SURVEYOR

NSQF LEVEL - 4

2ⁿᵈ Year

TRADE THEORY

SECTOR : CONSTRUCTION

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

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

Nimi NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Sector : Construction

Duration : 2 Years

Trade : Surveyor 2nd Year - Trade Theory - NSQF Level - 4 (Revised 2022)

FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, 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 Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Surveyor 2nd Year Trade Theory** in **Construction Sector** under **Annual Pattern.** The NSQF Level - 4 (Revised 2022) Trade Practical 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 - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages 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 (Training)
Ministry of Skill Development & Entrepreneurship,
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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 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 (NSQF) 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.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

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.

Chennai - 600 032   **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intended 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 - 4 (Revised 2022) syllabus are covered.

The manual is divided into Twelve modules.

Module 1	**Tacheometry Survey**
Module 2	**Contour Survey**
Module 3	**Curves**
Module 4	**Total Station**
Module 5	**Cadastral Survey**
Module 6	**AutoCAD**
Module 7	**Concept and Cartographic Projection**
Module 8	**Setting of GIS and GPS**
Module 9	**Hydrographic Survey**
Module 10	**Transmission Line Site Survey**
Module 11	**Railway Line Site Survey**
Module 12	**Building Drawing and Estimate**

The skill training in the shop floor is planned through a series of practical exercises centered 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.

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Surveyor 2nd Year NSQF Level - 4 (Revised 2022)** in **Construction**. The contents are sequenced according to the practical exercise contained in NSQF Level - 4 (Revised 2022) syllabus on Trade Theory 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 trade theory connected to each exercise at least 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.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No.	Learning Outcome	Exercise No.
1	Performing tachometric survey using tacheometer. (Mapped NOS: IES/N9443)	2.1.66 - 2.1.67
2	Make topography map using level instrument with contours. (Mapped NOS:CON/N0907)	2.2.68 - 2.2.75
3	Concept & set out of curves. (Mapped NOS:IES/N9444)	2.3.76 - 2.3.82
4	Perform survey work using modern survey instruments (Total station) for prepare a map. (Mapped NOS:CON/N0906)	2.4.83 - 2.4.86
5	Concept of cadastral survey & make a site plan. (Mapped NOS: IES/N9445)	2.5.87 - 2.5.88
6	Perform survey work for prepare a topographical map, cadastral map (mouza map), road project (survey camp in a suitable hilly / undulated area). (Mapped NOS: IES/N9446)	2.5.89 - 2.5.91
7	Perform AutoCAD drawing from field survey data. (Mapped NOS:IES/N9447	2.6.92
8	Concept & draw cartographic projection. (Mapped NOS: ES/N9448)	2.7.93 - 2.7.95
9	Plan and prepare setting of GIS & GPS, techniques in various fields. (Mapped NOS:IES/N9449)	2.8.96 - 2.8.100
10	Perform the hydrographic survey (cross section & velocity determination) using the hydrographic survey instruments. (Mapped NOS:IES/N9450)	2.9.101 - 2.9.104
11	Perform transmission line site survey & prepare a site plan. (Mapped NOS:IES/N9451)	2.10.105 - 2.10.110
12	Perform the railway line site survey using modern survey instruments. (Mapped NOS:IES/N9452)	2.11.111 - 2.11.115
13	Draw a double storied building by AutoCAD & prepare a detailed estimate of building.(Mapped NOS:CON/N1302)	2.12.116 - 2.12.117

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 56 Hrs.; Professional Knowledge 12 Hrs.	Performing tachometric survey using tacheometer.(Mapped NOS:IES/N9443)	66. Determination of horizontal and vertical distances by tachometric method. (30hrs.) 67. Determination of stadia constants of a tachometer. (26 hrs.)	Introduction of tachometry & terms use advantages and disadvantages. Tachometric constants & its determination. Determination of horizontal & vertical distances by various methods. (12hrs.)
Professional Skill 112 Hrs.; Professional Knowledge 32 Hrs.	Make topography map using level instrument with contours. (Mapped NOS:CON/N0907)	68. Prepare contour (direct/indirect method) (20hrs.) 69. Interpolation of contour. (15 hrs.) 70. Draw contour lines. (12 hrs.) 71. Locating contour gradients. (10hrs.) 72. Preparation of section from contour map. (15hrs.) 73. Computation of volume (prismoidal/trapezoidal) formula. (10hrs.) 74. Establishment of gradient by abney level. (10hrs.) 75. 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. (32hrs.)
Professional Skill 112 Hrs.; Professional Knowledge 32 Hrs.	Concept & set out of curves. (Mapped NOS: IES/N9444)	76. Computation of elements of simple curve. (20 hrs.) 77. Set out of simple curve by linear method. (15 hrs.) 78. Set out of simple curve by instrument method. (17 hrs.) 79. Set out of compound curve by instrument method. (15hrs.) 80. Set out of reverse curve by instrument method. (15hrs.) 81. Set out of transition curve by instrument method. (15hrs.) 82. 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. (Mapped NOS: CON/N0906)	83. Temporary adjustment of Total station. (20hrs.) 84. Measurement of angle & coordinates and heights. (27hrs.) 85. Traversing using Total station. (40hrs.) 86. 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 8 Hrs.	Concept of cadastral survey & make a site plan. (Mapped NOS: IES/N9445)	87. Prepare a site plan by the help of mouza map. (16 hrs.) 88. 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 56 Hrs.; Professional Knowledge 16 Hrs.	Perform the site survey using prismatic compass	89. Prepare topographical map (direct & indirect method). (20 hrs.) 90. Make a cadastral/ mouza map & calculate the plot area. (20hrs.) 91. Prepare a detail road project more than 1KM.(16 hrs.)	Details knowledge for preparation of topographical map. Details knowledge for preparation of cadastral map. Details knowledge for preparation of a road project. (16 hrs.)
Professional Skill 28 Hrs.; Professional Knowledge 08 Hrs.	Perform AutoCAD drawing from field survey data. (Mapped NOS: IES/N9447)	92. Survey drawing practice using AutoCAD commands (28 hrs.)	Use auto cad command survey software for survey drawing. (08 hrs.)
Professional Skill 28 Hrs.; Professional Knowledge 08 Hrs.	Concept & draw cartographic projection. (Mapped NOS: IES/N9448)	93. Drawing of Simple conical projection, polyconic, lambert's & UTM (Universal Transverse Mercator). (10 hrs.) 94. Construction of UTM Grid. (10 hrs.) 95. Use datum defining system 1984 (WGS-84). (8 hrs.)	Importance of cartographic projection. Uses of various types of cartographic projection for mapping. (8hrs.)
Professional Skill 112 Hrs.; Professional Knowledge 36 Hrs.	Plan and prepare setting of GIS & GPS, techniques in various fields. (Mapped NOS: IES/N9449)	96. Setting of GPS/DGPS. (10 hrs.) 97. Construction of UTM Grid. (10hrs.) Data collection (measurement of line & calculation of area) (20 hrs.) 98. Data collection in DGPS mode. (15 hrs.) 99. Processing of GPS data in software. (10 hrs.) 100. Plotting the contour lines with the help of Auto Civil/ Civil 3D Software/any other software. (57 hrs.)	Introduction of GIS& GPS. Elements of GPS/DGPS. Observation principles. Sources of error & handling of error in GPS. Various type of GPS application. Concept & use of survey software. (36hrs.)
Professional Skill 28 Hrs.; Professional Knowledge 20 Hrs.	Perform the hydrographic survey (cross section & velocity determination) using the hydrographic survey instruments. (Mapped NOS: IES/N9450)	101. Determine hydrographic depth by (sounding method)/ eco sounder. (10 hrs.) 102. Measure the velocity of flow. (07 hrs.) 103. Determine the crosssectional area of a river. (06 hrs.) 104. Calculate the discharge of a river (5 hrs.)	Introduction to hydrographic survey, practice various method s of water depth measurement process, floe velocity measurement & determination of cross sectional area of a river. Handling of eco sounder, current meter. (20hrs.)

Professional Knowledge 28 Hrs. Professional Skill 16 Hrs.;	Perform transmission line site survey & prepare a site plan. (Mapped NOS: IES/ N9451)	105. Justify constructing a new transmission line. (03hrs.) 106. Marking of tentative alignment on existing topographical map. (04hrs.) 107. Conduct reconnaissance/ preliminary survey & select a good alignment. (6hrs.) 108. Conduct detailed survey, prepare a profile drawing using sag template. (6 hrs.) 109. Conduct final location survey. (6 hrs.) 110. Mark tower foundation pit point (as per type of tower) (03hrs.)	Basic terms used in transmission line survey, justification criteria for constructing new line, marking process of tentative alignment, selection process of a good alignment. Process of detail survey & final location survey. Use of sag template, Various type of tower, construction of tower foundation. (16hrs.)
Professional Skill 28 Hrs.; Professional Knowledge 8 Hrs.	Perform the railway line site survey using modern survey instruments. (Mapped NOS:IES/ N9452)	111. Justify to construct a new Railway line. (03 hrs.) 112. Marking of tentative alignment. (04 hrs.) 113. Conduct reconnaissance/ preliminary survey & select a good alignment. (8 hrs.) 114. Conduct detailed survey, prepare of drawing including design of curves with setting out table. (7hrs.) 115. Conduct final location survey. (6hrs.)	Basic terms used in railway line project survey, justification criteria for constructing new line, marking process of tentative alignment, selection process of a good alignment. Process of detail survey & final location survey. (8hrs.)
Professional Skill 112 Hrs.; Professional Knowledge 32 Hrs.	Draw a double storied building by AutoCAD & prepare a detailed estimate of building. (Mapped NOS: CON/ N1302)	116. Draw a double storied residential building plan, elevation, cross section, site plan, lay out plan, foundation details etc. (78 hrs.) 117. Prepare a detail estimate of this building. (34 hrs.)	Specification & uses of various types of building materials, types of foundation, knowledge of R.C.C. works, & other construction related items. Procedure of prepare a detail estimate. (32hrs.)

Introduction to tacheometry

Objectives: At the end of this lesson you shall be able to
• **explain the term tacheometry**
• **explain what is meant by tacheometer**
• **explain the principle of tacheometer**
• **explain the theory of stadia tacheometry.**

Introduction

Tacheometry is an optical distance measurement method. In this method the horizontal and vertical distances are determined by instrumental observations. It is usually adopted in hilly and rough terrains, where direct chaining and levelling are either very difficult or not possible.(Fig 1)

Instrument required

• **Tacheometer:** A tacheometer is nothing, but a theodolite provided with stadia wires. The diaphragm of such theodolite consists of two additional hairs equidistant from central hair, one above and the other below.

Fig 1

DIFFERENT FORMS OF STADIA DIAPHRAGM
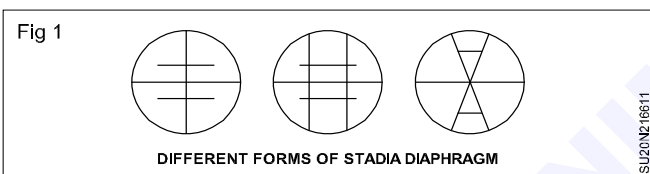
• **Stadia rod:** Stadia rod is a staffs which is longer than an ordinary levelling staff. As the length of sight is more than 100m, the rod is specially designed graduated. These rods are also 4m long and graduations are bold and clear. The least count of this staff is 0.001m.

For short distances, ordinary levelling staff is used for taking staff readings.

Principle of tacheometry; tacheometry is based on the property of isosceles triangle, that the ratio of the distance of the base from the apex and the length of the base is always a constant.

In Fig 2 all are isosceles triangles where distance between instrument and points A, B, C are D_1, D_2, D_3 respectively and the lengths of the bases (staff intercepts) are S_1, S_2, S_3.

So, according to the stated principle,

Fig 2
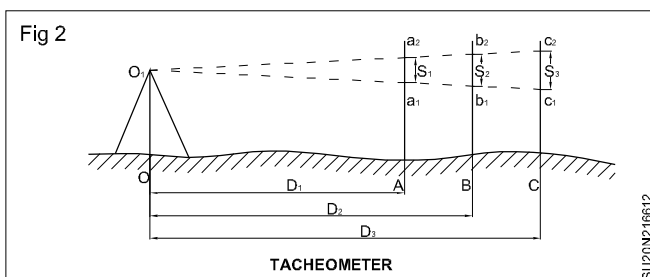
TACHEOMETER

$$\frac{D_1}{S_1} = \frac{D_2}{S_2} = \frac{D_3}{S_3} = \frac{f}{i} \text{ (constant)}$$

The constant f/i is known as the multiplying constant,

Where, f = focal length of objectives i = interval between stadia hairs.

Theory of stadia tacheometry: The following is the notation used in stadia tacheometry (Fig 3)

THEORY OF STADIA TACHEOMETRY
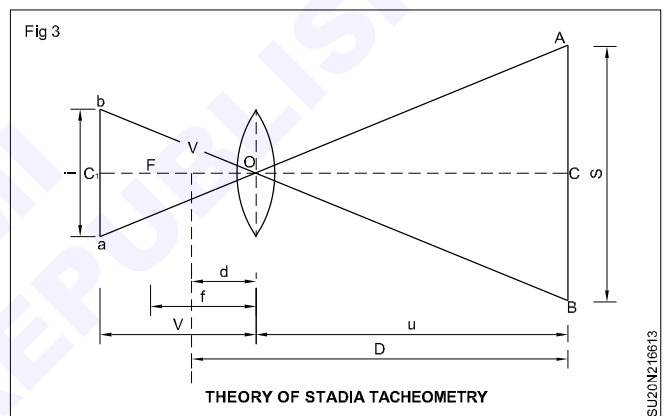
O = optical centre of object glass

A, B, C = readings on staff cut by three hairs

a, b, c = bottom, top and central hairs of diaphragm

i = length of image

S = staff intercept

F = focus

V = vertical axis of instrument.

f = focal length of object glass

d = distance between optical centre and vertical axis of instrument

D = horizontal distance of the staff from the vertical axis of instrument

u = distance between optical centre and staff

v = distance between optical centre and image

From similar triangles and, $\dfrac{i}{s} = \dfrac{v}{u}$ Or v = $\dfrac{iu}{s}$ (1)

From the properties of lenses,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

1

Putting the value of v in eq. (2),

$$\frac{1}{iu/s}+\frac{1}{u}=\frac{1}{f} \qquad (2)$$

Or $\dfrac{s}{iu}+\dfrac{1}{u}=\dfrac{1}{f}$

Or $\dfrac{1}{u}\left(\dfrac{s}{i}+1\right)=\dfrac{1}{f}$

Or $u=\left(\dfrac{s}{i}+1\right)\times f$

But D = u + d

So, $D=\left[\left(\dfrac{s}{i}+1\right)\times f\right]+d$

$=\dfrac{s}{i}\times f+f+d=\left(\dfrac{f}{i}\right)\times s+(f+d)$

The quantities (f/i) and (f+d) are known as tacheometric constants. (f/i) is called the multiplying constant, as already stated, and (f+d) the additive constant.

By adopting an anallatic lens in the telescope of a tacheometer, the multiplying constant is made 100, and the additive constant zero.

Determination of tacheometric or stadia constant

The constants may be determined by

- Laboratory measurement
- Field measurement

Laboratory measurement The focal length f of the lens can be determined by means of an optical bench, according to the equation:

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

The interval between stadia hairs i can be measured from the diaphragm with the help of a vernier calliper.

The distance 'd' between the optical centre and the vertical axis of the instrument can also be measured.

In this manner, the multiplying (f/i) and additive (f + d) constants can be calculated.

Field measurement

- A fairly level ground is selected. The tacheometer is set up at O and pegs are fixed at A_1, A_2, A_3 are known distances apart. (Fig 4).
- The staff intercepts (stadia hair readings) are noted at each of the pegs. Let these intercepts be s_1, s_2 & s_3.
- By substituting the values of 'D' and 's' in general equation.

FIELD MEASUREMENT
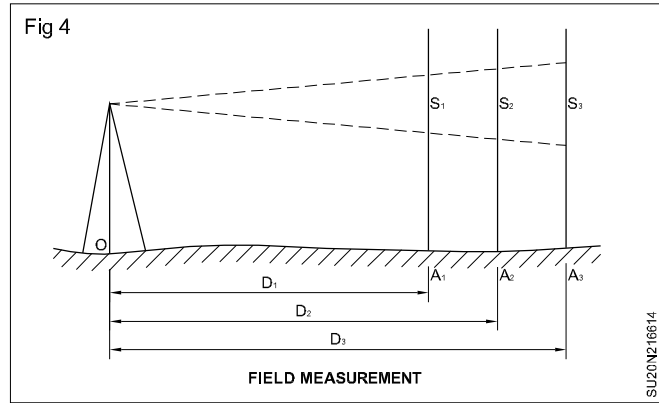
$$D=\left(\frac{f}{i}\right)S+(f+d)$$

We get a number of equations, are follows:

$$D_1=\left(\frac{f}{i}\right)S+(f+d)$$

$$D_2=\left(\frac{f}{i}\right)S_2+(f+d) \text{ and so on.}$$

- By solving the equations in pairs, several values of (f/i) and (f + d) are obtained. The mean of these values gives the required constant.

