribrach (to exchange prism carrier and total station)

4 Data Processing
   a Laptop computer with serial port or USB port
   b Serial cable or USB-serial adaptor
   c Terminal application
   d Application programme: MS Excel, Adobe Illustrator, Co-ordinate Converter, etc.
   e Data backup device and media (Zip, memory card, etc.)

5 Survey tools
   a Stakes, nails, paint, marker
   b Hammer
   c Thermometer, barometer / altimeter
   d A pair of radio (with hands-free head set)
   e Clipboard, field note, pen
   f Compass

Setup

The following steps followed for the setup of a total station, at a station point.

1 Choose an adequate instrument station. Make sure that an observer can safely operate the instrument without knocking it over. It is necessary to have the center of the instrument, which is the point of intersection of the transverse axis and the vertical axis of the instrument, directly over a given point on the ground (the instrument station).

2 Remove the plastic cap from the tripod, and leave the instrument in the case until the tripod is nearly level. Stretch the tripod legs 10 - 15 cm shorter than their maximum length.

3 Open the legs of the tripod to set the tripod head at the level of the operator's upper chest. When the total station is set up on the head, the operator's eye should be slightly above the eyepiece. The instrument height is important for an effective and comfortable survey. It differs in the looking-down position and the looking up position. One should not touch or cling to the tripod during the survey.

4 At a new station without a reference point on the ground, level up the total station at an arbitrary point, where a stake can easily go in and be steady, and put down the stake at the center using the plummet.

5 To occupy an existing station above a reference point, first roughly level up the tripod head right above the point. For levelling up, a small level is useful to find out the position, use a plumb bob or drop a stone through the hole in the tripod head.

6 Once roughly levelled and centered, push each tip of the tripod leg firmly into the ground, applying full weight of the observer on the step above the tip. Apply the weight along the tripod leg without bending it.

7 Check the level and center it again. Adjust the level by changing the leg length.

8 Fix a tribrach with a plummet, a tribrach and a prism carrier with a plummet or a total station with a built-in plummet on the tripod head.

9 Adjust the three screws of the tribrach to center the bubble of a spirit level with the following steps:
   a Release the lock of the horizontal circle. Rotate the instrument to the plate level parallel to AB at the 1st position. (Fig 1)

b Turn the foot screws A and B in the opposite direction, the same amount to center the plate level. This will adjust the tilt on the aa[1] axis.

c Rotate the instrument 90º to set the plate level at the 2nd position.

d Turn the foot screw C to the centre plate level, adjusting the tilt along cc'.

e Rotate the instrument 90º to set the plate level in the 3rd position.

f Turn the foot screws A and B in the opposite direction, the same amount to eliminate half the centering error.

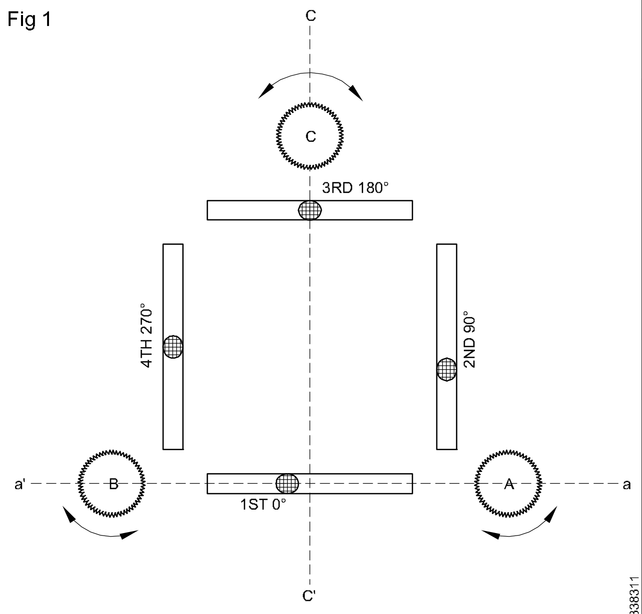
g rotate the instrument 90º to set the plate level at the 4th position.

h Turn the foot screw C to eliminate half the centering error.

i Repeat b to h until the plate level is centered in all directions (give a little time for slow movement of the bubble in viscous fluid).

10 Pull out the optical plummet and use the optic ring to focus at the graticule and then focus at the mark on the ground. Turn on the laser plummet. Rotate the plummet or the total station to check it is centered within 1 cm from the reference point. If not, estimate the amount of offset and carefully translate the entire tripod as much as offset. Return to 4 and try to level and center, therefore, rough centering within 1 cm is necessary. Be careful to see that the center of the optical plummet or the laser point is on an axis perpendicular to the horizontal circle of the total station. If the total station is not level, the plummet line does not coincide with the plumb line.

Fig 1



FINE LEVELLING PROCEDURE

11 Put the total station on the tribrach if it is not there.

12 Use the plate level for the final levelling of the total station. Follow the instructions given in Fig.1

13 When the total station is finely levelled up, use the plummet to check centering. If the plummet center is off the reference point, slightly loosen the fixing screw below the tripod head and translate the tribrach to place the plummet center on the exact point. Do not rotate. When the translation is done, tighten the fixing screw moderately. If any portion of the base of the tribrach goes outside the tripod head, return to 4.

14 Rotate the total station by 180º. If the plummet center goes away from the point, slightly loosen the fixing screw and slide the total station halfway to the center.

15 Repeat the steps 12 and 13 until the plummet center stays exactly on the center of the mark.

16 Tighten the fixing screw firmly without applying too much pressure. Never loosen the screw until all the measurements are finished.

17 Measure the instrument height. The centre of the total station is marked on the side of the alidade. The vertical distance between the mark and the ground is the instrument height.

18 Check the plate level from time to time during the measurement before the total station tilts beyond the automatic correction.

Setting up a back sight

A back sight is a reference point for the horizontal angle. At the beginning of a new survey, a back sight can be set at an arbitrary point and marked. The best way to set up a back sight is to use a prism carrier and tribrach on a tripod. the procedure for levelling up and centering of the prism is the same as that for the total station. If there is not plummet in the tribrach and the prism carrier, use the plummet of the total station and then exchange the total station above the tribrach with a prism carrier. A prism should be put right on the reference point when sighting is possible from the total station.

Measure the target height at the back sight. This height is the vertical distance between the center of the target (prism) and the ground beneath. When the station and back sight are ready, measure the azimuth from the station to the back sight using a compass. The azimuth is between 0º and 360º measured clockwise from north. Correct the magnetic declination to get the true azimuth and record the true azimuth. If the geographic coordinate or grid coordinates of the point occupied by the total station and the target at the back sight is known, then the total station will automatically calculate the true azimuth, provided the station values are fed into the total station manually.

Measurement with total station

When both the total station and back sight are finely levelled and centered, the hardware setup is over and the software setup is to be started. The software setup of a total station differs from one make to another. One has to follow the user's manual of each instrument. The list below gives common important settings for most instruments. Most total stations memorize these settings, but it is better to check through the setup menu in order to avoid a false setting.

System: Choose appropriate existing interface for data output.

Angle measurements: Tilt correction / tilt compensator (2 axis)

Horizontal angle increments: At right angles (Clockwise).

Unit setting: Angle in degrees / min. / sec., distance in meters, temperature in ºC and pressure in hPa.

EDM settings: Select IR laser, fine measuring mode, use RL with caution. Set appropriate value for the prism constant (from the user's manual of the equipment).

Atmospheric parameters: Get ppm for the diagram from the manual of the equipment or let the total station calculate from hPa and degree centigrade.

Communications: Set all parameters the same for a total station and data logger / PC. They array baud rate, database, parity, end mark and stop bits. Refer the manual for each device.

Open and closed traverse

Objective: At the end of this lesson you shall be able to
- **explain open and closed traverse in surveying.**

Open and closed traverses in surveying

Background: A traverse is a form of control survey used in wide variety of engineering and property surveys. Essentially, traverses are a series of established stations tied together by angle and distance. Angles are measured by theodolites or total station, the distance can be measured by electronic distance measurement (EDM) instruments, sometimes by steel tapes. Traverses can be open, as in route surveys, or closed, as in closed geometric figures (Fig 1, 2).