Example

The levelling staff is held vertical at distances of 100m and 300m from the axis of a tacheometer and the staff intercept for horizontal sights are 0.99 m and 3m respectively. Find the constant of the instrument. Solution

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

Given
$$D_1=100 \text{ m}, \qquad S_1=0.99\text{m}$$
$$D_2=300 \text{ m}, \qquad S_2=3\text{m}$$

Now

$$D_1=\left(\frac{f}{i}\right)S+(f+d)$$

$$100=\left(\frac{f}{i}\right)0.99+(f+d)$$

$$D_2=\left(\frac{f}{i}\right)S_2+(f+d)$$

$$300=\left(\frac{f}{i}\right)^3+(f+d)$$

Eqn (2) - eqn (1)

200m = 2.01 (f/i)

$$\left(\frac{f}{i}\right) = \frac{200}{2.01} = 99.50$$

Substituting $\left(\dfrac{f}{i}\right)$ in second eqn

300 = 99.50 x 3 + (f + d)

(f + d) = 300 - 298.5 = 1.50

Multiplying constant $\left(\dfrac{f}{i}\right)$ = 99.50

Additive constant (f + d) = 1.50

Exercise

Determine the values of stadia constants from the following observations.

Instrument station	Staff reading on	Distance	Stadia readings	
			Lower	**Upper**
0	A	150	1.255	2.750
	B	200	1.000	3.000

Methods of tacheometry

Objectives: At the end of this lesson you shall be able to
• **list the methods of tacheometry**
• **explain the fixed hair method**
• **explain the movable hair method.**

Methods of tacheometry

Tacheometry involves mainly two methods:

• The stadia method.

• The tangential method.

The stadia method: In this method the diaphragm of the tacheometer is provided with two stadia hairs (upper and lower). Looking through the telescope the stadia hair readings are taken. The difference in these readings gives the staff intercept. To determine the distance between the station and the staff, the staff intercept is multiplied by the stadia constant (i.e. multiplying constant, 100). The stadia method may, in turn, be of two kinds.

The fixed hair method: The distance between the stadia hairs is fixed in this method, which is the one commonly used. When the staff is sighted through the telescope, a certain portion of the staff is intercepted by the upper and lower stadia. The value of the staff intercept varies with the distance. However, the distance between the station and the staff can be obtained by multiplying the staff intercept by the stadia constant.

The moveable hair method: The stadia hairs are not fixed in this method. They can be moved or adjusted by micrometer screws. The staff is provided with two targets or vanes a known distance apart. During observation, the distance between stadia hairs is so adjusted that the upper hair bisects the upper target and the lower hair bisects the lower target. The variable stadia intercept is measured and the required distance is then computed.

This method is not generally used.

Fixed hair method (Fig 1)

FIXED HAIR METHOD-CASE I
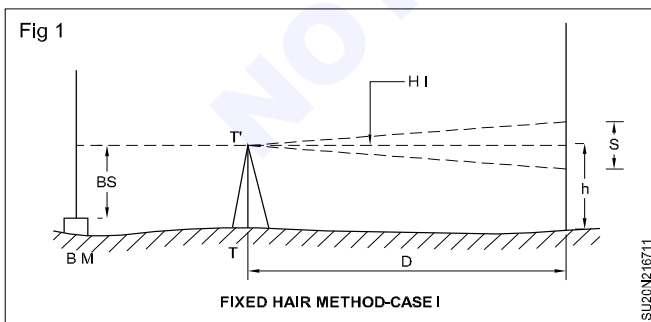
Case 1

When line of sight is horizontal and staff is held vertically.

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

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

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

RL of staff station P = HI - h

Where HI = RL of BM + BS (HI = height of instrument BS = backsight)

h = central hair reading

Case II

When line of sight is inclined, but staff is held vertically here, the measured angle may be the angle of elevation or that of depression.

Considering angle of elevation (positive)

In Fig 2

FIXED HAIR METHOD-CASE II
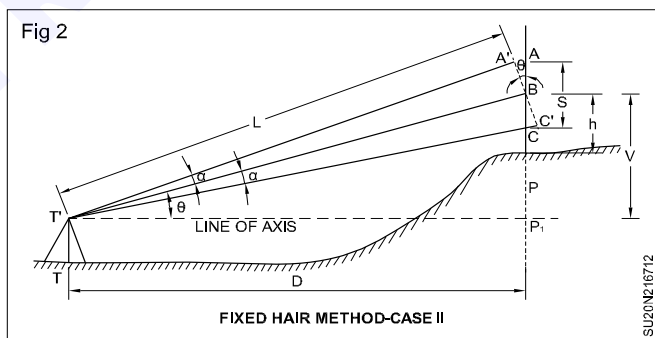
T = instrument station

T_1 = axis of instrument

P = staff station

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

S = AC = staff intercept

h = central hair reading

V = vertical distance between instrument axis and central hair

D = horizontal distance between instrument and staff

L = inclined distance between instrument axis and B

θ = angle of elevation

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

A'C' is drawn perpendicular to the central ray, T_1B.

Now, inclined distance, $L = \dfrac{f}{i}(A'C') + (f+d)$

Horizontal distance $D = L \cos \theta$

$D = \dfrac{f}{i}(A'C')\cos \theta + (f+d)\cos \theta$

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

In Δs ABA' and CBC',

$\angle ABA' = \angle CBC' = \theta$

$\angle AA'B = 90° + \alpha$

$\angle BC'C = 90° - \alpha$

The angle α is very small.

$\angle AA'B$ and $\angle BC'C$ may be taken equal to 90°.

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

So,

From Eq. (1)

$D = \dfrac{f}{i}(S\cos\theta)\cos\theta + (f+d)\cos\theta$

$\therefore D = \dfrac{f}{i} \times S \cos^2 \theta + (f+d)\cos\theta$ (1)

Again $V = L \sin \theta$

$= \left\{ \dfrac{f}{i} \times S\cos\theta + (f+d) \right\} \sin\theta$

$= \dfrac{f}{i} \times S\cos\theta \sin\theta + (f+d)\sin\theta$

$\therefore v = \dfrac{f}{i} \times \dfrac{S \times \sin 2\theta}{2} + (f+d)\sin\theta$ (2)

Also $V = D \tan \theta$

RL of staff station P = RL of axis of instrument + V-h (3)

Problems on fixed hair method - line of sight horizontal

Example

The multiplying and additive constants of a tacheometer are 100 and 0.5 respectively. Find the distance of the station from the instrument, and its elevation, if the bottom, middle and top readings are 0.750, 1.500 and 2.250 respectively, when the collimation line is horizontal. The height of instrument is 100.00.

Solution

Horizontal distance, $D = (f/i) S + (f + d)$

Given f/i = 100, f + d = 0.5

S = 2.250 - 0.750 = 1.500

D = (100 x 1.500) + 0.5 = 150.50 units.

Height of instrument = 100.00

Staff reading on instrument station = 1.500

Reduced level of instrument station = 100.00 - 1.500 = 98.500 units.

Exercise 1: The multiplying and additive constants of a tacheometer are 100 and 0.495 respectively. Find the distance of the station from the instrument, and its elevation, if the bottom, middle and the top readings are 0.795, 1.0025 and 1.255 respectively, when the collimation line is horizontal. From the present position of the instrument a BS 1.640 was taken on a bench mark of RL 56.750.

Problems on fixed hair method - line of sight inclined.

Example: The instrument is set up at station A and the staff is held vertical at a point B. When the telescope is inclined at an angle of depression 10° to the horizontal, the readings on a staff are 2.670, 1.835, 1.000m. Calculate the reduced level of B and its horizontal distance from A. The staff reading taken on a bench mark of reduced level 400.00 is 1.250. The additive and multiplying constants of the instruments are 1.5 and 99.5 respectively.

Given f/i = 99.5, f + d = 1.5, R.L of Axial instrument = 400 + 1.250

Now S = 2.670 - 1.00 = 1.670, $\phi = 10°$, h = 1.835

We have, horizontal distance,

$D = (f/i)S\cos^2\phi + (f+d)\cos\phi$

= 99.5 x 1.670 cos² 10° + 1.5 cos10°

= 162.63 m ....Ans

Vertical distance,

$V = \left(\dfrac{1}{2} \times 90.5 \times 1.670 \sin 20 \right) + 1.5 \times \sin 10°$

= 28.67 m

RL of B = RL of Axial of instrument - v - h = 400 + 1.250 - 28.67 - 1.835 = 370.745 ....Ans

Exercise 1: The instrument is set up at station A and the staff is held vertical at a point B. The multiplying and additive constants of a tacheometer are 100 and 0.495 respectively. Find the distance of the station B from the instrument A and its elevation, when the telescope is inclined at an angle of elevation 7° to the horizontal. The bottom, middle and the top hair staff readings at B are 0.795, 1.0025 and 1.255 respectively. The staff reading taken on a bench mark of reduced level 286.500 is 1.650.

Tangential method of tacheometry

Objectives: At the end of this lesson you shall be able to
• **explain the tangential method of tacheometry**
• **explain the construction of sub tense bar**
• **explain the sub tense method of tacheometry.**

Tangential method

In this method, ordinary theodolite can be used for the measurements.

The staff consists of two vanes or targets of known distance apart. To measure the staff intercept, two pointings are required. The angles of elevation or depression are measured and their tangents are used for finding the horizontal distances and elevations.

This method is also not generally used. The stadia method requires only one observation, but the tangential method requires two pointings of the telescope.

The horizontal and vertical distance are computed as explained below:

Case I

When both angles of target are angles of elevation.

In this case, the staff is held vertically, in Fig 1

TANGENTIAL METHOD - CASE I
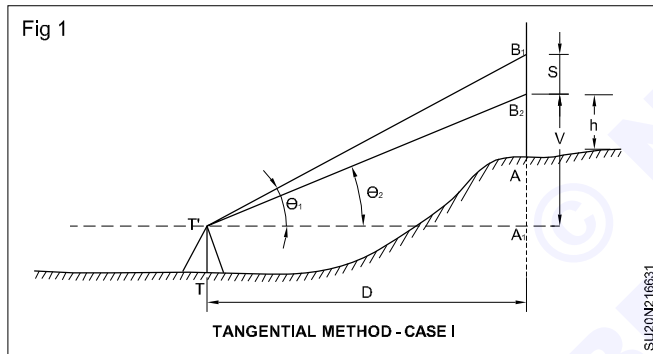
T = instrument station

T_1 = instrument axis

A = staff station

V = vertical distance between lower vane and axis of instrument

S = distance between targets

θ_1 = vertical angle made by upper target

θ_2 = vertical angle made by lower target

h = height of lower vane above the staff station.

From the figure, $V + S = D \tan\theta_1$ (1)

and $V = D \tan\theta_2$ (2)

eqn (1) - eqn (2)

$\therefore S = D(\tan\theta_1 - \tan\theta_2)$

or $D = \dfrac{S}{\tan\theta_1 - \tan\theta_2}$ (3)

$\therefore V = \dfrac{S \tan\theta_2}{\tan\theta_1 - \tan\theta_2}$ (4)

RL of A = RL of instrument axis + V - h

Case I

When both angles of target are angles of depression In such a situation, the staff is held vertically.

The notation used is the same as in case I.

In (Fig 2)

TANGENTIAL METHOD - CASE II
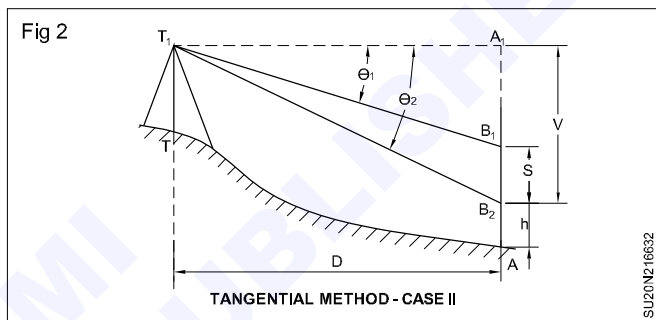
$V = D \tan\theta_2$ (1)

and $V - S = D \tan\theta_1$ (2)

eqn (1) - eqn (2)

$\therefore S = (\tan\theta_2 - \tan\theta_1)$

or $D = \dfrac{S}{(\tan\theta_2 - \tan\theta_1)}$ (3)

$\therefore V = D \tan\theta_2 = \dfrac{S \tan\theta_2}{(\tan\theta_2 - \tan\theta_1)}$

RL of A = RL of instrument axis - V - h

Problems on tangential method

Example

The following observations were taken with a transit theodolite. (Fig 3)

S= 3.250 - 0.950 = 2.300, and h= 0.950

We have, $D = \dfrac{S}{(\tan 6°30' - \tan 4°30')}$

2.300/(tan 6°30' - tan 4°30')

= 65.34 m ....Ans

V = D tan 4°30'

= 65.34 x tan 4°30'

= 5.142 m

Fig 3

TRANSIT THEODOLITE
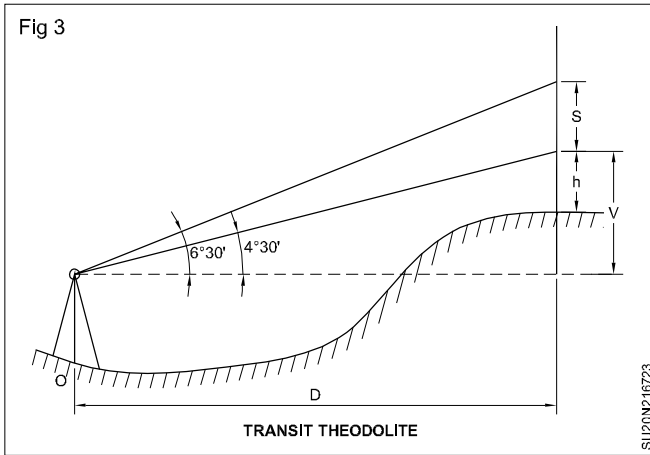
RI of A = RL of instrument axis + V-h

= 250.00 + 5.142-0.950 = 254.192 m   ....Ans

Exercise 1: In the tangential method of tacheometry, two vanes were fixed at an interval of 1m on a 3m staff with bottom vane at 1.0m. The staff was held vertical at station A and vertical angles measured for the two vanes were 5°30' and 3°15' respectively. Find the reduced level and horizontal distance of A, if the RL of BM was 200m.

Instrument station	Staff station	Target	Vertical angle	Staff reading	Remark
O	A	Lower	+4°30'	0.950	RI of instrument
		Upper	+6°30'	3.250	Axis = 250.000

Tacheometry

Advantage and disadvantages of tacheometry

Advantages

- For horizontal distances, no corrections computed by tacheometry

- From single station; required no. of points to survey details, may be provided.

- Accuracy of the survey may be verified by observing check points without loss of hours.

- Simultaneously we can proceed detail survey and contouring.

- Location of points may be find without resorting to intersections from two or more station point

- Accuracy of detail survey & contouring and other details is better than that of obtainable with a clinometer

Disadvantage

- An excess assistant and levelling staffs are needed

Determination of tacheometric constants: The value of constants A' & B' may he calculated by readings in field book

The additive constants B = (F + D) may be find by measuring distance along the theodolite telescope. The values of A & B can be calculated by doing field observation.

The

1 Measure two distances D_1, & D_2 on fairly level ground from instrument station

2 At the end of distance D_1 hold the staff having 2 targets 's' meters apart.

3 Bisect the centre target and rotate both micrometer simultaneously to bisect upper and lower targets. let the total distance moved be m1

4 Next shift the staff at D_2

5 Biscet the control target and rotate both the micrometers simultaneously to bisect lower & upper targets let the total distance moved be 'm2

Substituting the values in equation

$$D1 = \frac{A}{m1}(S + B) \qquad ---- 1$$

$$D2 = \frac{A}{m2}(S + B) \qquad ---- 2$$

2 - 1

$$D2 - D1 = AS\left(\frac{1}{m2} - \frac{1}{m1}\right)$$

$$= \frac{AS(m1 - m2)}{m1\ m2}$$

$$A = \frac{(D_2 - D_1)m1m2}{\delta(m1 - m2)}$$

Substitute the value of 'A' in eqn (2)

$$D2 = \frac{(D_2 - D_1)m1m2}{(m1-m2) \times m2} + B$$

$$B = D2 - \left[\frac{(D2-D1)m1}{m1-m2}\right]$$

$$B = \frac{D2\ (m1-m2) - (D2-D1)m1}{m1-m2}$$

$$B = \frac{D1m1 - D2m2}{m1-m2}$$

Note:

a The value of multiplying constant 'A' in equation

$$D = \frac{AS}{m} + (F + D)\ \text{varies 600 - 1000}$$

b The inclined line of sight. the formula used for fixed hair stadia tacheometry are equaly applicable to this method.