Fig 1

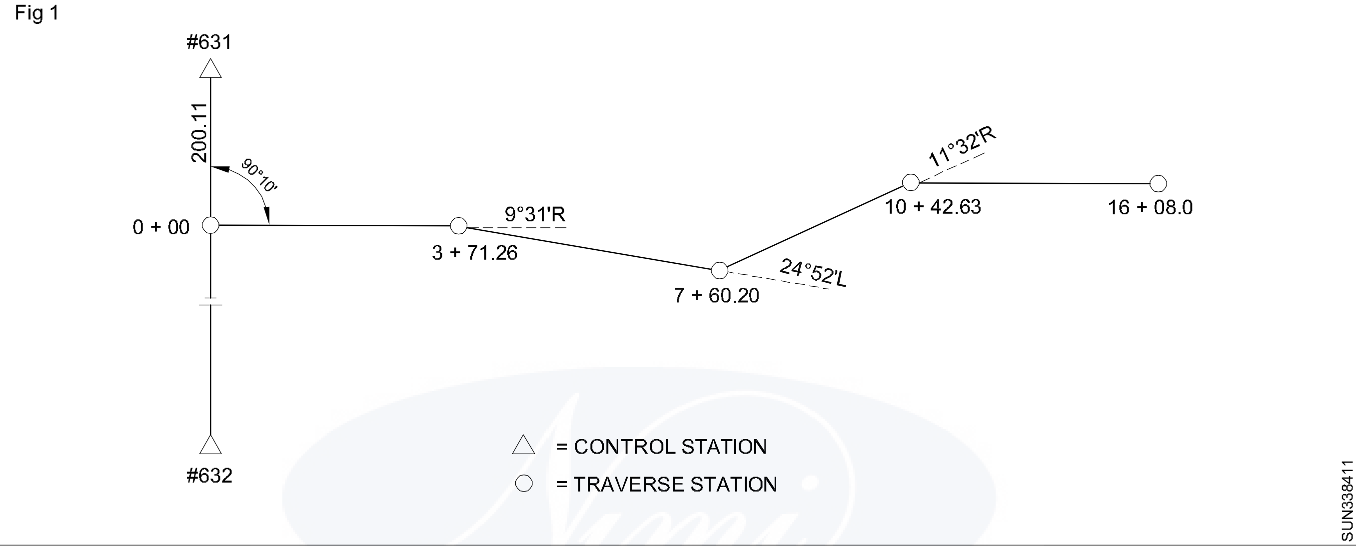


Figure 1: Open traverse

Traverse computations are used to do the following: Balance field angles, compute latitudes and departures, compute traverse error, distribute the errors by balancing the latitudes and departures, adjust original distances and directions. compute coordinates of the traverse stations, and compute the area enclosed by a closed traverse. In modem practice, these computations are routinely performed on computers and/or on some total stations or their electronic field books/data collectors. In this article. We will perform traverse computations manually (using calculators) to demonstrate and reinforce the mathematical concepts underlying each stage of these computations.

Figure 2: Closed traverse or loop traverse

In engineering work, traverses are used as control surveys.

1 To locate topographic detail for the preparation of topographic plans and engineering design plan and profiles.

2 to lay out (locate) engineering works, and

3 for the processing and ordering of earthwork and other engineering quantities. Traverses can also help provide horizontal control for aerial surveys in the preparation of photogrammetric mapping.

Open traverse

An open traverse (Figure 1) is particularly useful as a control for preliminary and construction surveys for highways, roads, pipelines, electricity transmission lines, and the like These surveys may be from a few hundred feet (metres) to many miles (kilo meter) in length. The distances are normally measured by using EDM (sometimes steel tapes). Each time the survey line changes direction, a deflection angles are measured from the prolongation of the back line to the forward line (Fig 1) the angles are measured either to right or to the left (LorR) and the direction (L or R) is shown in the field notes, along with the numerical values.

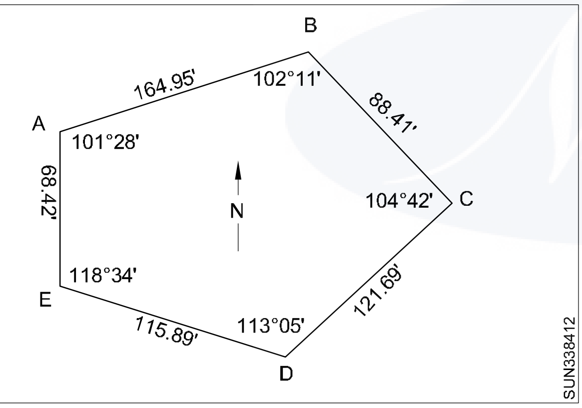
Field notes for open traverse

Angles are measured at least twice to eliminate mistake and to improve accuracy. The distance are shown in the form of stations (chainages), which are cumulative measurements referenced to the initial point of the survey, 0 + 00, Open traverses may extend for long distances without the opportunity for checking the accuracy of the ongoing work. Thus all survey measurements are repeated carefully at the time of the work and every opportunity for checking for position and direction is utilized (adjacent property surveys and intersecting road and railroad rights of-way are checked when practical.)Global positioning system (GPS) surveying techniques are also used to determined and verify traverse station positing. Many states and provinces have provided densely placed control monuments as an extension to their coordinate grid systems. It is now possible to tie in the initial and terminal survey stations of a route survey to Coordinate control monuments. Because the y and X (and Z) Coordinates of these monuments have been precisely determined, the route surveys changes from an open traverse to a closed traverse and is then subjects to geometric verification and analysis. Of course it is now also possible, using appropriate satellite-positioning techniques, to directly determine the easting, northing, and elevation of all survey stations.

Closed traverse

A closed traverse is one that either beggins and ends at the same point or beging and ends at points whose position have been previously determined (as described above). In both cases, the angles can be closed geometrically, and the position closure can be determined mathematically. A closed traverse that begins and ends at the same point is called a loop traverse (Fig 2.) In this case, the distances are measured from one station to the next and verified, using a steel tape or EDM instrument. The interior angle is measured at each station, and each angle is measured at least twice.

Fig 2



In this survey, distances are booked simply as dimensions, not as stations or chainages.

The difference between closed and open traverse comment on the advisability of using open traverses.

The difference between the two is that a closed traverse starts and ends on the points with known location and open traverse starts with a known point, but ends on a point with unknown location. An open traverse is usually not used since the error in location measurements cannot be computed. However, if an open traverse is used, measurements should be taken repeatedly

What is the sum of the interior angles of a closed polygon traverse that has a) 6 sides, b) 8 sides and c) 12 sides? Answer;

Sum of interior angles = (n-2) 180°

a) (6-2) 180=720°

b) (8-2) 180=1080°

c) (12-2) 180=1800°

The interior angles in five sided closed polygon traverse were measured and found to be;

A = 139°10’11"

B = 126° 17’43",

C = 94°28’30",

D = 71°04’59" and E = 108°58’31".

Compute the angular disclosure For what order and class is this survey ?

Types of total station

Objectives: At the end of this lesson you shall be able to
- **explain the advantages and disadvantages of total station**
- **explain the types of total stations**
- **explain the precautions to be taken while using total station.**

Advantages of total station

The advantages of total station include:

1 Quick setting of the instrument on the tripod using laser plummet.

2 On-board area computation programme to compute the area of the field.

3 Greater accuracy in area computation because of the possibility of taking arcs in area computation.

4 Graphical view of plots and land for quick visualization.

5 Coding to do automated mapping. As soon as the field jobs are finished, the map of the area with dimensions is ready after data transfer.

6 Enormous plotting and area computation at any user.

7 Integration of database (exporting map to GIs packages)

8 Automation of old maps.

9 Full GIS creation (using map in to software)

10 Local language support

Disadvantage of total station

1 Their use does not provide hard copies of field notes. Hence it may be difficult for the surveyor to look over and check the work while surveying.

2 For an overall check of the survey, it will be necessary to return to the office and prepare the drawings using appropriate software.

3 They should not be used for observations of the sun, unless special filters, such as the Troelof's prism, are used. If not, the EDM part of the instrument will be damaged.