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, hill or valleys.

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.

$$\text{Contour interval} = \frac{\text{Difference in elevation b/w the index contour line}}{\text{No.of contour lines from one index contour line to the next}}$$

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 1.0, 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

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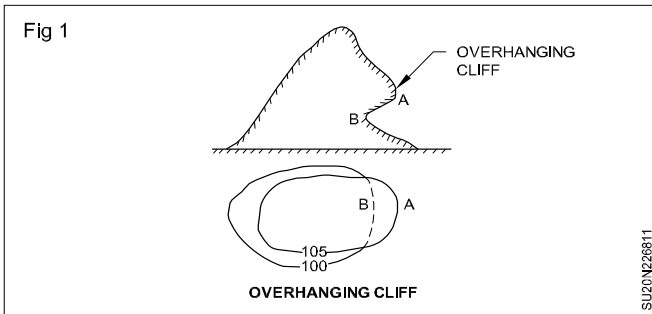
• Contours of different elevations do not unite to form one contour except in case of vertical cliff. (Fig 2)

Fig 2

VERTICAL CLIFF

100
105
110

VERTICAL CLIFF
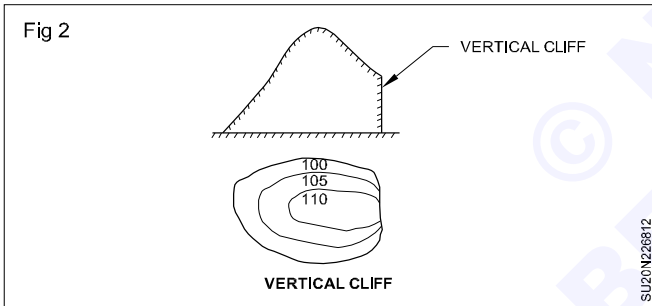
• Contours drawn closer represent a steep slope and if they are drawn far apart, represent a gentle slope. (Fig 3)

Fig 3

DOWN

UNIFORM, GENTLE SLOPE
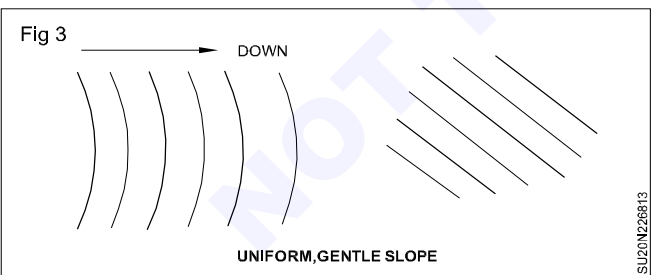
• Contours equally spaced represent a uniform slope. When contours are parallel, equidistant and straight they represent a plane area.

• 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. (Fig 4)

Fig 4

500
550
600
650

CONTOUR INTERVALS

500
550
600
650

CAKE
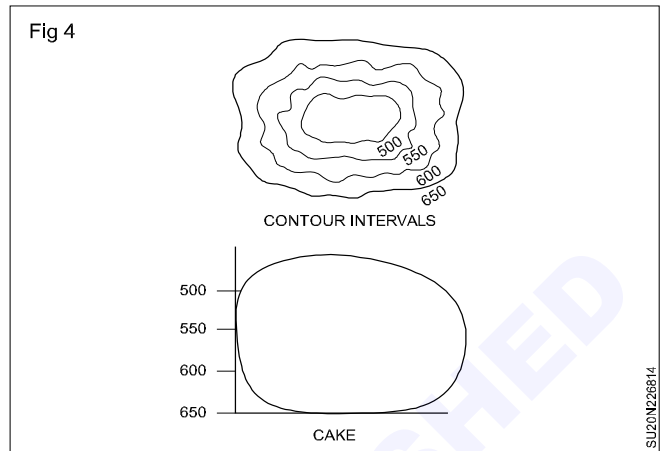
• A set of closed contours with higher values inside indicates a hill. (Fig 5)

Fig 5

700
600   650
550   500

METRES
750
700
650
600
550
500

A HILL
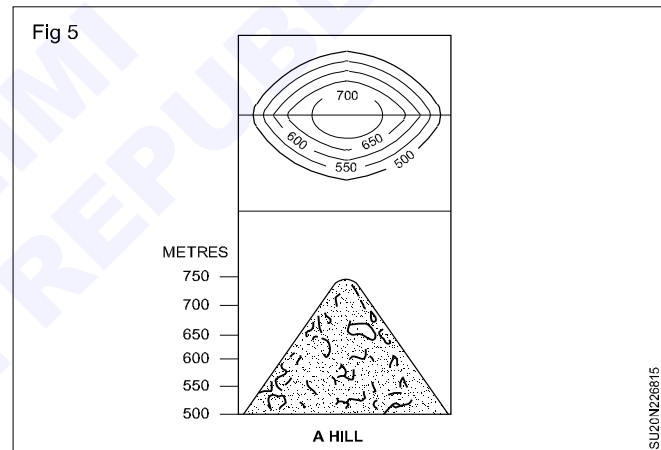
• Contours do not have sharp turnings.

• 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. (Fig 6)

• The same contour must appear on both the sides of the ridge or valley line.

• Depression between summits are called saddles. (Fig 7)

Fig 6

RIDGE LINE

VALLEY LINE

RIDGE LINE

VALLEY LINE

SU20N226816

Fig 7

SADDLE

SU20N226817
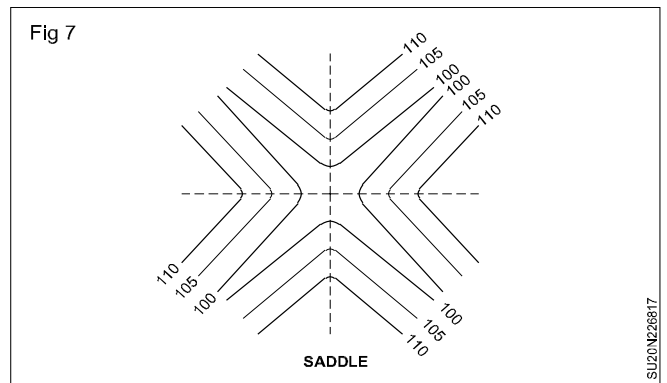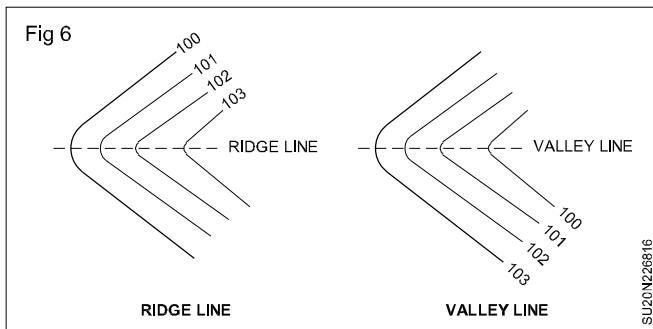
Uses of contours

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 intervisibility 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.

* The contour line is a topographical map to indicate grand depression & elevation. (up & down)

* Military uses contour maps for strategic planning.

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. Then BS reading is taken on the BM. From that calculate the height of instrument (H.I = B.S+R.L). 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 reduced 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. (Fig 1)

Fig 1
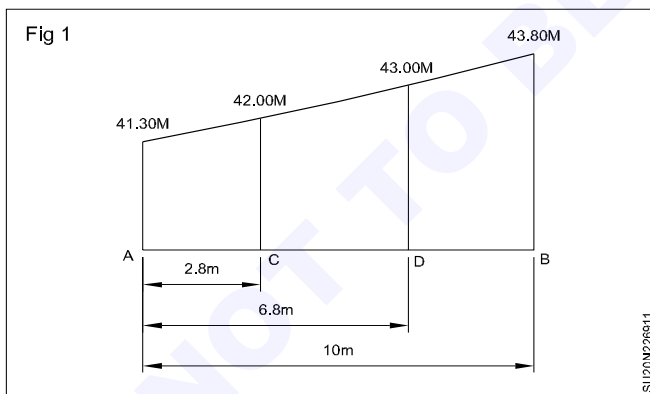
Difference in level between A and B = 43.8 - 41.3 = 2.5 m

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 $= 10 \times \dfrac{1.7}{2.5} = 6.8m$

Hence the points of reduced levels 42m and 43m are 2.8m 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.

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 2). Suppose it is required to interpolate contours between two points A and B of elevations 61.5 m and 72.5m respectively.

Fig 2
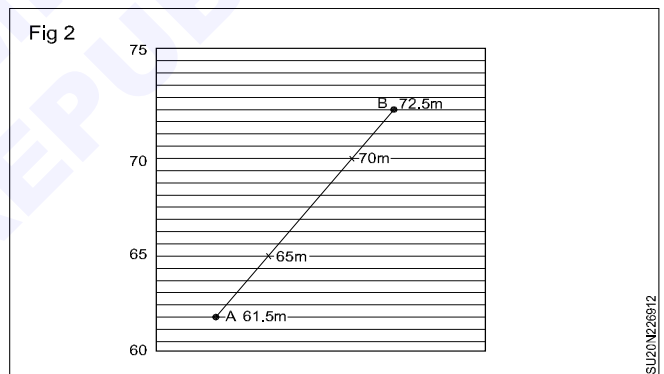
If the bottom line represents an elevation of 60m, then the successive thick lines will represent 65m, 70m and 75m etc. Place the tracing cloth so that the point A is on the third line from the bottom. Now, move the tracing cloth until B is on the fifth line above the 70m thick line. The intersections 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 ie B_1.

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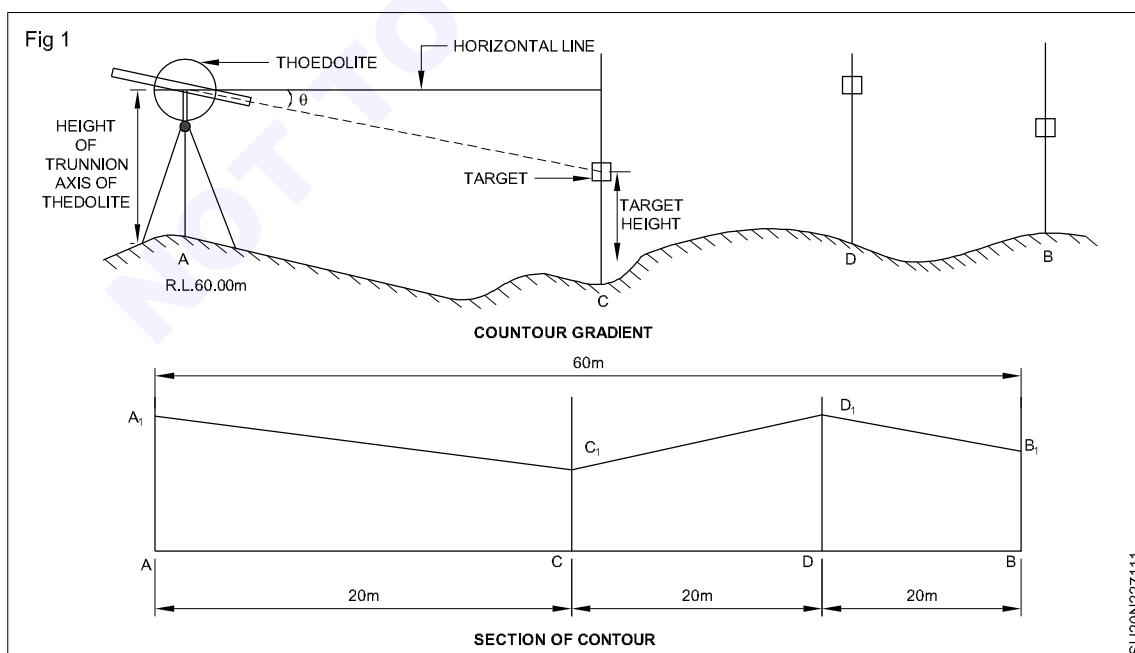
Now the grade rod = HI - the elevation of A.

= 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 without 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)

SECTIONS OF CONTOUR MAP
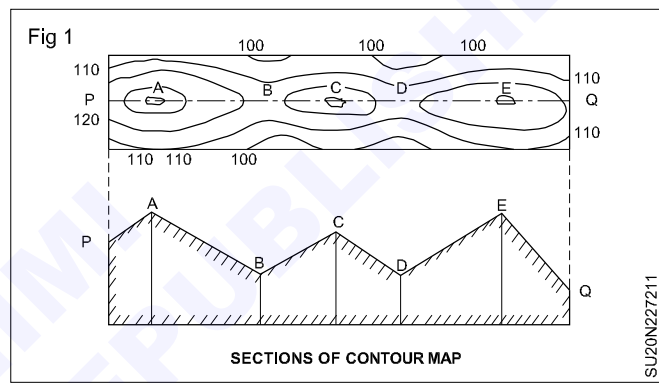
Tracing of grade of contour and computation of volume

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 100m 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 102m contour at 1. With 1 as centre and the same radius, draw an arc intersecting the 104m 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 102, 104, 106. 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 th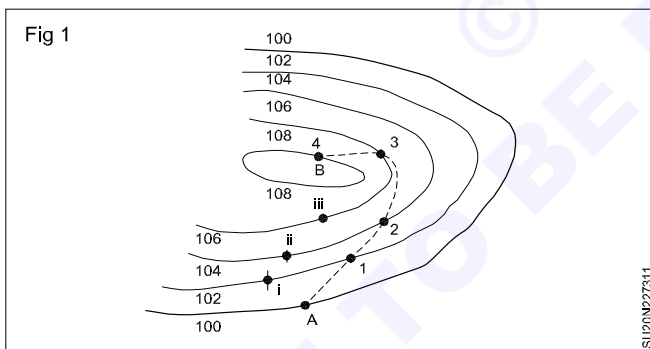e next and in most cases this assumption is incorrect. However sufficient accuracy can be attained if the contours are located with an interval small enough to record mirror features of the ground.

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:-

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

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

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

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

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

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

Fig 2
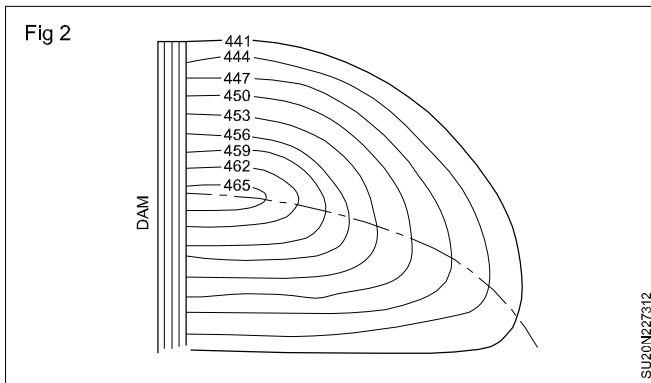
= 68,46,675 cu. metres

= 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, 462 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) 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

BONING ROD

Sight rail & boning rod (Fig 2)

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.
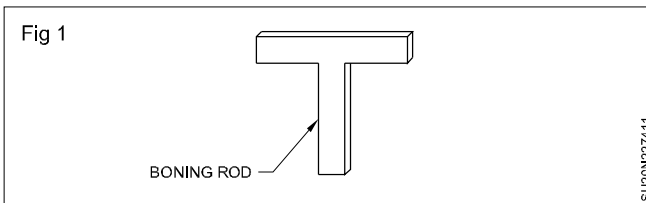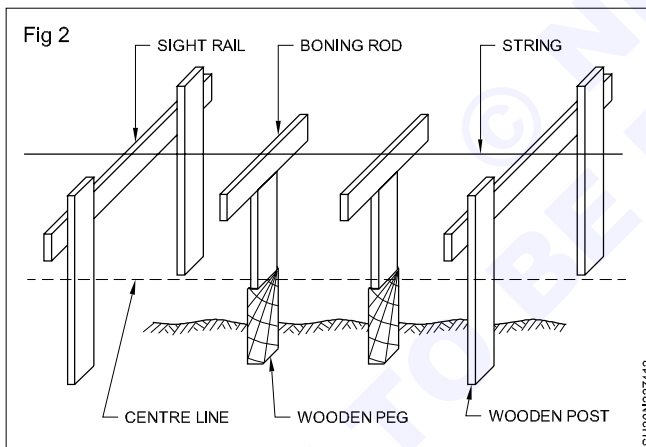

Fig 2   SIGHT RAIL   BONING ROD   STRING

CENTRE LINE   WOODEN PEG   WOODEN POST

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 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

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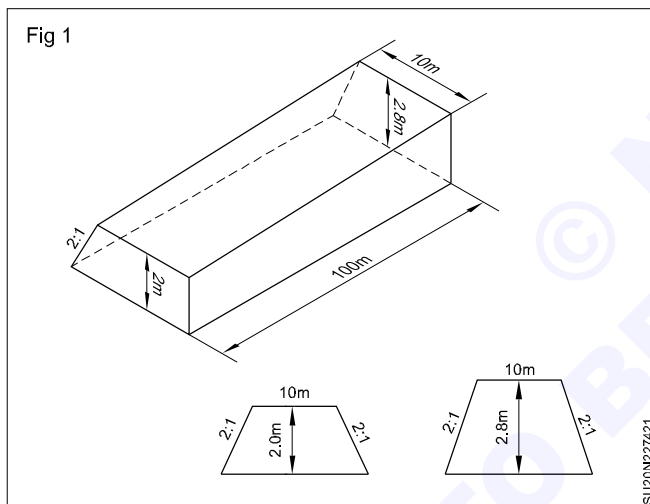
Given = B = 10 m ; L = 100 m ; S = 2

The height at section 1 = 2.0 m

The height of section 2 = 2.8 m

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

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 x 2.4 + 2 x 2.4^2) x 100

= (24 +11.52) x 100

or Volume V = 3552 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 x 2 +2 x 2^2 = 28m^2

A_2 = Bd$_2$ + Sd$^2_2$ = 10 x 2.8 + 2x2.8^2 = 43.68m^2

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

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

Now, total volume of earth work = sectional area length

V   = A x L

= 35.84 x 100

= 3584 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 x 2.8 + 2 x 2.8^2 - 43.68m^2

A = Bd + Sd^2=10 x 2.4 + 2 x 2.4^2

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

$= \dfrac{2.0 + 2.8}{2} = 2.4m$, A=(10 x 2.4) + (2 x 2.4^2) = 35.52m^2

From the prismoidal formula, we get

$$v = \frac{L}{6}(\text{area of first section} + 4 \times \text{area of mid section} + \text{area of last section})$$

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

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

Example 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)

Fig 2
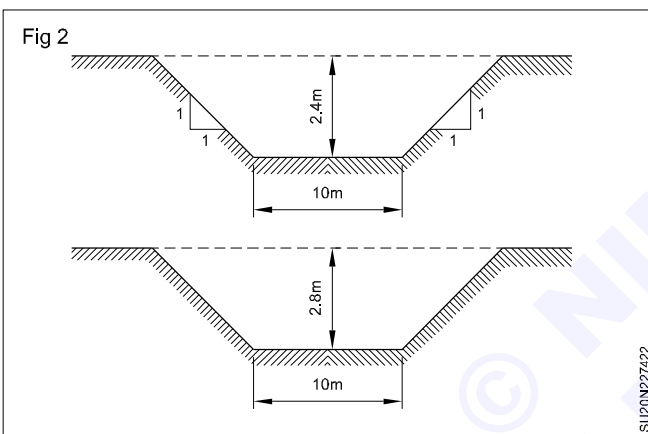
Solution. 1 Average depth method

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

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 m³. Ans

Average cross - sectional area method

Let A_1 = Cross sectional area at section 1

A_2 = Cross sectional area of section 2

$\therefore A_1 = Bd_1 + Sd^2_1 = 10 \times 2.4 + 2.4^2 = 29.76$

$A_2 = Bd_2 + Sd^2_2 = 10 \times 2.8 + 1 \times 2.8^2 - 35.84$m²

Average cross sectional area A =

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

Volume = Average cross sectional area x length

= 32.80 x 100 = 3280 m². 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 $A_1 = bd_1 + sd_1^2 = 10 \times 2.4 + 1 \times 2.4^2 = 29.76 \text{m}^2$

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

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

$$= \frac{2.4 + 2.8}{2} = 2.6 \text{m}$$

$\therefore A = bd + sd^2$

$= 10 \times 2.6 + 1 \times 2.6^2 = 32.76$ m²

Substituting the values in the prismoidal formula, we get.

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

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

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

= 3277.333 m³. Ans

Example 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	100.02
200	95.37	100.04
400	99.35	100.08
500	102.67	100.10
600	110.52	100.12
700	105.62	100.14
800	101.70	100.16
900	102.28	100.18
1000	96.77	100.20

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

Solution

Rise per 100 m distance

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

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
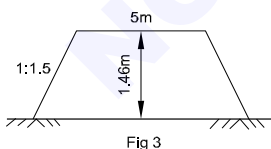
Area of cross section

= 5 x 1.46 + 1.5 x 1.46² = 10.50 m²

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

= 5 x 4.67 + 1.5 x 4.67²

= 56.06 m²
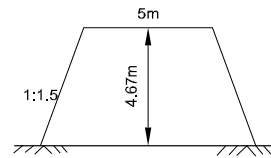
Fig 4

R. D 400 m (Fig 5)
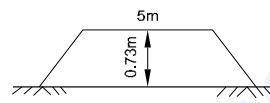
Fig 5

Formation level

= 100.00 + 0.08 = 100.08 m

Ground level = 99.35 m

∴ Ht. of embankment

= 100.08 - 99.35

= 0.73 m

Area of cross section = 5 x 0.73 + 1.5 x 0.73² = 4.45 m²

R. D 500 m (Fig 6)
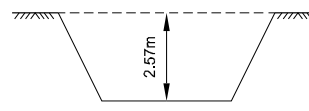
Fig 6

Formation level

= 100.00 + 0.10 = 100.10 m

Ground level = 102.67m

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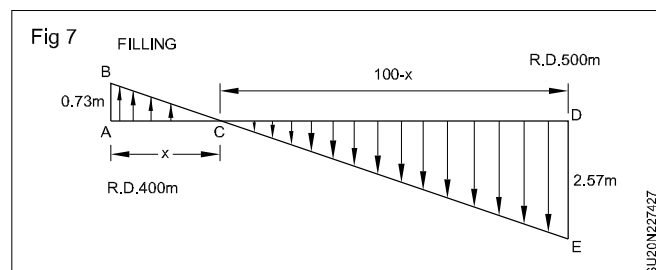
To locate the section having neither banking nor cutting, proceed as under :

Let C be the section having neither banking nor cutting.

Let   AC = x

∴   CD = 100 - x

From similar $\triangle$s ABC and CDE, we get

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

2.57x = (100 - X) 0.73

2.57 x = 73 - 0.73 x

3.3 x = 73

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

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)

Fig 8
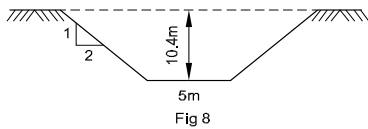
Formation level

= 100.00 + 0.12 = 100.12 m

Ground level = 110.52 m

Depth of cutting

= 110.52 - 100.12 = 10.40 m

Area of cross - section

= 5 x 10.4 + 2 x 10.4^2

= 268.32 m^2

R. D 700 m (Fig 9)

Fig 9
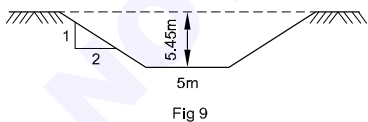
Formation level

= 100.00 + 0.14 = 100.14 m

Ground level = 105.62 m

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)

Fig 10
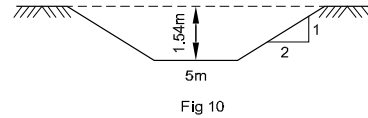
Formation level

= 100.00 + 0.16 = 100.16 m

Ground level = 101.70 m

Depth of cutting

= 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)

Fig 11
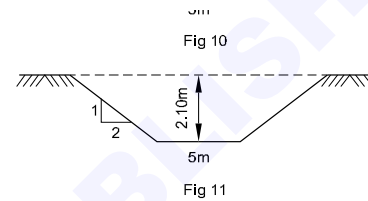
Formation level

= 100.00 + 0.18 = 100.18 m

Ground level = 102.28 m

Depth of cutting

= 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)

Fig 12
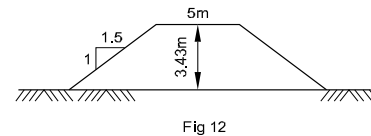
Formation level = 100.20 m

Ground level = 96. 77 m

Ht. of embankment

= 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)

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

$$3.43x + 2.10x = 210$$

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

Fig 13
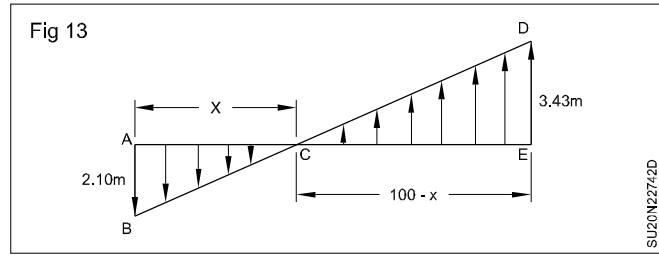
Calculation of the earthwork is done as tabulated here under:

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 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:

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

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 cutting and 1:2 in banking. There is no transverse slope of the ground. Apply prismoidal formula for computation.

Difference in formation level at 50 m distance.

$$\frac{0.8}{400} \times 50 = 0.1\,m$$

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	0.06	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)
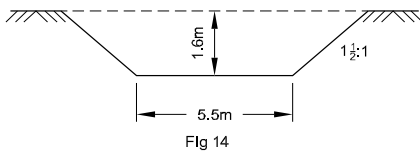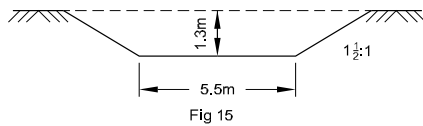
Fig 14

Area   = 5.5 x 1.6 + 1.5 x 1.6^2

        = 12.64 m^2.

Section B : (Fig 15)

Fig 15

Area   = 5.5 x 1.3 + 1.5 x 1.3^2

        = 9.69 m^2

Section C : (Fig 16)

Fig 16

Area   = 5.5 x 1.0 + 1.5 x 1.0^2

        = 7.00 m^2

Section D : (Fig 17)

Fig 17

Area   = 5.5 x 0.6 + 1.5 x 0.6^2
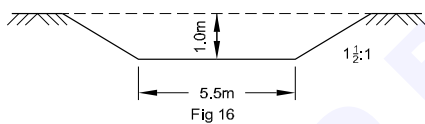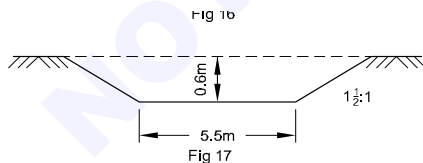
        = 3.84 m^2

Section E : (Fig 18)

Area   = zero = 0.00 m^2
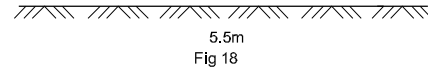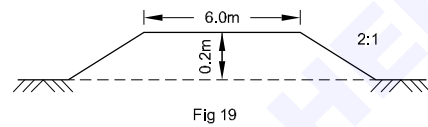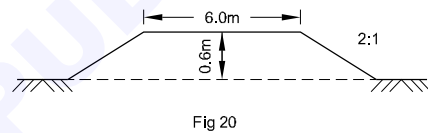
5.5m
Fig 18

Section F : (Fig 19)

Fig 19

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

        = 1.28 m^2

Section G : (Fig 20)

Fig 20

Area   = 6 x 0.6 + 2 x 0.6^2

        = 4.32 m^2

Section H : (Fig 21)

Fig 21

Area   = 6 x 0.9 + 2 x 0.9^2

        = 7.02 m^2

Section I : (Fig 22)

Fig 22

Area   = 6 x 0.6 + 2 x 0.6^2
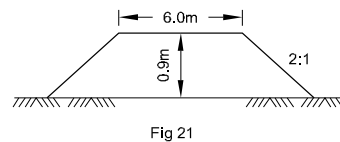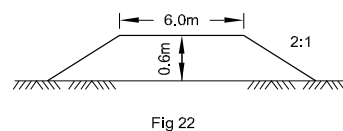
        = 4.32 m^2

Applying the prismoidal formula :

-(a)Volume in cutting

$$V = \frac{L}{3}\left(\text{First area} + \text{Last area} + 4\sum\text{Even area} + 2\sum\text{odd area}\right)$$

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

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

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

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

= 1346 m³. 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 m³. 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 nearby horizontal control points.

Locating details

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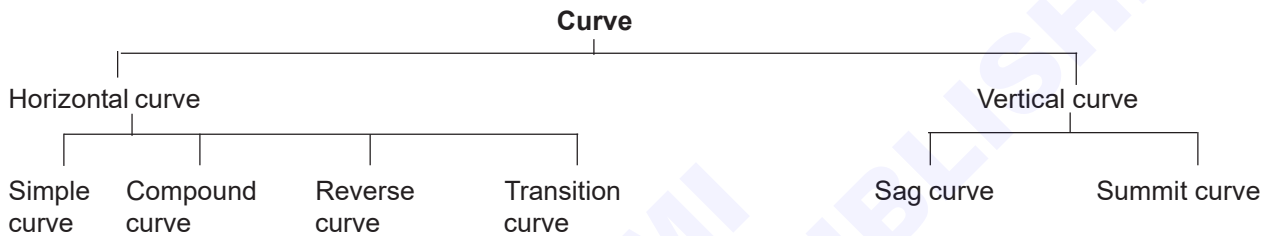
Curves are generally classified into two. They are horizontal and vertical.

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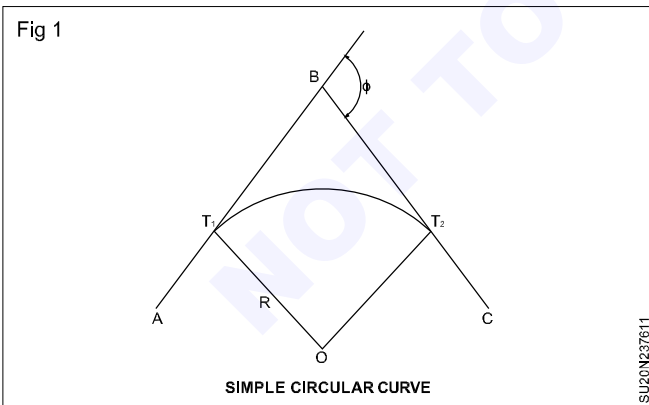
Compound curve: Curve which are consists of two or more arcs of different radii is called compound curve. (Fig 2)

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

COMPOUND CURVE
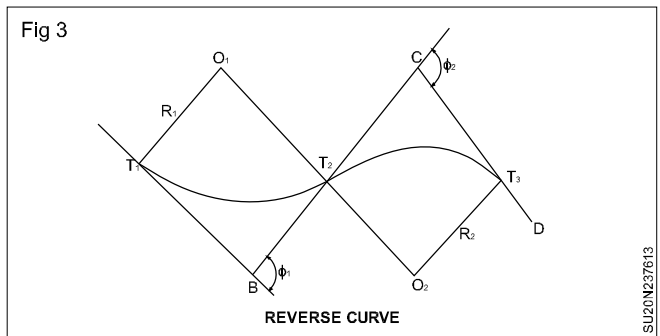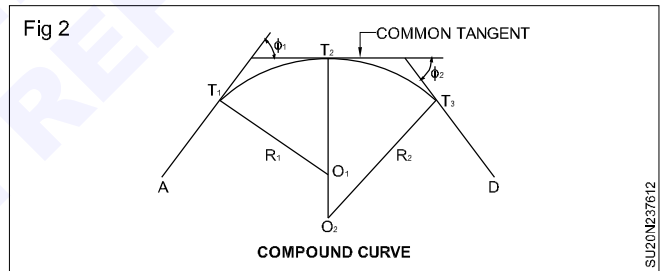
REVERSE CURVE

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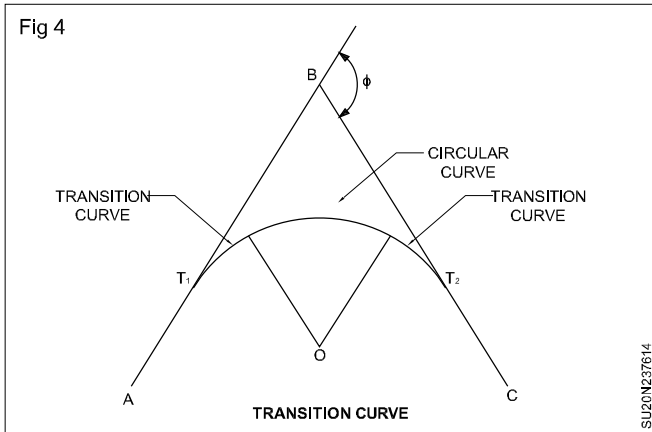
Vertical curves: Curves which are provided on roads or railways for easy change of grade called vertical curves.

Vertical curves are divided into two.