4 The instrument is costly, and for conducting surveys using total station, skilled personnel are required.

Types of total stations

In the early days, three classes of total stations were available: (i) Manual, (ii) Semi-automatic, (ii) Automatic.

1 Manual total stations: It was necessary to read the horizontal and vertical angles manually in this type of instrument. The only value that could be read electronically was the slope distances.

2 Semi-automatic total stations: The user had to manually read the horizontal circle for these instruments, but the vertical circle readings were shown digitally. Slope distances were measured electronically and the instruments could, in most cases be used to reduce the values to horizontal and vertical components.

2 Automatic total stations: This type is most common total station used now-a-days. They sense both the horizontal and vertical angles electronically and measure the slope distances, compute the horizontal and vertical components of those distances, and determine the coordinates of observed points. to compute the coordinates of observed points, it is necessary to properly orient the instrument of some known directions such as true north, magnetic north or to some known bearing. The coordinate information obtained can either be stored in the total station's memory or by using an external data collector.

Manual total stations and semi-automatic total stations are obsolete now. At present, it is the age of fully automatic total stations and robotic total stations.

Almost all total stations in the market use infrared as the carrier for distance measurement. The less expensive unit with a single prism reflector can measure distances up to 1000 m. Those in higher price range are capable of measuring distances up to 2000 m, when single prism is used. the accuracies of measurements with the less expensive instruments probably run about 6 (5 mm/ 5ppm) and the expensive total stations can run about 6 (1 mm / 1 ppm).

Precautions to be taken while using a total station

The following precautions need to be taken while using a total station:

1 Always carry a total station in a locked hard case even for a very short distance. Take the total station out of the hard case only for fixing it firmly on a tripod for taking observations.

2 Do not move or carry a tripod with the total station fixed on it. except for centering.

3 Use both bands to hold the total station handle.

4 Never release the handle before the total station is fixed with the tripod's fixing screw.

5 Set up the tripod as stable as possible.

6 Always keep the top of the tripod, the bottom and top of the tribrach and the bottom of the total station clean and away from any shock and impact.

7 Take maximum care when the tribrach is removed from the total station.

8 Do not make the total station wet.

Preliminary knowledge for prepare a site plan

Objective: At the end of this lesson you shall be able to
- **describe the preparation of a site plan.**

Site plan:

The site plan drawn to a scale of not less than 1:400 provided that circumstances are such as to make a smaller scale of necessary, the site plan may be with the consultant of authority to a scale of 1:800 site plan shall be fully dimensional and shall show.

- The boundaries of the plot and of any continuous and belonging to the owner there of including revenue survey particulars in full.
- The position of site plan in relation to the neighbouring streets and its main access.
- The name of such streets it any.
- All existing structure standing on. Over or under the plot.
- All existing streets of footpaths with in the plot
- The layout of street or footpaths with in adjoining or terminating at the site existing or proposed to widened or newly aligned.
- The proposed plot. Sub division it any, and the area and uses of each sub. division there of.
- The access to the each plot sub-division. If any
- The layout of any service road, or foot path and public parking space proposed or exiting if any
- The area and location of any land within the plot that is not proposed to developed or redeveloped.
- The area and location of any land that is proposed to reclaimed.
- North direction is relation to the site.

Digital planimeter

Objectives: At the end of this lesson you shall be able to
- **name the two measuring instrument**
- **explain two types of planimeter.**

Introduction:

The measurement is very important when it comes to engineering applications.

The device that is used to measure an unknown quantity with the known standard quantity is know as the measuring instruments.

The measuring instruments are basically classified in to two types.

1 Analogue

2 Digital

1 Analogue: The analogue instruments use the pointer and scale system in order to measure the physical quantity

2 Digital: The digital instruments are those that provide exact numeric values of the measured quantity.

This instrument is used to measure the area of maps of any scale.

It is very effective in measuring the area of the irregular images.

This instruments is mostly used by surveyors. in surveying application, as it helps in measuring the area in the most precise manner.

Basically there are two types of the planimeter:

1 Mechanical

2 Digital

Mechanical Planimeter

- It consists of two arms.
- One arm is free and it can easily be moved from one point to another.
- This arm is moved at the irregular boundary.
- Another arm is fixed and is connected to the weight that prevents its free movement.
- The movement of the arms helps in measuring the area of the contour.

Digital Planimeter

- Digital instruments to attain the highest degree of accuracy.
- It helps in providing the most accurate results.
- These work on the computer algorithm that helps in calculating area of the two dimensional figures.
- These devices contain microprocessor chips, display screen and other components.
- The working principle of the algorithm used in the digital planimeter. it is based on the green theorem.
- This theorem helps in calculating area
- The basic fundamental involved in this is the integral calculus.
- The whole figures is sub-divided in to different segment.
- The area of these segments is calculated and then added up in order to measure the whole area of the figure.

Principles of road alignment and classification of roads

Objectives: At the end of this lesson you shall be able to
- **state principles of road alignment**
- **describe the classification roads.**

Introduction

Road alignment is the position occupied by the centre line of the road in plan. The centre line of the road is marked before the commencement of its actual, construction. The cost of construction, maintenance, safety and ease in travel depends up on its alignment. Therefore a road alignment should be selected carefully.

The basic principles of road alignments are as follows.

Principles of road alignment

Road alignment is the position occupied by the centre line of a road in plan. The centre line of the road is marked before its actual construction. The cost of construction, maintenance, safety and ease in travel depends upon its alignment. Therefore a road alignment should be selected carefully.

The basic objects of road alignment are as given below:

The align of the road should be as short as possible to provide economy in the cost of construction.

The alignment should be as straight as possible which ensure higher speed to the traffic and lower cost of construction.

The alignment should be easy for construction, maintenance and traffic operations.

The alignment should cross the railway lines and other roads and bridges at right angles.

It should cross the rivers, canals or streams etc. at place where its width is minimum.

The alignment serves maximum population by connecting intermediate important towns and group of villages.

The alignment should pass through regions of natural beauty and scenery.

The alignment should be such that it crosses the minimum number of bridges, crossings, culverts and embankment places.

It should provide smooth curves and easy gradients.

It should be such that minimum earthwork in embankment or cutting is done.

The alignment should provide good sight distance.

It should be free from obstructions like ponds, lakes. Wells, monumental buildings and historical buildings etc.

The alignment should run through such places where materials of road construction and labour are easily available.

As far as possible it should run on good soil having good bearing capacity to bear the loads of traffic safety without any damage to the road.

The alignment should not run through much costly and cultivated land. It should also avoid forests.

The alignment should not have uneasy zig-zags in the way which reduces the speed of the traffic and increases accident possibility.

The alignment should not have lengthy straight routes to avoid monotony. Hence after certain length of straight routes (say 5 km) of a road, a slight bend should be provided to break the monotony and to keep the drivers alert.

Classification of roads:

The roads are classified as under:

- According to location.
- According to importance.
- According to traffic.
- According to tonnage.

Classification of roads according to location:

The classification of roads was done as per recommendations made in the Nagpur plan finalized by the Indian road congress in 1943. So this classification is called as I.R.C. classification of roads. According to this, the roads are broadly classified into the following four main types:

- National highway (NH).
- Provincial or state Highways (SH)
- District roads:
  - Major district roads (MDR).
  - Other district roads (ODR).
  - Village roads (VR).

National highways

All the main highway running through length and breadth of the country, connecting major ports, capitals of states, foreign highways etc. are known as national highways. These roads constitute the main arteries of the transport in the country and are also of military importance. These roads should be selected in such a manner that they afford uninterrupted road communication through the country. These national highways should have carriageway of at least two lane width i.e., of 8 m width. These should have modern type of surfacing. The responsibility of construction and maintenance of these highways lies with the central government.

State highways

It is the highway which connects important cities and towns in a state or important cities and district head quarters with national highways. These roads serve as the main arteries of traffic to and from district roads within the state. The state highway should also have two lane width with 2.0 m wide shoulders on each side. The responsibility of construction and its maintenance rests with the state government. However, the central government gives grant for the development of these roads.