Sag curve or valley curve: (Fig 5)

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 5)

Fig 5

Fig 5a

SAG CURVE

Fig 5b

SUMMIT CURVE
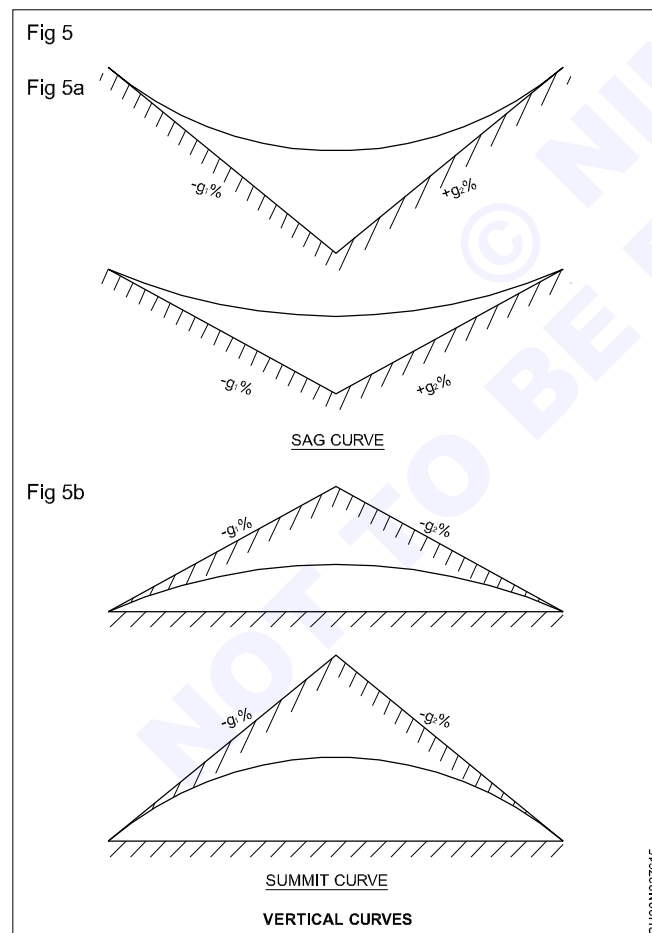
VERTICAL CURVES

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

Fig 6

ELEMENTS OF A CIRCULAR CURVE
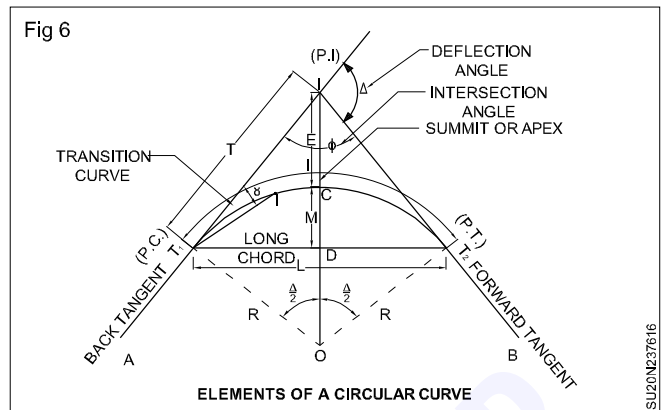
Back tangent: The tangent AT_1 at the point of commencement T_1 of the curve, is the back tangent.

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.

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 (I): 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. 7).

Fig 7

GEOMETRICS OF A CIRCLE
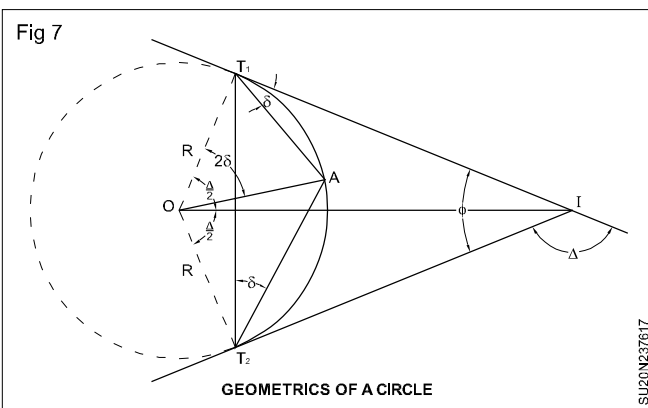
Length of tangents $T_1I = IT_2 = T = R \tan \dfrac{\Delta}{2}$

Long chord $T_1 T_2 = 2 \ R \ Sin \dfrac{\Delta}{2}$

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

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

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.

$\angle AT_2 T_1 = \angle IT_1A$
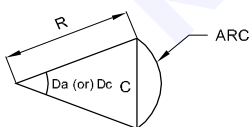
$R = \dfrac{C}{2Sin\left(\dfrac{D_C}{2}\right)}$

where

C = Chord length

R = Radius of curvature

DL = Degree of curvature

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 (Fig 5)

Length of curve (I)

$I = T_1 CT_2$

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

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

Alternatively, from arc definition

Here,

$\dfrac{Da}{30} = \dfrac{\Delta}{I}$

$I = OT_1 \tan \dfrac{\Delta}{2}$

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

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)

$T = T_1I = IT_2$

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

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

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+ I

Long chord (L)

$L = T_1T_2$

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

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

External distance (E)

E = IC

= OI - OC

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

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

Mid - ordinate (M)

M = DC

= OC - OD

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

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

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

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

Super elevation 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:

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

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:

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

Where

B = the gauge of the railway track (B = 1.676 m for broad gauge and 1.00m 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, 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 8)

Fig 8
ARC DEFINITION
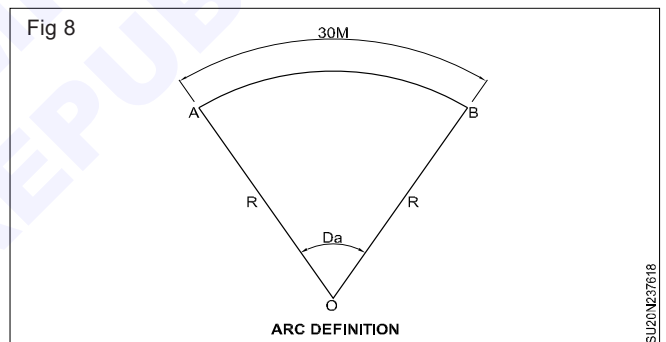
Here the degree of curve is the central angle D_a that is subtended by an arc AB of 30 m length. The arc definition for degree of curve, is the method most frequently followed in highway practice.

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

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

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

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

If the arc length is taken as 20 m then

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

Chord definition (Fig 9)
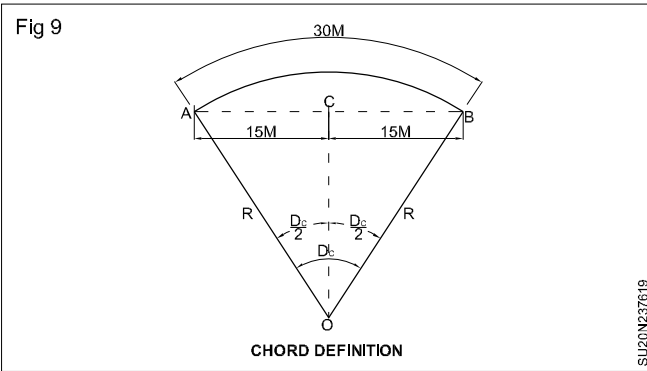
CHORD DEFINITION

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 10)

ELEMENTS OF SIMPLE CURVE
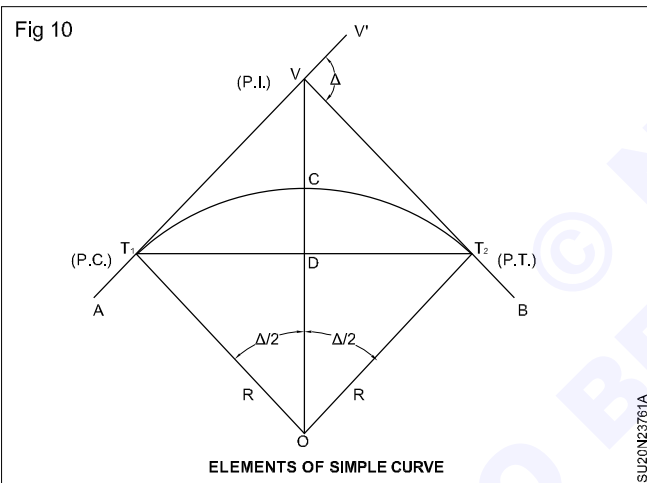
1 Length of curve (l)

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.

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

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) = $l = T_1T_2$

$$= 2 \; OT_1\text{Sin}\frac{\Delta}{2} = 2R\sin\left[\frac{\Delta}{2}\right]$$

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)

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

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

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 (Figs 1 & 2).

OFFSETS OR ORDINATES FROM LONG CHORD

OFFSETS OR ORDINATES FROM LONG CHORD
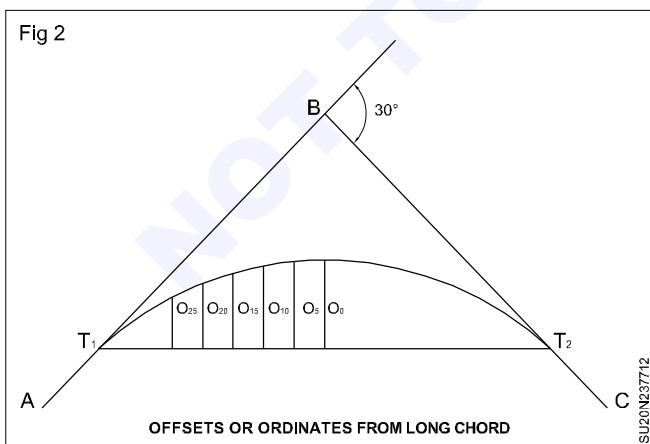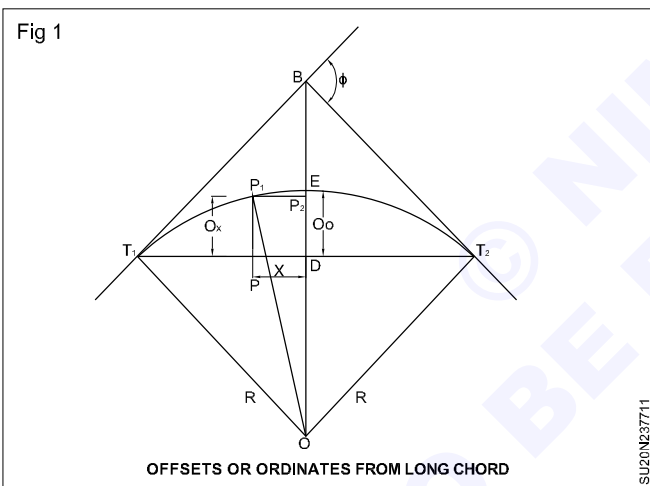
The tangent length is calculated according to the formula;
TL = R tan ϕ/2

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 ϕ/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 ϕ/2) (1)

(b) Again OE = 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) $O_0 = R - \sqrt{R^2 - (L/2)^2}$ (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 those 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 = $R \tan \dfrac{\phi}{2}$

= 100 x tan 15° = 26.79 m

Chainage of T_1 = 150.50 - 26.79 = 123.71 m

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

Chainage of T_2 = 123.71+ 52.36 = 176.07 m

Length of long chord (L) = 2R sin ϕ/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, $O_0 = R - \sqrt{R^2 - \left(\dfrac{L}{2}\right)^2}$

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

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

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

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.

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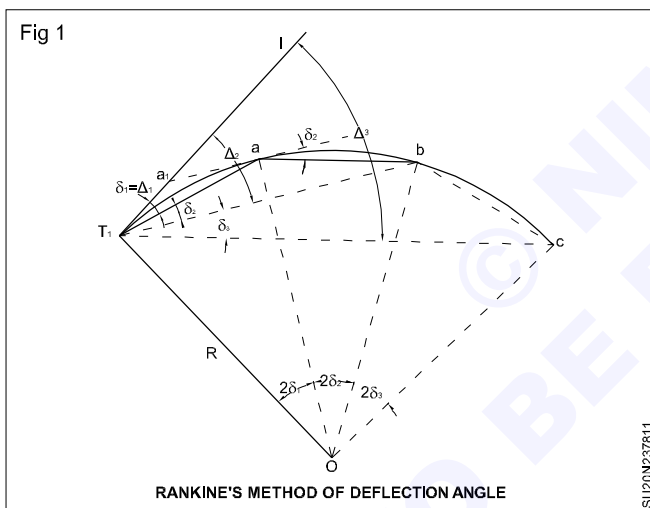
A deflection angle to any point on the curve is the angle at P.C. between the tangent and the chord from P.C. to that point. According to Rankine's method, this deflection angle is equal to half the angle subtended by the arc at the centre.

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, c 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,

$$\Delta T_1 Oa = 2 \times \angle IT_1 a = 2\delta_1$$

Now R x $2\delta_1$ = $T_1 a$ = C_1

or $\delta_1 = \dfrac{C_1}{2R}$ radians

or $\delta_1 = \dfrac{C_1}{2R} \times \dfrac{180°}{\pi}$ degrees

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

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

Similarly,

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

For the first chord $T_1 a$, the deflection angle Δ_1 is its tangential angle δ_1. For the second point b on the curve, the deflection angle $\Delta_2 = \angle IT_1 b$

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 $\angle aT_1 b = \delta_2$, so that

$$\Delta_2 = \angle IT_1 b = \angle IT_1 a + \angle aT_1 b$$

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

Similarly, $\angle bT_1 c = \delta_2$, so that

Similarly, $\angle bTc = \delta_2$,

$$\Delta_3 = \angle IT_1 c = \angle IT_1 b + \angle bT_1 c$$
$$= \delta_1 + \delta_2 + \delta_3 = \Delta_2 + \delta_3$$
$$\text{and} \Delta_n = \delta_1 + \delta_2 + \dots + \delta_n$$
$$= \Delta_{n-1} + \delta_n$$

Last point of the curve is T_2, so that

$$= \angle IT_1 T_2 = \dfrac{\Delta}{2}$$

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 ϕ/2

= 250 x tan 15° = 67.0 m

$$Curve\,lengh = \frac{\pi R\phi°}{180°} = \frac{\pi \times 250 \times 30°}{180°} = 130.89m$$

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,

$$\delta_1 = \frac{1,718.9 \times 7.0}{250} \text{ mins} = 0°\,48'\,8''$$

Deflection angle for full chord,

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

Deflection angle for final sub-chord,

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

Arithmetical check:

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

$$\phi/2 = \frac{30°}{2} = 15°$$

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
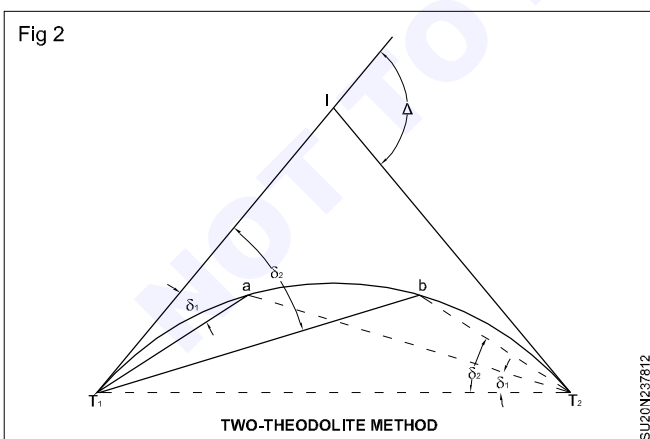
$\angle IT_1a = \delta_1 \angle aT_2T_1$ and $\angle IT_1b = \delta_2 = \angle bT_2T_1$

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
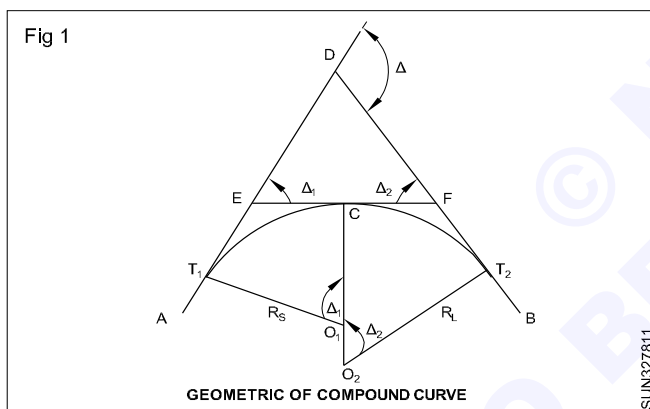
The essential components of a compound arc:

Δ = Total deflection angle

Δ_1 = deflection angle DEF

Δ_2 = deflection angle DFE

R_s = radius of small arc T_1 C

R_L = radius of large arc T_2 C

T_s = total tangent length (small) = T_1 D

T_L = 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

$T_1E = CE = t_1$ and $CF = F T_2 = t_2$

t_1= tangent for small arc T_1C

t_2= tangent for large arc T_2C

Applying sine rule to DEC we get

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

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

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

Hence total tangent length Ts = T_1E + ED

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

Total tangent length = T_L = 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.

Elements of reverse curve: (Flg 1)

ELEMENTS OF A REVERSE CURVE
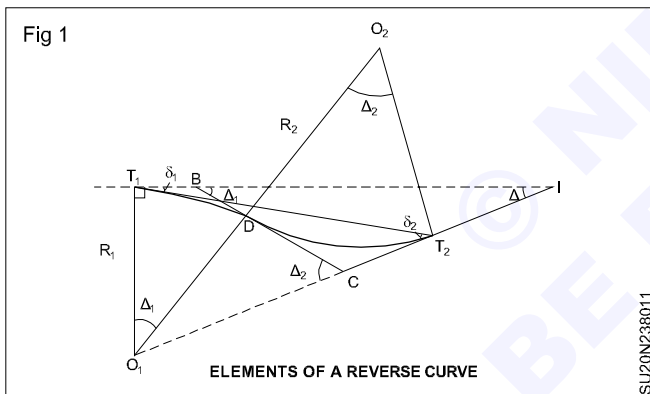
1 Radii R_1, R_2 are two circular arcs

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 ($\Delta_1 > \Delta_2$)

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)

NON-PARALLEL STRAIGHTS $\Delta_1 > \Delta_2$
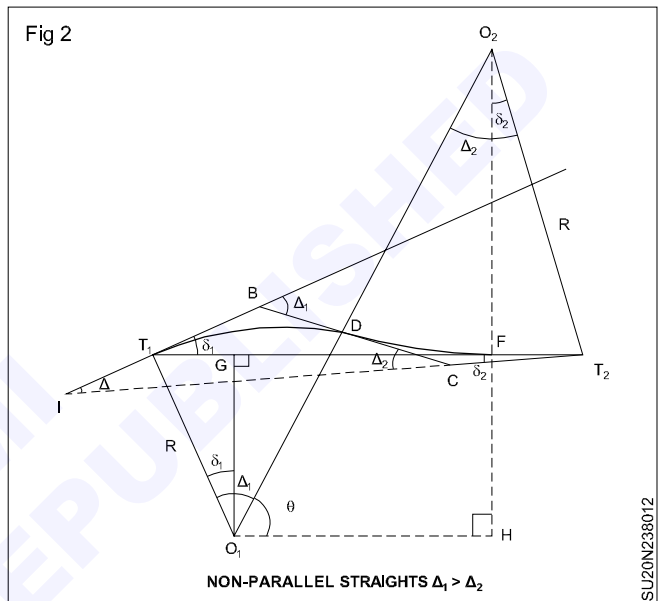
The angles δ1 and δ2 between the line T_1, T_2 and back straight. T, B and forward straight CT_2 respectively.

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 O_1 H perpendicular to O_2 F

let the angle $O_2 O_1 H$ be θ

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

O, G = R Cos δ_1 = FH

O_2 F = R Cos δ_2

$O_1 O_2$ = 2R.

$$\sin \theta = \frac{O_2 H}{O_1 O_2} = \frac{O_2 F + FH}{O_1 O_2} = \frac{R \cos \delta_1 + R \cos \delta_2}{2R}$$

$$\theta = \sin^{-1} \left[\frac{\cos \delta_1 + \cos \delta_2}{2} \right]$$

Again: $T_1 G = R . \sin \delta_1$

$G F = O_1 H = 2R \cos \theta$

$FT_2 = R \sin \delta_2$

Substitute values in

$L = R \sin \delta_1 + 2R \cos \theta + R \sin \delta_2$

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

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

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)

Fig 1
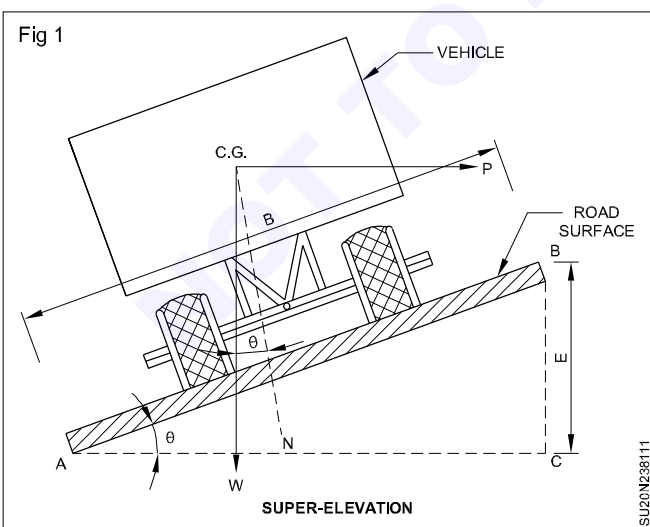
SUPER-ELEVATION

Super elevation: When a fast moving vehicles negotiates a horizontal curves the centrifugal force acts on the vehicle from 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.

Super elevation $e = \dfrac{BC}{AC} = \tan\theta$

In practice the value of θ is so small, then $\tan\theta$ is equal to $\sin\theta$

Then $e = \tan\theta = \sin\theta = \dfrac{BC}{AB} = \dfrac{E}{B}$

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 $e = \dfrac{V^2}{127R}$

(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)

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

Where:

I : Total length of transition curve

R: Radius of circular curve

L: distance measured along curve

X= perpendicular offset form tangent

CUBICAL SPIRAL
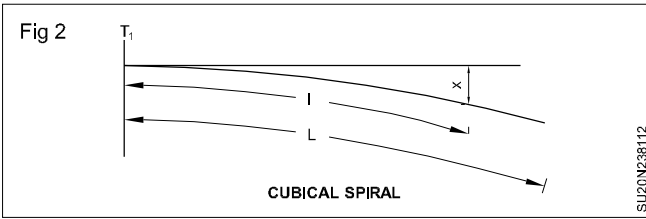
2 Cubic parabola equation (Fig 3)

CUBIC PARABOLA
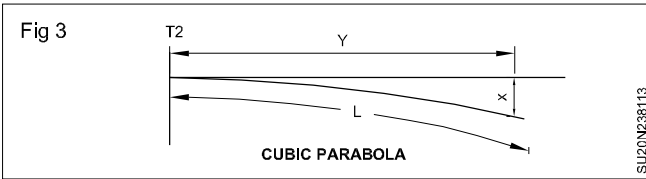
$$x = \frac{Y^3}{6RL}$$

X = Perpendicular offset from tangent

Y = Distance measured along the tangent

R = Radius of circular curve

L = Length of transition curve

3 Lemniscates curve equation (Fig 4)

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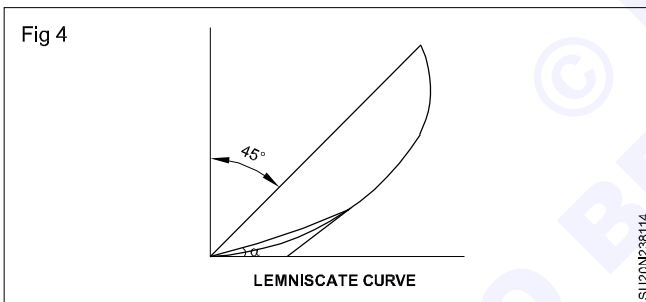
$$r - \frac{P}{3 \sin \propto}$$

Where:

r = radius of curvature

p = polar ray of any point

∝ = Polar deflection angle (angle between polar ray and straight)

The ideal transition curve (Fig 5)

Centrifugal force action on a vehicle $P = \dfrac{Wv^2}{gr}$

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

THE IDEAL TRANSITION CURVE
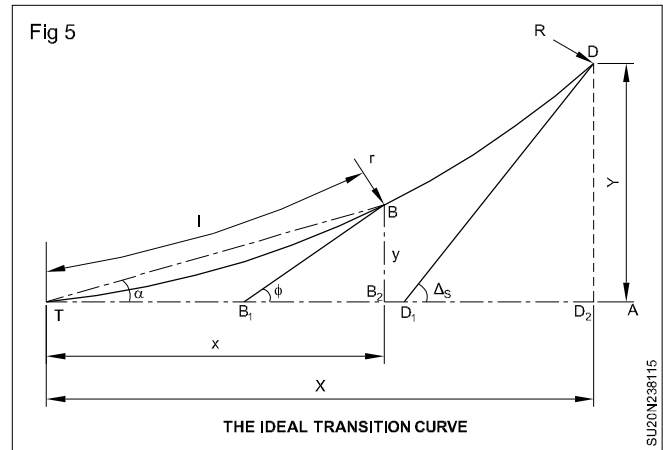
T = Tangent point = beginning of trans curve.

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.

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

Δ s Spiral angle.

l = Length of curve fron l to B.

R = Radius of the circular curve

$L = d\theta = \dfrac{}{RL} .dl$ = Total length of transition curve.

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

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

$x = TB_2$ = x co-ordinate of any point B on transition curve.

$Y = BB_2$= y co-ordinate of any point B on transition curve.

We know I.r. $= L.R. \therefore \dfrac{1}{r} = \dfrac{l}{RL}$

But $\dfrac{1}{r} = $ curvature $\dfrac{d\theta}{dl} = \dfrac{l}{RL}$

$\therefore d\theta = \dfrac{l - dl}{RL}$

Integrating we get $= \theta = \dfrac{l^2}{2RL} + C$

When I = 0 & θ = 0 ∴ C = 0

$\boxed{\therefore \theta = l^2/2RL}$ it is intrinsic equation of the ideal transition curve.

This equation also expressed in the form of

$$I = \sqrt{2RL\varphi} = k\sqrt{\varphi}$$

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

$$I = L\phi = \Delta s = \frac{L^2}{2RL} = \frac{L}{2R}$$

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.

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

$$\therefore I = \frac{1}{r} = \text{constant LR.}$$

Total length of curve up to its end = L

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

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

Where : r = radius of curve

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

$$e \propto I \propto 1.18 \frac{v^2}{r} \text{ or } I = \frac{1}{r}$$

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. Circular arc or parabola arc may be used.

The general Grade or gradient to railway or highway are 2% or 3% i.e 1 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 $= \dfrac{dy}{dx} = 2ax + b$

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

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

SUMMIT (OR) CONVEX
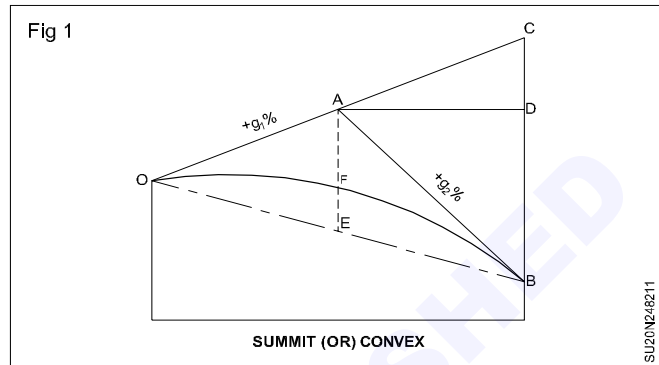
2 A down grade (-g %) followed by an upgrade grade (+g$_2$%) (Fig 2)

Fig 2
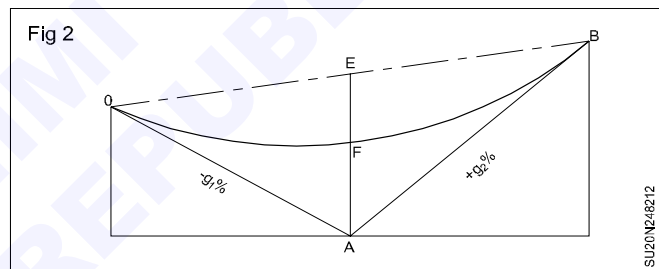
3 An upgrade (+g$_1$%) followed by another upgrade (+ g$_2$%) g$_2$ > g$_1$ (Fig 3)

Fig 3
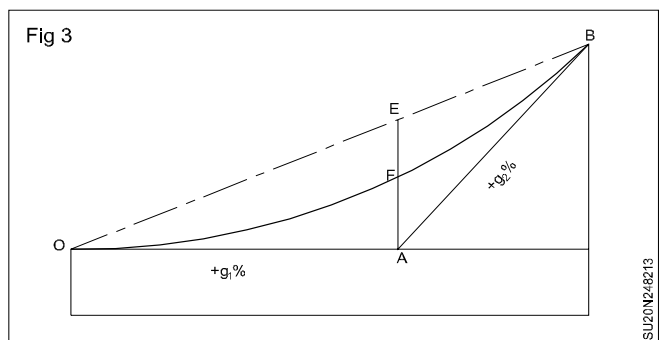
4 An upgrade (+g$_1$ %) followed by another grade (+g$_2$ %) (g$_1$ > g$_2$) (Fig 4)

Fig 4
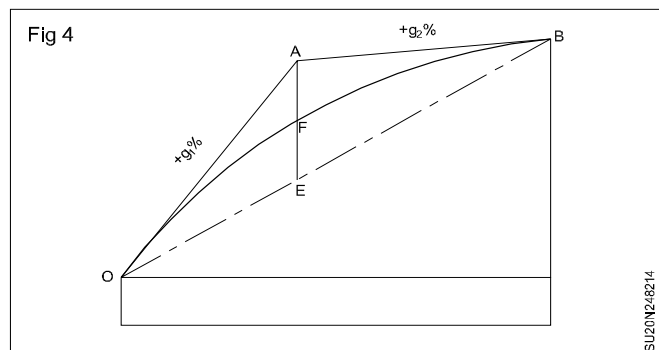
5   A down grade (-g_1%) followed by another downgrade
    (-g_2%) $g_2 > g_1$ (Fig 5)

Fig 5
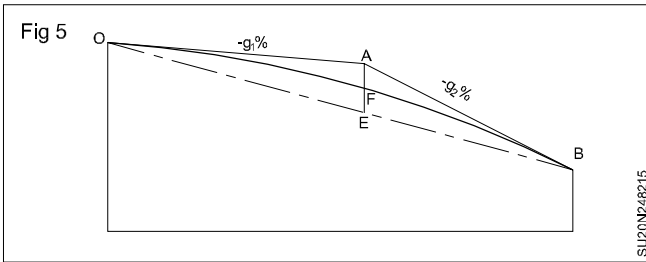
6   A down grade (-g_1%) followed by another down grade
    (-g_2%) ($g_1 > g_2$) (Fig 6)

Fig 6
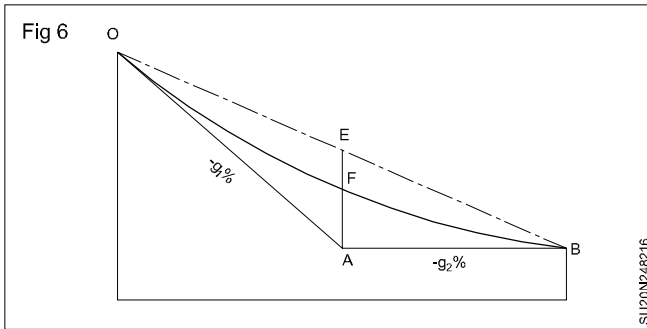
Computation and setting out of vertical curve (Fig 7)

Fig 7

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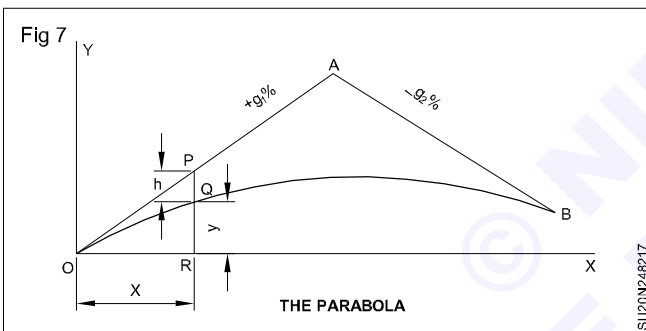
In vertical curves all distances along the curve are measured horizontally and all offsets from the tangents to the curve are measured vertically from the Fig 7

OY and OX are ordinates passing through beginning of the curve 'O'.

OA Tangent + g_1%

AB Tangent – g_2 % slope

Q. any point on curve having co-ordinates (x, y)

Draw PQR perpendicular Via Q to OX.