District roads

The district roads traverse each district serving areas of production and markets, industries, residential areas, railway stations and airports etc. and connecting these places with each other. These roads take road traffic into the heart of rural areas without any interruption. The responsibility of construction and maintenance of these roads lies with the district authorities. However, the state government gives grant for the development of these roads. In the Nagpur plan it was decided that every village in highly populated area should be within about 3 km of such areas and about 8km or so in the other areas.

The district roads are further divided into two types:

- Major district roads.
- Other district roads.

Major district roads

These are the roads which connect important towns or areas of production, and markets with either a national highway, state highway or railway station. The specifications of the major district roads are same as of state or provincial highways. They should have at least single lane metalled carriageway.

Other district roads

These roads run within a particular town connecting a town and village or a town with major district road or state highway. These roads are of the specifications lower than major district roads. Many of these roads remain closed due to the traffic during monsoon. These should have single lane width of at least stabilized soil, gravel or water bound-macadam surface. District authorities look after these roads.

Village roads

Roads connecting the villages or group of villages with each other or with the nearest district road is called a village road. These also sometimes connect towns or railway stations etc. These are generally unmetalled with stabilised soil or gravel. These roads allow the transport to carry the rural products to the market. The local district board authorities are responsible for the construction and maintenance of these roads.

Classification of roads according to importance:

According to this classification, roads are classified as under:

- Class I roads
- Class II roads
- Class III roads

Classification of roads according to traffic

According to intensity of traffic, the roads are classified as under:

Very heavy traffic roads: Which carry above 600 vehicles a day.

Heavy traffic roads: Which carry 251 to 600 vehicles a day.

Medium traffic roads: Which carry 70 to 250 vehicles a day.

Light traffic roads: Which carry below 70 vehicles a day.

Classification of roads according to tonnage

According to this category, the roads are classified as under:

Very high traffic roads: Which carry over 1524 metric tonne per day.

Heavy traffic roads: Which carry 1017 to 1524 M.T. per day.

Medium traffic roads: Which carry 508 to 1016 M.T. per day.

Light traffic roads: Which carry below 508 M.T. per day.

These standards have been fixed by the British road engineers.

Reconnaissance survey in Road project

Objectives: At the end of this lesson you shall be able to
- **describe the necessity of road projects**
- **explain various types of surveys involved in road projects.**

Introduction

Before constructing a new road due to public demand or some strategic reason, a primary investigation is carried out to examine whether this road is necessary.

The following points are to be kept in mind at the time of such investigation.

Total population benefitted by the project.

Number of villages, towns, industrial places etc to be connected.

Prospect of tourism, if any

Strategic importance for the defence of the country.

Any other information related to the project should be noted.

Types of surveys for the location of a road

Before finalising the alignment of a road, the engineering surveys must be carried out in four following stages.

1 Map study

2 Reconnaissance survey

3 Preliminary survey

4 Final survey

1 Map study

In this map study if the topographic map of the area is available, the selected routes of the road may be marked on it. The alignment can be located on the map from the following available details.

- Avoidable points, such as ponds, valleys, lakes etc.
- Possibly of crossing through a mountain pass.
- Location of a bridge site for crossing the river, avoiding bends etc.

2 Reconnaissance survey

The main object of this survey is to examine the general characteristics of the area for determining the most feasible route or routes for further detailed investigations. The reconnaissance survey may be conducted in the following sequence.

(i) Study of topographical survey sheets, agricultural soil, geological and meteorological maps and aerial photographs if available.

(ii) Aerial reconnaissance

(iii) Ground reconnaissance

(i) Study of topographical survey sheet

Reconnaissance begins with the study of all available maps. In India topographical sheets are available to the scale of 1:50,000. After the study of the topographical features on the maps, a number of alignment feasible in a general way are selected while selecting the alignment following points should be kept in view.

- The alignment should be shortest and most economical with the requirements of gradient and curvature.
- Shape of the alignment
- As far as possible avoid marshy ground, step terrain, unstable hill features.
- Need of connecting important villages and towns, industrial places, or religious importance etc.
- Number of bridges and their lengths.

If the photographs of the area are not available, aerial photography may be arranged for further study for the sake of overall economy. These photographs may be taken on a scale of 1:20,000 to 1:50,000.

(ii) Aerial reconnaissance

Final alignment is selected on the basis of the aerial reconnaissance. It will also help to identify factors which may be helpful with rejection or modification of any of the alignment. This will provide a bird's eye view of the alignments under consideration along with the surrounding area.

(iii) Ground reconnaissance

It consists of general examination of the ground by walking or riding along the selected alignment of a road. It may be done by using the following instruments.

- Compass
- Abney level
- Pedometer
- Cline meter
- Ghats tracer

During this survey following points should be kept in mind.

- Details of route
- Length of the road
- Number of bridges and their lengths

- Geometrics/Gradients, curves and hair pin bends etc.
- Right of way available.

Terrain and soil conditions - Geology of area, nature of soil, drainage conditions and nature of hill slopes.

Road length passing through

- Mountainous terrain
- Steep terrain
- Area subjected to inundation and flooding
- Area of poor soil and drainage conditions.
- General elevations of the road

Climatic conditions

- Temperature-maximum and minimum readings
- Rainfall
- Wind velocities and direction
- Water table conditions.

Value of land - agricultural land, irrigation land, built up land, forest land etc.

- Approximate cost of construction
- Period required for construction
- Important villages, towns and marketing centres connected
- Crossings with railway lines and other existing highways.
- Position of ancient monuments, burial grounds, religious structures, hospitals and schools etc.

3 Preliminary survey

This survey is relatively large scale instrument survey conducted for the purpose of collecting all physical information which affects the proposed location of a new highway. In case of new road it consists of running an accurate traverse line along the new route selected, on the basis of reconnaissance survey. During this phase of survey, topographic features and other features like houses, places of worships etc. are to be considered.

Longitudinal sections and cross sections are taken and bench marks established. This data will form the basis for the determination of final centre line of the road.

During preliminary survey usually levelling work should be kept to the minimum. Generally fly levels at 50 m intervals and at all intermediate breaks in ground should be taken along the traverse line.

The cross section at about 100m to 250m interval in plain terrain and at about 50m intervals in rolling terrain should be taken.

4 Final location survey

This survey is carried out to lay out the final centre line of the road in the field based on the alignment selected in the design office and to collect necessary data for the preparation of working drawings. In this survey only two steps are involved.

- Staking out the final centre line of the road by means of a continuous transit survey.
- Detailed levelling.

Road alignment

The position or the layout of the centre line of the highway on the ground is called the alignment. In a new road should be aligned carefully otherwise it is faulty. It causes more construction, maintenance cost and also increase the accident rates.

The alignment may be,

- Short
- It should be easy
- It should be safe
- It should be economical
- Height of embankment

The height of the embankment depends upon the desired grade line of the highway and topography of the area. Sometimes it is also governed by the stability of foundation specially when the soil is weak usually it is taken 0.6m

Road gradient

The rate of rise or fall along the length of the road with respect to the horizontal length is called gradient.

The maximum, ruling and exceptional gradients as recommended by Indian Road Congress are given below.

Sl.No.	Type of Terrain	Maximum gradient
1	Plain or rolling	1 in 20
2	Mountainous and steep terrain with elevation upto 3000m	1 in 16.7
3	Elevation more than 3000m	1 in 14.3

Road way

Road way comprises of the width of carriageway including traffic separator and shoulders on either side.

Road way width as per recommendations of I.R.C

National and State highway	12.0m
Major district roads	10.0m
Other district roads	8.0m
Village roads	7.5m

Computation of earth work in embankment and cutting

Objectives: At the end of this lesson you shall be able to
- **explain the various methods for the quantity of earth work**
- **compute quantity of earth work by average depth method**
- **compute the quantity of earth work by trapezoidal formula and prismoidal formula.**

Introduction

The volume of earth work in excavations and embankments of roads, railways, canals, etc., it is usually determined by finding the areas of a number of sections at known distance. The cross sections are generally of well defined geometrical shapes, hence, their areas may be obtained by ordinary methods of menstruations i.e.

Area of a triangle = $= \frac{1}{2} \times$ base x height

Area of a rectangle = base x height

Area of trapezium = $= \frac{h}{2} \times$ X sum of parallel sides perpendicular distance between them canal projects, a longitudinal section along the proposed alignment is prepared by normal methods of levelling. Cross sections of the ground at desired intervals, depending upon the topography of the terrain, are also plotted. The formation levels is decided as per design requirements. Knowing the formation levels and ground levels at different sections, the height of embankments and depth of cutting, are calculated.