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

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

At $x = 0$, $\frac{dy}{dx} = +g_1$

$g_1 = 2a (0) + b$

$\therefore b = g_1$

Have equating of parabola $y = ax^2 + g_x$ (1)
Let PQ = h = Tangent correction

PQ = PR –QR = lent PR = $g_1 x$

          QR = y

$\therefore$ PQ = h = $g_1 x$ –y

but $g_1 x$ –y = -ax^2 from Eqn   (1)

$\therefore$ h = $g_1 x$- 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 slightly 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)

CALCULATION OF CONSTANT 'K'
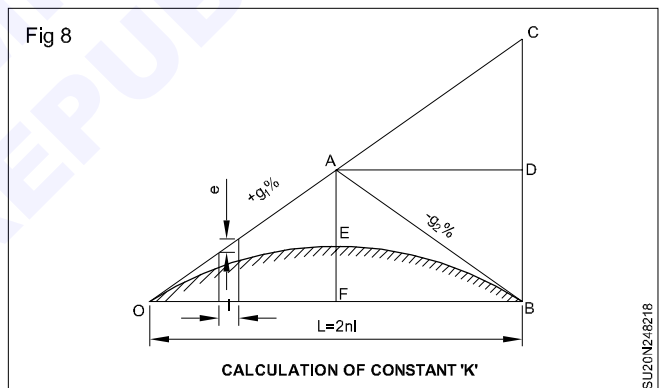
Can be found by the Fig 8.

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 per chord lengh 'l'

OA = AC

CD = ne_1

BD = -ne_2

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

From Eqn h = kN^2, CB = KN^2

Where N = 2n

$4Kn^2$ = 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 total station 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

TOTAL STATION - INSTRUMENT COMPONENTS
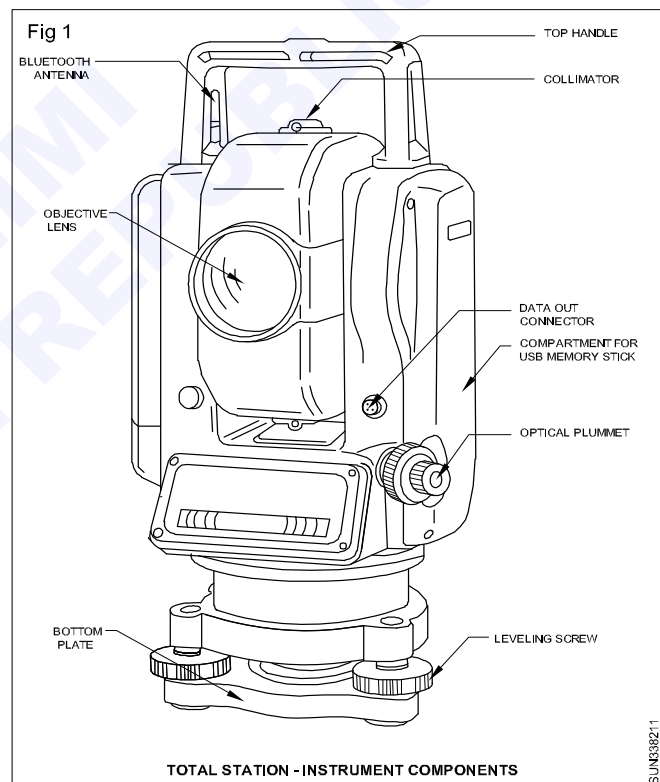
Use of total station

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.

Accessories of total station
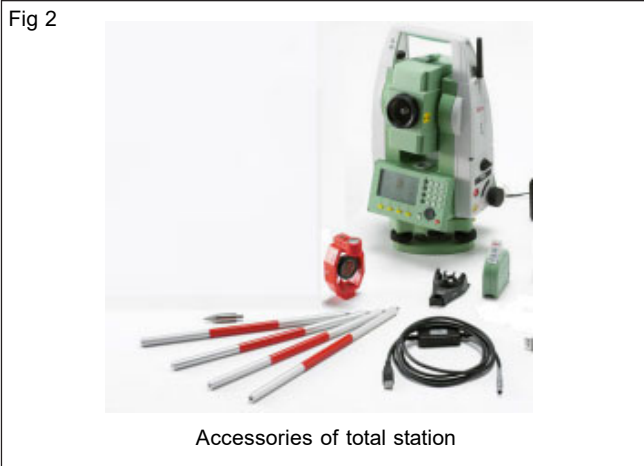
Total station definition

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

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)

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 (Figs 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.

MEASUREMENT PRINCIPLE

MEASUREMENT PRINCIPLE
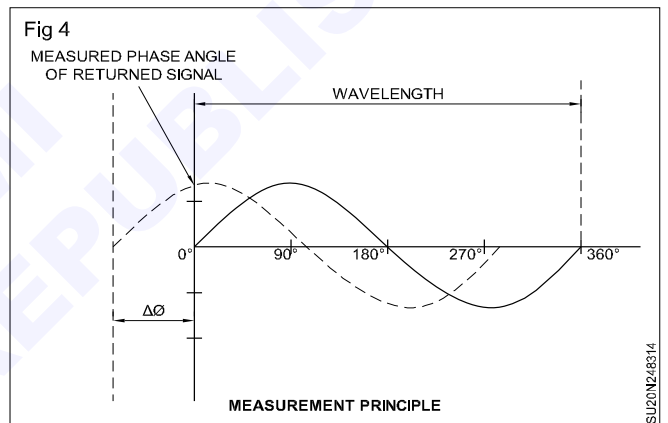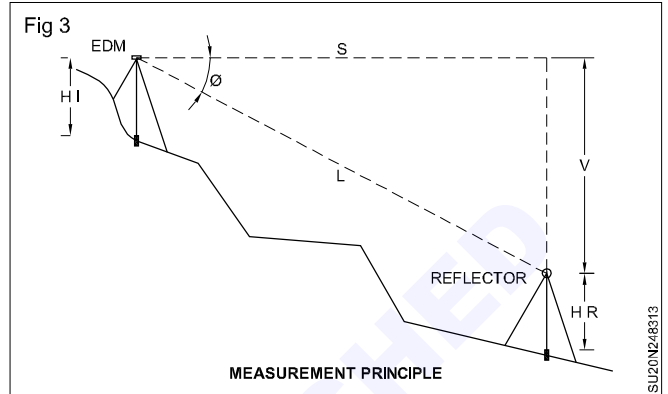
Most modern total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar-codes etched on rotating glass cylinders or discs within the instrument. The best quality total stations are capable of measuring angles to 0.5 arc second. Inexpensive "construction 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	Angle measurement	Preparation of site plan	Reduce level calculation
Electronic Distance Measurement (EDM)	Absolute continuous Encoder	3D coordinate system.	
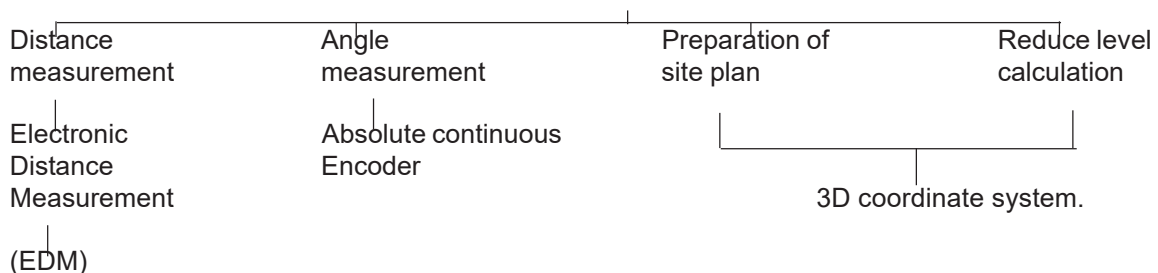
3D coordinates (Fig 5)

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
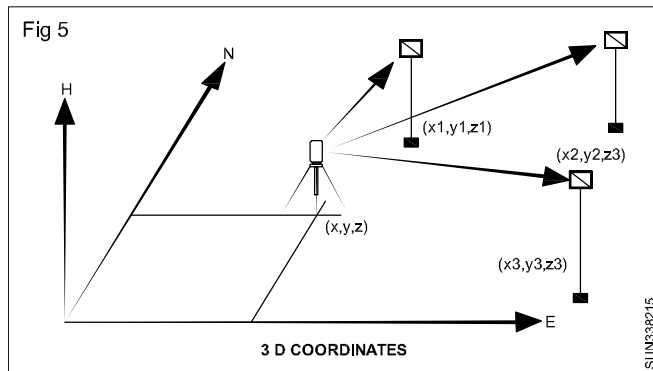
3 D COORDINATES

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. (Fig 6)

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
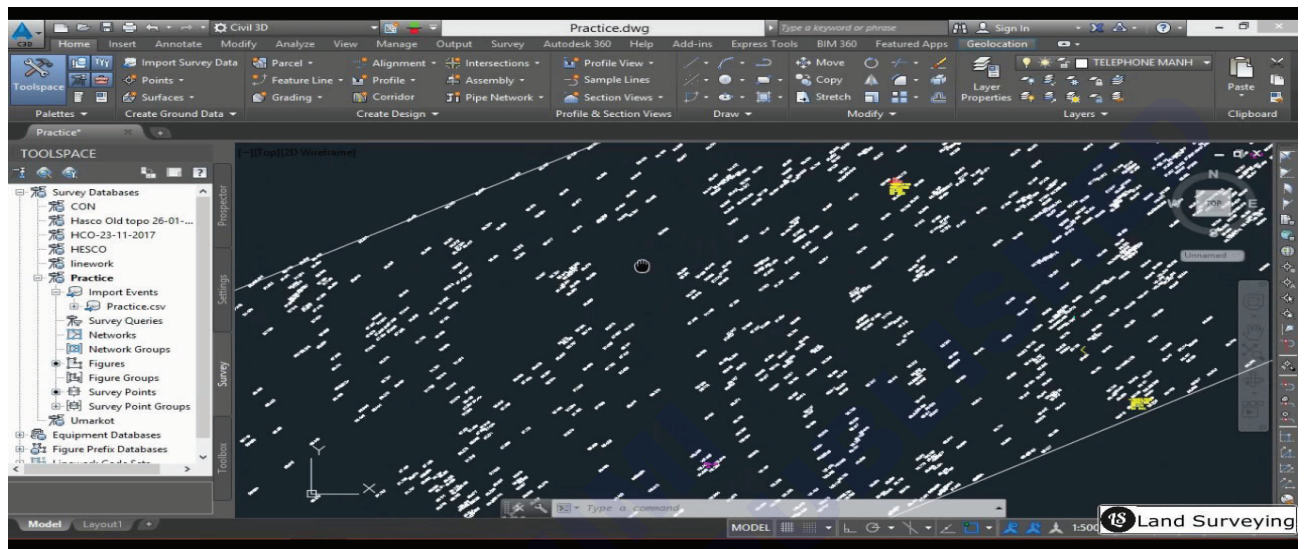
Measurement with total station

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 Centering 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

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 (Figs 1 & 2).
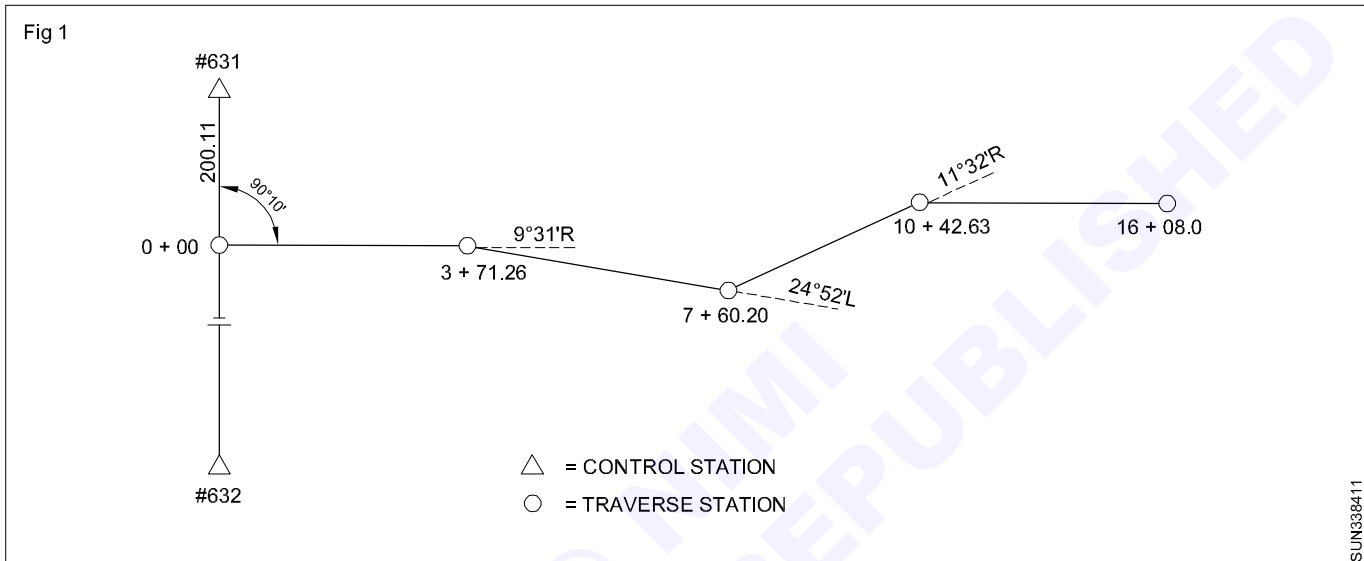
Figure 1: Open traverse

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 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, 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 determine and verify traverse station positioning. 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 subjected 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 begining 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
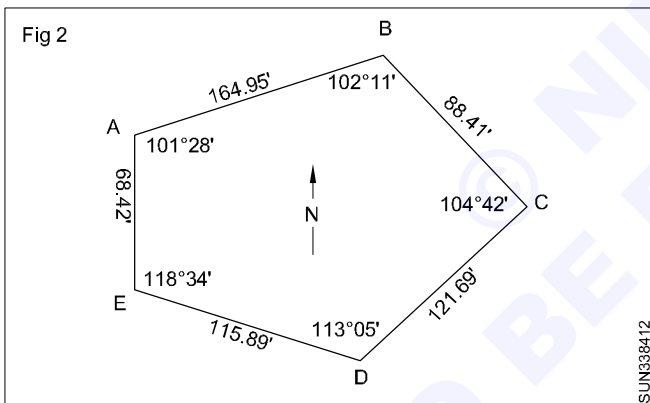
In this survey, distances are booked simply as dimensions, not as stations or chainages.

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.

Nowadays 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 if 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 if 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 existing 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 in 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.**

Definition

Planimeter

A planimeter is also known as platometer, is a measuring instrument used to determine the area of an arbitrary two dimensional shape.

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 to measure 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.

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 from 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 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)

TOPOGRAPHIC PLAN SHOWING PHYSICAL DETAIL
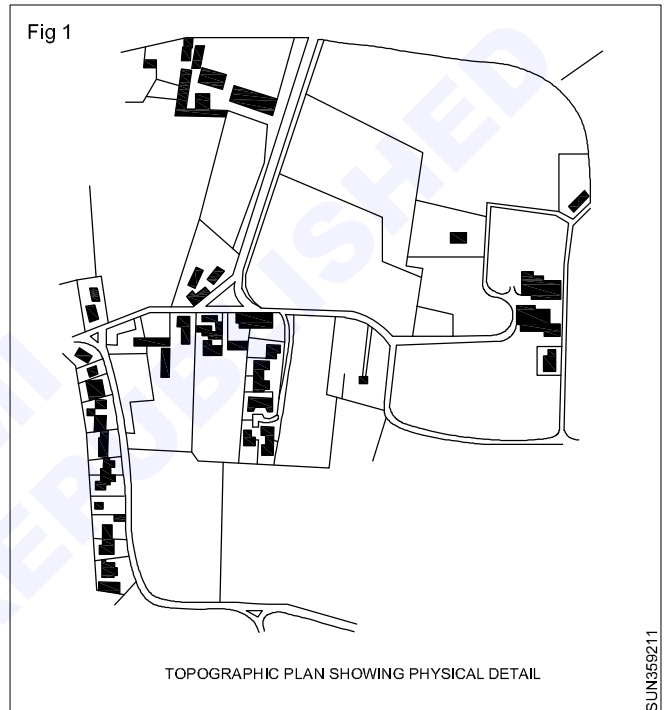
Topographic maps represent the Earth's features accurately and to scale on a two-dimensional surface. Topographic maps are an excellent planning tool and guide.

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 1:50000.

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, forest & plantation

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.

Preparation of cadastral map

Objectives: At the end of this lesson you shall be able to
• **define the term of cadaster**
• **define the term of cadastral map**
• **describe the principle used in cadastral maps in the grid.**

Cadaster: cadaster is a technical term of records showing the extent, value and ownership of land, strictly speaking, a cadaster is a record of areas and values of land and of land holders that originally was compiled for purposes of taxation.

A modern cadaster 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.