For proper utilization of the excavated materials, the alignment of the proposed project is so selected that the excavated material is used for the embankments.

Accuracy of Measurements of earth work

As per ISI : 1200 (Part I) 1974, the earth work shall be calculated in cubic metres. For the calculation of the cubic content, the following accuracies in the measurements of the quantities, are recommended.

(i) Each dimension of the earth work shall be measured correct to one centimetre. In case any dimension is more than 25 m, its value may be obtained correct to 0.1 metre.

(ii) Areas of cross sections shall be calculated to the nearest to $0.01 m^2$.

(iii) The volume of the earth work shall be calculated to the nearest $0.001 m^3$.

Methods of Calculation of earth work

The quantities of the earth work of roads, railways, and canals may be calculated by the following methods :

1 Average depth method

2 Average cross sectional area method

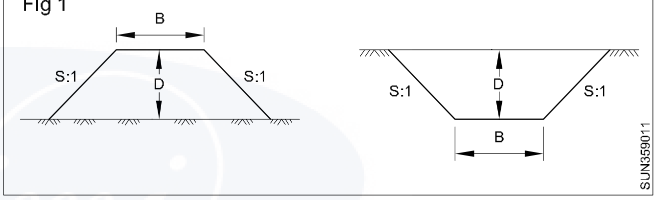
3 Prismoidal formula

4 Graphical method

1 Average depth method

In this method, the average height of embankments or average depth of cuttings at the mid - section of two known sections, are calculated. Knowing the formation width, average depth and side slopes, the area of the corss -section at mid - section may be calculated as explained below (Fig 1).

Fig 1



Let B = formation width

D = depth/height of the cutting/ embankment.

S : 1 = side slopes i.e horizontals : 1 vertical

The cross sectional area

$$A = BD + 2\left\{\frac{1}{2}.SD.D\right\}$$

$$= BD + SD^2 \qquad .... (1)$$

Now, knowing the area A of the mid-section and length L between two sections, the volume of the earth work.

$$V = A.L \qquad .... (2)$$

Derivation of the formula (Fig 2)

Let d_1 and d_2 = height of the embankment at two sections

ι= distance between the sections

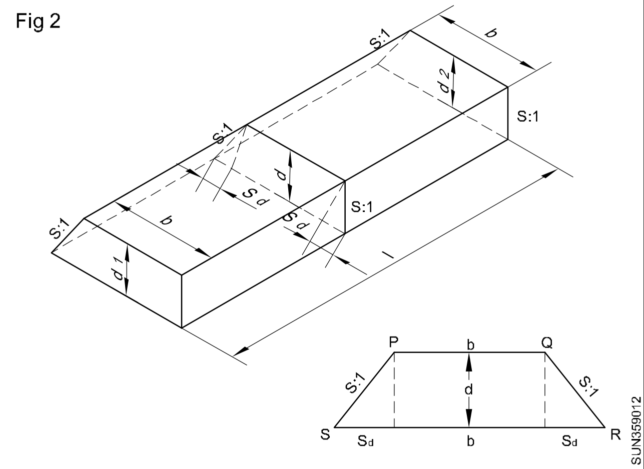
b= formation width

S: 1 = sides slopes i.e horizontals : 1 vertical

The average height of the embankment. (Fig 2)

$$= \frac{d_1 + d_2}{2} = d$$

Fig 2



The quantity of the earth work = Area of trapezium x length.

From eqn. (1), the area of the trapezium PQRS = bd + sd^2

∴ The quantity of the earth work $V = (bd+sd^2)ι$........(3)

Similarly, it can be shown that quantity of the cutting

$V = (bd+sd^2)ι$

where: b is formation width, d is the depth of cutting and S:1 is the slope of the cutting

2 Average cross sectional area method

In this method, the average area of mid - cross section is obtained from the areas of cross - section of two sections and is multiplied by the distance between the sections.

Let d_1 and d_2 be the lengths of the embankment at two sections.

l is the distance between two sections

b is the formation width

S : 1 is the side slope i.e S horizontal : 1 vertical

The cross sectional area of section 1.

$A_1 = bd_1 + sd^2_1$

The cross sectional area of section 2

$A_2 = bd2 + sd_2^2$

$$\therefore \text{The mean sectional area } = \frac{A_1 + A_2}{2} + A$$

Quantity of the earth work = mean area x length

V = A x l

3 Prismoidal formula

Let d_1, d_2= heights of the embankment at sections 1 and 2.

l = distance between the given sections.

b = formation width

S : 1 = side slopes i.e S horizontals : 1 vertical

d = average height at the mid - section

A_1, A_2 = cross sectional areas of sections 1 and 2.

A = cross- sectional area at the mid - section.

Apparently,

$$= \frac{L}{6}\left[\left(Bd_1 + Sd_1^2\right) + 4\left\{B \times \frac{d_1 + d_2}{2} + S\left(\frac{d_1 + d_2}{2}\right)^2\right\} + \left(Bd_2 + Sd_2^2\right)\right]$$

$$= \frac{L}{6}\left[Bd_1 + Sd_1^2 + \frac{4B\left(d_1 + d_2\right)}{2} + \frac{4S\left(d_1 + d_2\right)}{4} + Bd_2 + Sd_2^2\right]$$

$$= \frac{L}{6}\left[Bd_1 + Sd_1^2 + 2Bd_1 + 2Bd_2 + Sd_1^2 + 2Sd_1d_2 + Sd_2^2 + Bd_2Sd_2^2\right]$$

$$= \frac{L}{6}\left[3Bd_1 + 3Bd_2 + 2Sd_1^2 + 2Sd_2^2 + 2Sd_2^2 + 2Sd_1d_2\right]$$

$$= \frac{3BL}{6}\left[\left(d_1 + d_2\right) + \frac{2LS}{6} + \left(d_1^2 + d_2^2 + d_1d_2\right)\right]$$

$$= \frac{BL}{2}\left[\left(d_1 + d_2\right) + \frac{LS}{3}\left(d_1^2 + d_2^2 + d_1d_2\right)\right]$$

$$\text{or} V = \left[\frac{B\left(d_1 + d_2\right)}{2} + S\frac{\left(d_2^1 + d_2^2 + d_1d_2\right)}{3}\right] \times L$$

Prismoidal formula

$$d = \text{mean height} = = \frac{d_1 + d_2}{2}$$

By applying the Simpson's rule we get

$$V = \frac{L}{6}\left[A_1 + 4A + A_2\right]$$

The eqn. (5) may be reduced to a more practical form as under :

$$V = \frac{L}{6}\left[A_1 + 4A + A_2\right]$$

General formulae for the earth work calculations

In case, the earth work consists of a series of cross - sections taken at equal intervals, the trapezoidal and Prismoidal formulae for the earthwork reduce to :

Volume by trapezoidal formula :

$$V = \frac{L}{2}\left[A_1 + 2A_2 + 2A_3 + 2A_4 + \dots\dots\dots + 2A_{n-1} + A_n\right]$$

$$L\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + A_4 + \dots\dots\dots + A_{n-1}\right]$$

Volume by Prismoidal formula :

$$V = \frac{L}{3}\left[A_1 + 4A_2 + 2A_3 + 4A_4 + 2A_5 + \dots\dots\dots + A_n\right]$$

$$V = \frac{L}{3}\left[A_1 + A_n + 4\left(A_2 + A_4 + A_6 + \dots\dots\dots\dots + \right) + 2\left(A_3 + A_5 + A_7 + \dots\dots\dots\dots)\right)\right]$$

$$= \frac{L}{3}\left[\text{Firstsection} + \text{Lastsection} + \text{Four}\sum\text{Even} + \text{Twice}\sum\text{odd}\right]$$

where A_1, A_2, A_3, ... A_n represent the areas of cross sections and L is the distance between the sections.

Note : The following points may be noted :

(i) For the application of the Prismoidal formula, the number of cross sections should be odd. If the number of cross sections is even, the volume of the portion bounded by the sections at either end, may be calculated by trapezoidal formula and the volume of the portion containing only odd sections may be calculated by the Prismoidal formula.

(ii) The volume calculated by the Prismoidal formula is more accurate than that calculated by average depth method and average cross sectional area method.

Road and railway embankments

While calculating the volume of the earthwork involved in road or railway projects, the following cases may arise:

1 The transverse slope of the ground being zero.

2 The transverse slope of the ground being r :1 i.e r horizontals : 1 vertical.

3 The transverse slope of the ground being r_1 : 1 and r_2 : 1 1 on either side of the alignment.

4 The transverse slope of the ground being irregular.

Preparation of Topographic map

Objectives: At the end of this lesson you shall be able to
- **state topographic terminology**
- **explain topographic map**
- **describe representation of colours and scale.**
- **explain grid of map and find a location of map**
- **describe navigate with a compass and a topographic map.**

Topographic terminology

Bearing: The horizontal angle at a given point, measured clockwise form magnetic north or true north to a second point.

Classified roads: Roads for which surface type, width and use are identified.

Contour lines: Lines on a map connecting points of equal elevation above mean sea level. using contour lines, relief features can be profiled into a three-dimensional perspective.

Elevation: Vertical distance from a datum (Usually mean sea level) to a point or object on the earth's surface.

Horizontal datum: The positional reference or basis for the geographic location of features on a map.

Legend: A description, explanation table of symbols, or other information, on a map or chart to provide a better understanding and interpretation of it.

Magnetic north: Direction to which a compass needle points.

Mean sea level: The average height of the surface of the sea for all stages of tide. Used as a reference surface from which elevations are measured.

National topographic system: An orderly index system suitable for a series of maps of different scales

Projection: Geometric representation of the curved surface of the earth on a flat sheet of paper.

Relief: The physical configuration of the Earth's surface, depicted on a topographic map by contour lines and spot heights.

Spot elevation: A point on a map where height above mean sea level is noted, usually by a dot and elevation value, it is shown wherever practical (road intersections , summits, lakes, large flat areas and depressions).

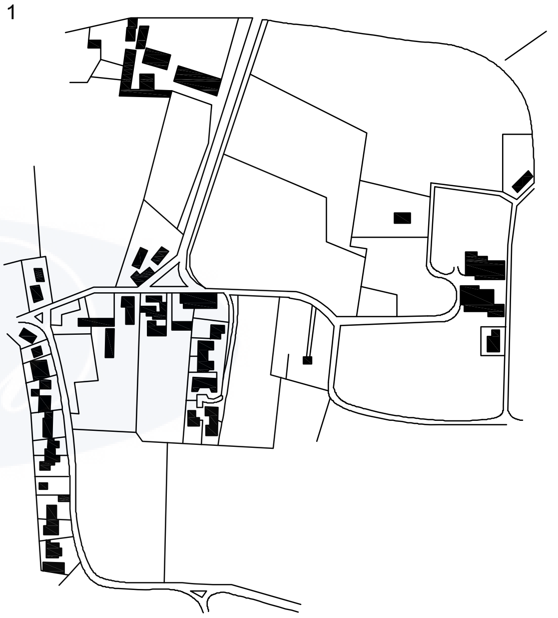
Symbols: A diagram, design, letter or abbreviations, placed on maps, that (By convention, usage or reference to a a legend) is understood to stand for or represent a specific feature or object.

Topography: Surface features both natural and man-made, collectively depicted on topographic maps.

Unclassified roads: Roads for which the surface is unidentified.

Topographic map (Fig 1)

Fig 1



TOPOGRAPHIC PLAN SHOWING PHYSICAL DETAIL

SUN359211

Topographic maps represent the Earth's features accurately and to scale on a two-dimensional surface. Topographic maps are an excellent planning tool and guide.

A topographic map is a detailed and accurate illustration of man-made, and natural features on the ground such as roads, railways, power transmission lines, contours, elevations, rivers, lakes and geographical names.

The topographic map is a two-dimensional representation of the Earth's three-dimensional landscape. The most frequently used topographic map is at the scale of 1:50.000.

Topographic maps identify numerous ground features, which can be grouped into the following categories.

Relief: Mountains, valleys, slopes, depressions as defined by contours

Hydrography: lakes, rivers, streams, swamps, rapids, falls

Vegetation: Wooded areas

Transportation: Roads, trails, railways, bridges, airports/ airfield, seaplane anchorages.

Culture: buildings, urban development, power transmission line, pipelines, towers

Boundaries: international, provincial/ territorial, administrative, recreational, geographical

Toponymy: Place names, water feature names, landform names, boundary names

Refer to the map legend for a complete listing of all features and their corresponding symbols. Information along the map borders provides valuable details to help you understand and use a topographic map. For example, here you will find the map scale and other important information about the map such as the year, the edition and information pertaining to the map data.

Representation of colours: A variety of colours can be found on a map, each relating to different types of features.

- **Black:** shows cultural features such as buildings, railways and power transmission lines. It is also used to show geographical names (toponymy). Certain symbols, geographic coordinates and precise elevations.
- **Blue:** represents water features, such as lakes, rivers, falls, rapids, swamps and marshes. The name of water bodies and water courses are also shown in blue, as are magnetic declination and UTM grid information.
- **Green:** indicates vegetation such as wooded areas, orchards and vineyards.
- **Scale:** Maps are made to scale. In each case, the scale represents the ratio of a distance on the map to the actual distance on the ground. A standard topographic map is produced at 1: 50 000, where 2cm on the map represents 1km on the ground.

$$\frac{\text{MAP DISTANCE}}{\text{GROUND DISTANCE}} = \frac{2\text{ CM}}{1\text{ KM}} = \frac{2\text{ CM}}{1{,}00{,}000\text{ CM}} = \frac{1}{50{,}000}$$

scale = 1: 50,000

Medium-scale maps (e.g. 1:50 000) cover smaller areas in greater detail, whereas small-scale maps (e.g. 1:250000) cover large areas in less detail. A 1:250 000 scale national topographic system (NTS) map covers the same area as sixteen 1:50 000 scale NTS maps.

Grid of map: A grid is a regular pattern of parallel line intersecting at right angles and forming squares, it is used to identify precise position. To help you locate your position accurately on the surface of the earth (or map sheet), topographic maps have two kinds of referencing systems.

Universal transverse mercator (UTM) projection (easting /northing)

Geographic: Degrees and minutes (longitude/latitude)

The projection used for topographic maps is UTM.

The UTM grid is a square grid system of lines depicted on maps and based on the transverse mercator projection. it can be used to accurately locate the position of features on the map by distance or direction. To express your location in grid coordinates or geographic coordinates, read the following section.

Find a location of map: You can find or express a location on a map by using geographic coordinates (longitude, latitude) or by using UTM grid coordinates (easting, northing)

Geographic coordinates are expressed in degrees, minutes and seconds and can be determined on the map by using the longitude and latitude graticules placed along the edges of the map. Latitude graticules are placed along the east and west edges of the map and longitude graticules are placed along the north and south edges of the map. The longitude and latitude of your location can be determined by projecting your location to the map edges and then by reading the corresponding latitude and longitude values.

UTM grid coordinates are expressed in metres and can be determined on the map by using the UTM grid lines. These grid lines are equally spaced horizontal and vertical lines superimposed over the entire map. The coordinate value for each grid line can be found along the edge of the map. Northing values can be read along the east or west edges of the map and easting values can be read along the north or south edges of the map. The easting and northing of your location can be determined by projecting your location to the nearest horizontal and vertical grid lines and then reading the corresponding easting and northing values.

How can i determine where i am on a map using a GPS receiver?

If you have a GPS receiver, your location can be determined very quickly. This satellite receiving system displays a position in terms of latitude, longitude, and height, providing you with precise coordinates for map reference. (Some receivers also provide a direct conversion of position to a selected map grid such as UTM.) with this GPS coordinate, you can then use the geographic or UTM grid reference system on the map to determine where you are..

How can i determine “where I am” on a map without using a GPS?

If you do not have a GPS receiver, identify as many features around you as you can, man-made or natural, and locate those same features on your map. Then orient the map, in relation to yourself, so that its orientation corresponds to the ground features that you have identified. If this is difficult to do, use a compass to help you orient the map to north and try again to identify surrounding features. By estimation, or by using a compass, take bearings to the known features and then from the know features, plot the bearing lines. The intersection of these lies should indicate your location.

Navigate with a compass and a topographic map

Navigating by compass requires determining bearings with respect to true or grid north from a map sheet and converting them to magnetic bearings for use with a compass. One way of doing this is described in the following steps.

Place the compass on the map with the direction-of-travel arrow pointing along the desired line of travel.

Rotate the compass dial so that the parallel lines within the capsule line up with the grid lines on the map. Convert the grid bearing to a magnetic bearing by using the information given (as in the accompanying diagram) on the map sheet. If declination is west, add it to the grid bearing, if declination is east, subtract it from the grid bearing.

Adjust the dial to read the value of the magnetic bearing opposite the direction-of-travel arrow. Make certain to account for the difference between grid north and true north.

Now pick up and rotate the whole compass until the red end of the needle points to the north marker on the dial. The direction-of-travel arrow on the compass card will point to your destination. Choose a landmark in that direction and walk toward it.

Topographic tip: Using a compass along with a topographic map ensures obtaining an exact direction for locating features. An approximate but quick way to orient your map is to align the compass needle (when it is pointing north) with the top of the map.

Remember that north is always at the top of a topographic map.

Preparation of cadastral map

Objectives: At the end of this lesson you shall be able to
- **define the term of cadastre**
- **define the term of cadastral map**
- **describe the principle used in cadastral maps in the grid.**

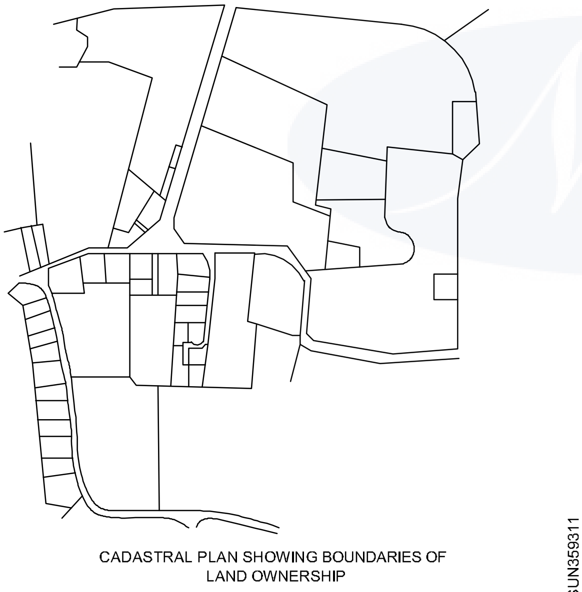
Cadastre: cadastre is a technical term of records showing the extent, value and ownership of land, strictly speaking, a cadastre is a record of areas and values of land and of land holders that originally was compiled for purposes of taxation.

A modern cadastre consists of a series of large scale maps or plans and corresponding registers.

Cadastral map (Fig 1)

A cadastral map will show the boundaries of such plots but may in addition incorporate details of the resources associated with them, including the physical structures on or beneath them, their geology, soils and vegetation and the manner in with the land is used.

Fig 1



CADASTRAL PLAN SHOWING BOUNDARIES OF LAND OWNERSHIP

Since the map and the corresponding registers form complimentary parts of the same system of description and identification, there must be some system of cross referencing between what is shown on the map and what is recorded in the registers. This means that either names or numbers must be given to each separate land plot. These references are known as property identifiers or unique plot reference numbers, various reference system given below.

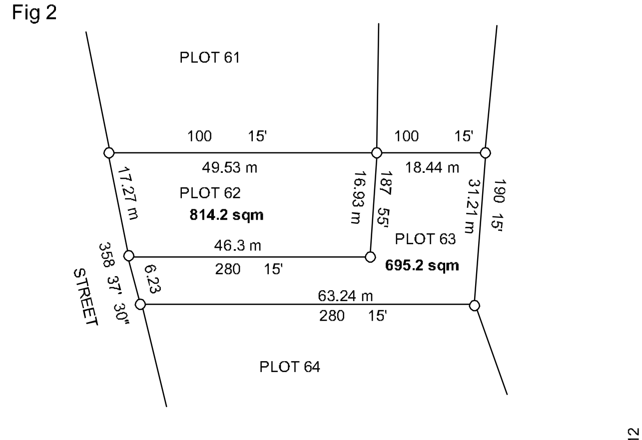
- The name of the owner
- A sequential title number
- The volume and folio numbers on which the plot is registered
- The name of a farm or locality with an individual plot number
- The registration block and individual plot numbers
- Post office address
- Street index reference and plot number
- A grid coordinate

The reference chosen should be easy to understand and easy to remember, easy to use for the public. It does change with the sale of a property, but capable of being updated when there is for example a subdivision of the land, unique, accurate and economic to introduce.

- These numbers or names are drawn on a map that they do not obscure the details of the map itself.
- The cadastral map should show the boundaries of each land parcel and in some jurisdictions may also shown its area and the actual length and bearing of each boundary line.
- Most cadastral maps and to be scales of between 1:500 and 1:2500 although in densely developed areas a longer scale may be needed while in open country side much smaller scale may be acceptable.
- Large scale plans are initially much more expensive than small- scale maps.
- Once the large-scale survey has been completed accurate maps on any smaller scale can be derived from them.
- Usually cadastral maps used only be “planimetric” maps. They need not show topographical relief there may be special reasons why altitudes should be recorded on cadastral maps, but ordinarily all that is needed a plan of what is seen; without stereoscopy from a point vertically above the piece of land observed.
- Distances recorded on such plans are the horizontal distances between points and not the surface distances actually measured on the ground (Fig 2)
- The area recorded for a plot of land on a steep hillside will be the horizontal equivalent which may be significantly less than the actual surface area.
- Another important requirement of cadastral maps is that they should show a sufficient number of points which can be accurately identified on the ground to

enable any other point can be ground to be identified on the map by eye or by simple and short measurements.

Fig 2



CADASTRAL PLAN SHOWING BEARINGS AND DISTANCES OF SIDES ,AREAS, AND PLOT NUMBERS

One principle method of identification used in cadastral maps in the grid:

A grid has been laid out on the ground creating a rectangular system.

- All plots of land are formed by straight lines, often running north to south and east to west.
- A grid is used as a referencing system so that the coordinates of all boundary turning points can be measured, calculated and recorded.
- The data can be stored and used re-establish lost boundary marks.
- The plot of land reference number can be used to identify the plot.
- It can be cross referenced such as, its dimensions, and to the data on ownership, value and use. The records are held in the survey department.
- A cadastral map must be up to date at all times

Prepare a road map for 1 km showing details on both sides (Open traversing)

Objective: At the end of this lesson you shall be able to
- **prepare a road map locate the details on both sides .**

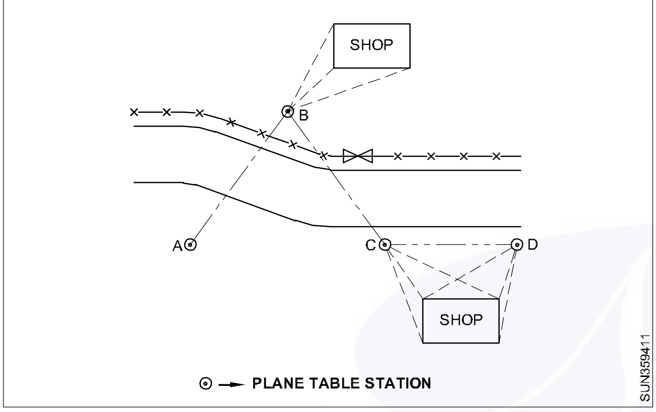
Prepare a road map locate the details on both sides:

Make a visit to the proposed road for the purpose of identifying the objects and special features located on the sides of road to be surveyed.

Selected an instrument station at the beginning of road which gives maximum details for mapping.

Set up the instrument over the selected station 'A'.(Fig 1)

Fig 1



Transfer the ground station 'A' to the drawing sheet as 'a' such that the entire details to be covered within the sheet.

Sight the objects and locate the details of the road around station 'A' by radiation or intersection method.

Fix a ranging rod at 'B' to a visible convenient distance from station 'A' towards the opposite direction of road.

Sight the station 'B' and mark the station on the sheet as 'b'.

Shift the table and setup over the station 'B' and orient it to 'A'.

Sight the objects and locate the details of the road around 'B' by radiation or intersection.

Similarly select the remaining station and locate the details from all the stations up to the end of the road.

Make the convenient symbols along the road sides are drawn for different details.

Finish the map by erasing the unwanted lines and points

Run the survey line along the side of the road only, to avoid traffic problems.

Use Auto CAD command survey software for survey drawing.

Objectives: At the end of this lesson you shall be able to
- **state how to create a plot plan using survey**
- **describe how to enter plot line in formation**
- **describe how to create a curved plot line with specific radius.**
- **describe to view the plot perimeter in 3D.**

How do i create a plot plan using survey information?

You can create a CAD polyline representation of your plot plan using the distance and bearing information from a survey, then edit the rectangular terrain perimeter line to fit it exactly. For the purposes of this example, we will use the following survey information. (Fig 1)

Line 1-77.23 feet

N 3° 18' 25"E

Line 2-65,81 feet

N 86° 41' 1" E

Line 3 – 58.97 feet

S7° 5'56"E

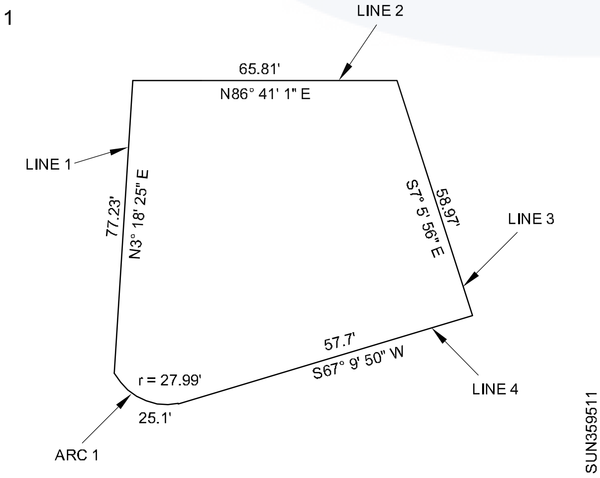
Line 4-57.7 feet

S67° 9'50" W

Arc 1 – 25, 1 feet

Radius 27.99 feet

Fig 1



This image above shows what the completed plot plan will look like, based on this data. We have added the distance and bearing information with text for clarification.

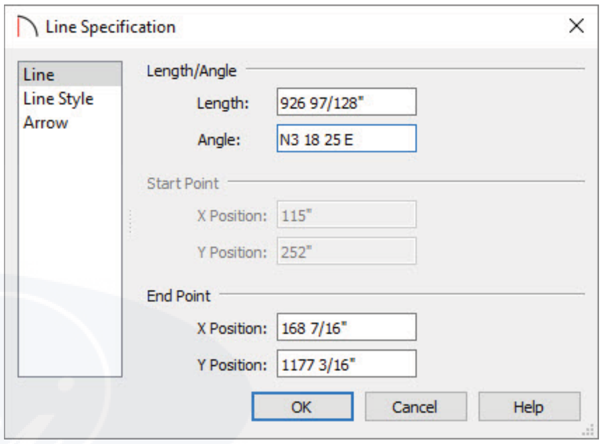
To enter plot line information (Fig 2)

1 To begin, start off by selecting **File> New plan** to open a new, blank plan based on the default style template.

2 Next, from the menu, select **CAD> draw line** and click to begin by drawing CAD Line 1, starting from the bottom of the screen and dragging upwards.

3 Once the line has been created, use the **select objects** tool to select the line, then click on the **open object** edit button.

Fig 2



4 In the line specification dialog:
- Enter the LENGTH information for line1.
- Press the TAB key on your keyboard to update the dialog and move to the ANGLE field.

When you press the Tab key, your length information will automatically convert to inches,

- Enter the ANGLE information for this line
- Bearing information can be entered in this format: N3°18' 25" E
- Click OK to close the dialog and apply your changes.

5 Repeat these steps to create line 2, line 3 and line 4.

Length, angle, and other line properties can be adjusted on the SELECTED LINE panel of the POLYLINE SPECIFICATION dialog.

To create a curved plot line with a specific radius.

1 Next, using the **draw line** tool, click and drag to draw a CAD line from the end of line 4 to the beginning of line 1 to connect the two.

2 Select this line and click on the **change line/Arc** edit button, By default, the arc will curve outward, similar to the sample image above.

3 With the arc selected, click the **open object** edit button.

4 On the SELECTED **Arc** panel of the **polyline specification** dialog:

- Specify the **Radius** of the arc.
- Click **Ok** to close the dialog and apply your change.

Keep in mind when you go to create your own plot plan, after completing this tutorial, that if you have received the plot plan information from a surveyor, any given line can be described in two ways using quadrant bearings, and not all surveyors will describe the lines of a given plot in the same direction, i.e., clockwise or counter clockwise. If the lines are not described in the same direction, your result will not be a closed polyline

You now have a completed plot plan, with this being a CAD polyline, it can only be seen in a 2D floor plan view. To create a 3D object that can be seen in 3D camera views, you can create a terrain perimeter and modify its shape to match the CAD polyline.

To view the plot perimeter in 3D

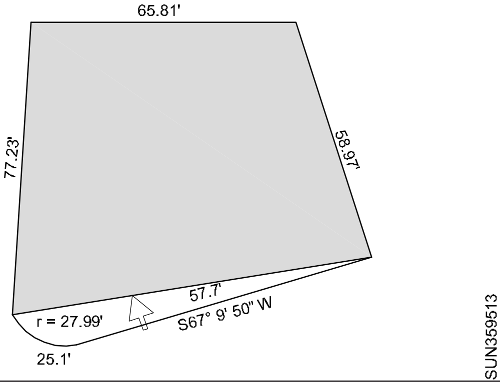
1 From the menu, select **Terrain> Create Terrain perimeter** to create a basic rectangular terrain.

2 Using the **select objects** tool, click on one of the lines or the rectangle making up the terrain perimeter to select it, then click and drag the centre move edit handle so that the Terrain Perimeter is centred over your plot plan polyline

3 Next, click on the edit handle in the top left corner, and drag it to the top left corner of your polyline at the end of Line 1.

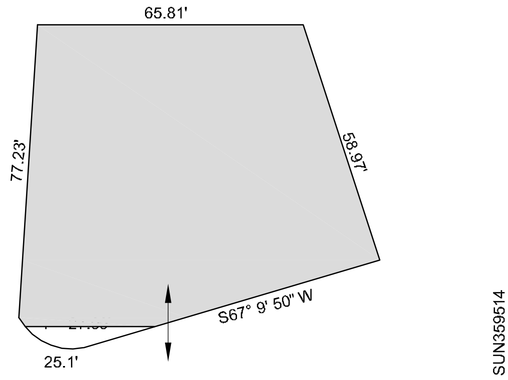
4 Similarly, drag the top right edit handle to the end of Line2, the bottom right edit handle to the end of line 3, and the bottom left edit handle to the beginning of line 1. (Fig 3)

Fig 3



5 After you have done this, select the bottom line of the Terrain Perimeter, select the **Break Line** edit tool, and then click on the bottom line near the plot plan arc to create a new corner handle at the point where you clicked.

Fig 4



6 Now you can now click and drag this new diamond shaped edit handle to the end of line. 4

7 Select the new line segment that needs to become the arc and click the **change Line/Arc** edit button, as you did earlier to create the arc in the plot plan.

8 Finally, with the new curved segment selected, click **open object** edit button and on the **selected line/ arc** panel of the **Terrain specification** dialog.

- Enter the same **radius** value as you did for the plot plan polyline.
- Click **ok** the plot plan and terrain should now match. (Fig 4)

If you wish, you can use the Text tools to add length and bearing information in a 2D floor plan view.

Home designer professional has the capability to show this information by checking both the Show Length and Show Angles display option checkboxes on the line Style Panel of the Polyline Specification dialog.