CADASTRAL PLAN SHOWING BOUNDARIES OF
LAND OWNERSHIP
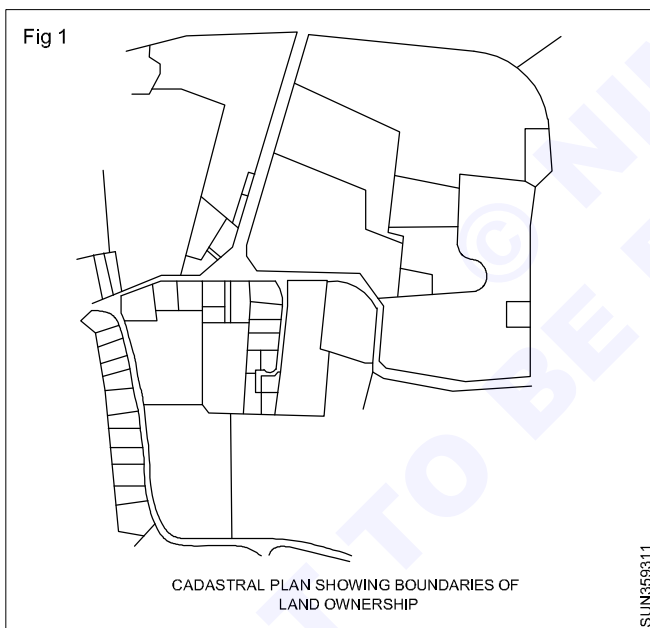
Since the map and the corresponding registers form complimentary parts of the same system of description and identification, there must be some system of cross referencing between what is shown on the map and what is recorded in the registers. This means that either names or numbers must be given to 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 same 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 and

to enable any other point on 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
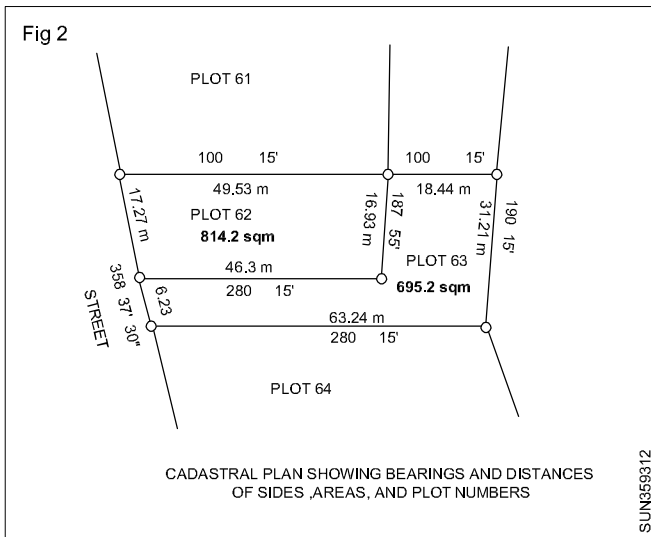
Prepare a road map for 1 km showing details on both sides (Open traversing)

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.

Select 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

⊙ → PLANE TABLE STATION
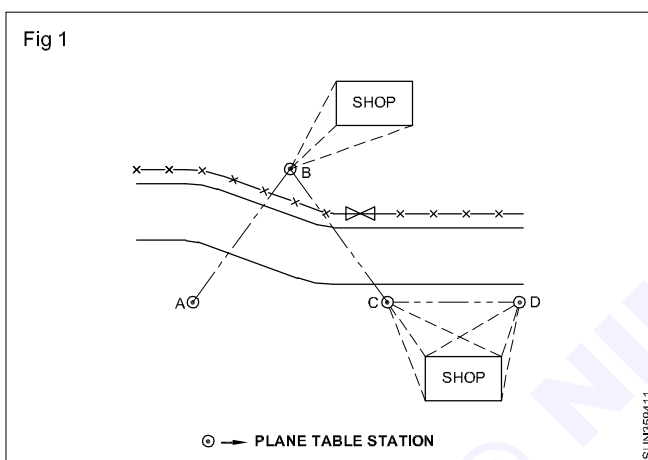
Transfer the ground station 'A' to the drawing sheet as 'a' such that the entire details to be covered within the sheet.

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 and 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
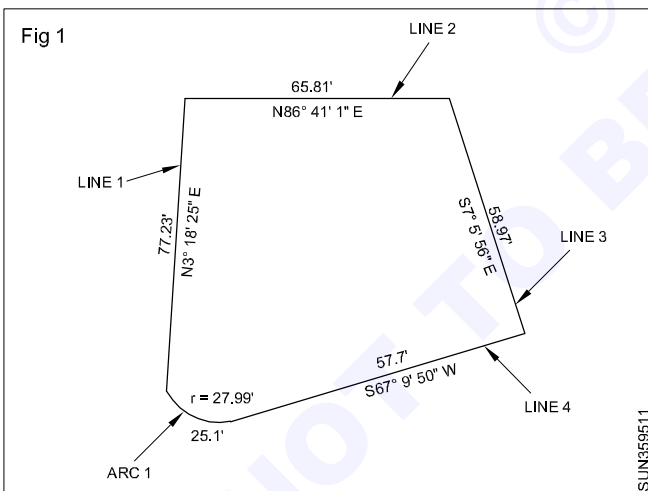
This image above shows what the completed plot plan will look like, based on this data. We have added the distance and bearing information with text for clarification.

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
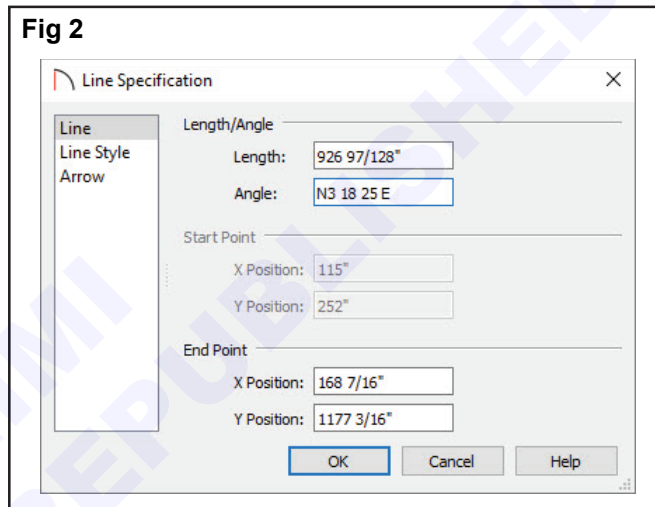
4   In the line specification dialog:

- 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
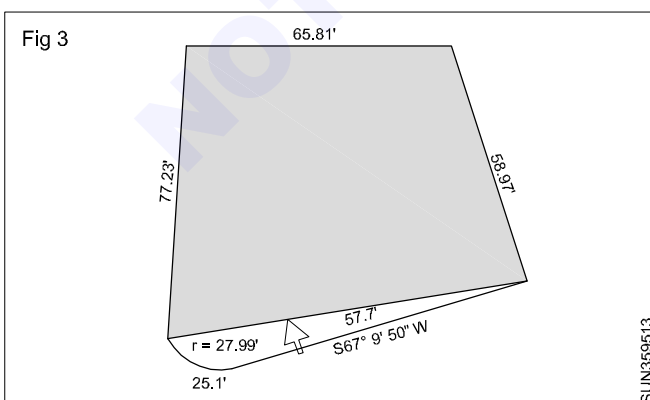
5 After you have done this, select the bottom line of the Terrain Perimeter, select the **Break Line** ⤬ edit tool, and then click on the bottom line near the plot plan arc to create a new corner handle at the point where you clicked.

Fig 4
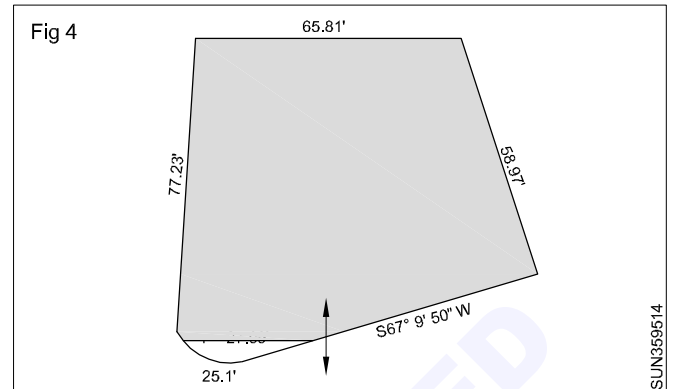
6 Now you can click and drag this new diamond shaped edit handle to the end of line 4.

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.

Importance of cartographic projection

Objectives: At the end of this lesson you shall be able to
• **define the tenon mercator projection**
• **explain the mercator projection.**

Definition

Systematic representation of feature of a curved surface, on a flat surface as that of the earth.

Mercator projection

The mercator projection is a transformation of a cylindrical projection, but it must be derived mathematically. This type of map projection introduced by Gerardus mercator.

• The meridian are equally spaced parallel vertical lines and the parallels of latitude are parallel horizontal straight lines that are spaced farther and farther above as their distance from the equator increases.

• This projection is widely used for navigation chart.

• Any straight line on a mercator projectin map is a line of constant true bearing that enables a navigator to plot a straight line course.

• It is less practical for world maps, because the scale is distorted, areas further away from the equator appear disproportionately large.

• The mercator projection is still widely used, especially when north-south dimensions are of chief importance.

Mercator projection, type of map projection introduced in 1569 by Gerardus Mercator.It is often described as a cylindrical projection, but it must be derived mathematically. The mercator projection is a transformation of a cylindrical projection used for navigation.

Geradus mercator, his name in the "Mercator projection", which he used on his world map in 1569, navigation chart, century they were replaced by Mercator projection charts that showed compass directions as straight projection.

The Mercator projection is still widely usesd, especially when north-south dimensions are of chief importance, More about mercator projection.

Here are some reasons why cartographic projection is important:

Accurate representation of spatial data: Cartographic projection allows us to create maps that accurately represent spatial data, such as landforms, water bodies, and transportation networks. This is essential for a wide range of applications, including navigation, land-use planning, and environmental analysis.

Comparison of different regions: Cartographic projection allows us to compare different regions of the world on a single map. This is useful for analyzing global patterns and trends, such as climate change or economic development.

Communication: Maps are a powerful tool for communication. Cartographic projection allows us to create maps that are easy to read and understand, which is essential for conveying information to a wide range of audiences.

Visualization: Cartographic projection allows us to create visually compelling maps that can help us visualize spatial data in new and innovative ways. This can lead to new insights and discoveries in a wide range of fields, including geography, ecology, and urban planning.

Navigation: Cartographic projection is essential for navigation, both on land and at sea. Maps that accurately represent spatial data can help us navigate through unfamiliar terrain and avoid hazards such as cliffs, rocks, and shoals.

Cartographic projection

Objectives: At the end of this lesson you shall be able to
• **define cartographic projection**
• **uses of cartographic projection.**

The study and practice of making maps is known as catography.

Catographer also known as map makers attempt to transfer the earth around spherical globe to flat paper.

Cartographic projection are the different techhiques used by cartographers for presenting a round globe of earth on a flat surface, it can also be defined by transformation of spherical grid of parallel and meridian on a plane surface.

Types of Cartographic Projection

Cartographic projection refers to the process of representing a three-dimensional surface of the earth onto a two-dimensional surface of a map. There are several types of cartographic projections, including:

Cylindrical Projection: This type of projection is created by projecting the Earth's surface onto a cylinder. This is the most common type of projection, and it is used to create maps of the equatorial regions.

Conic Projection: In this projection, the Earth's surface is projected onto a cone. Conic projection is used to create maps of mid-latitude regions.

Azimuthal Projection: In this projection, the Earth's surface is projected onto a plane. This type of projection is used to create maps of the polar regions.

Planar Projection: This projection is similar to the azimuthal projection, but it is created by projecting the Earth's surface onto a flat plane instead of a curved surface. Planar projection is used to create maps of small areas.

Polyhedral Projection: This type of projection uses a polyhedron (a three-dimensional object with flat faces) to represent the Earth's surface. The most famous polyhedral projection is the Dymaxion map, which shows the entire world on a single flat surface by using a truncated icosahedron.

Interrupted Projection: This type of projection breaks up the Earth's surface into several pieces and projects each piece onto a separate flat surface. This is done to reduce the distortion that occurs when trying to represent a spherical surface on a flat map.

There are many variations of each of these projection types, and cartographers use different projections depending on the purpose of the map and the area being represented.

Cartographic projection

The primary uses of cartographic projection:

Navigation: Maps are essential tools for navigation. They help people to find their way and to plan routes to their destinations. Cartographic projections can help to make maps more accurate and useful for navigation.

Geographic Information Systems (GIS): GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. Cartographic projection is an integral part of GIS because it enables the conversion of three-dimensional data into two-dimensional maps.

Planning and Design: Cartographic projections can be used to create maps that are useful for planning and design purposes. Maps can show the location of infrastructure, topography, and other features that are important for planning and design.

Environmental Analysis: Cartographic projections can be used to create maps that help to analyze and understand the environment. Maps can show the distribution of natural resources, the impact of human activities on the environment, and the vulnerability of ecosystems to environmental change.

Education: Maps are essential tools for teaching geography and environmental studies. Cartographic projections can help to create maps that are more accurate and informative, which can enhance the educational experience.

Polyconic projections

Objectives: At the end of this lesson you shall be able to
• **describe the ordinary polyconic projection**
• **describe rectangular or war office polyconic map**
• **define modified polyconic projection.**

Ordinary polyconic projection (Fig 1)

• Prespective projections the conic spherical surfaces coincide.

• They are standard lines with correct scale.

• However, the map may be split along parallels in several strips.

Fig 1
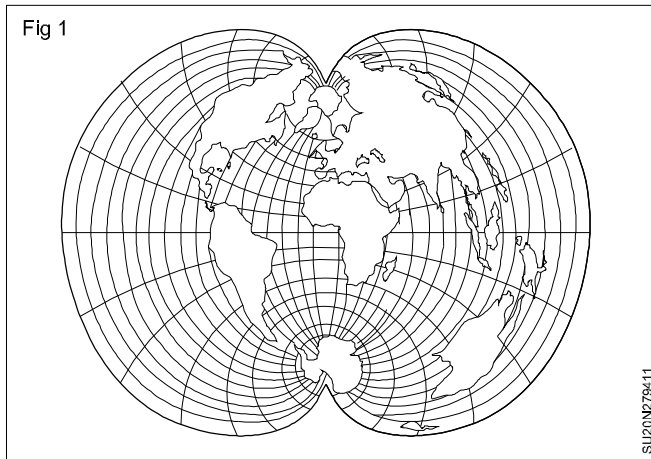
- Each strips fitted to a different cone.

- This is similar to the polycylindrical concept.

- The cone constant is made to change from one at the poles to zero at the equator.

- The strips do not touch except along the central meridian.

- When infinity many cones are used, each optionally tangent to a thin strip containing a single parallel, the gap disappear.

- If the base projection is an equidistant conic, then central meridian has constant correct scale.

- Continuous result is the common polyconic projection or classic polyconic projection.

- The classic polyconic projection has circular parallels (except the equator) all with constant and correct scale but not concentrically.

- The curvature of each parallel is the some of its counter part on a cone tangent at its latitude.

- The same scale applies to the straight central meridian all other meridians are curved.

- This projection is better suited for local or regional maps.

- Its main disadvantages is the much wider range of scale variation.

- The ordinary polyconic projection is usually applied to local or regional, rather than world maps.

Rectangular polyconic projection

- In the rectangular polyconic projection, parallels or circular arcs, again equally spaced along the straight total meridian.

- Their scale is not constant, changing in order to make each meridian cross every parallel at right angles.

- This is not a sufficient condition for conformality, neither is the result equivalent.

- Only the equator (the common case) or two parallels symmetrical about the equator have true length.

- Usage of the rectangular polyconic projection is similar to the classic polyconic's infact, for small regions by they are barely distintinguishable.

Rectangular or war office polyconic map, with the equator as standard parallel. (Fig 2)

Fig 2
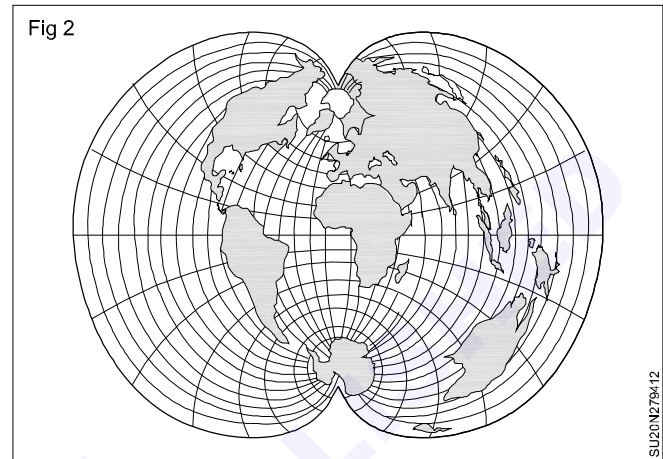
Modified polyconic projection: A modification of the classic polyconic projection was need in the international map of the world series, a set of separate sheets in the 1:1000000 scale. (The project is also known as the map of the million or the millionth map of the world)

- Each sheet comprise a single quadrangle bounded by the parallels separated by 4°, both standard lines.

- All parallels are non-concentric circular areas with curvature identical to the classic polyconic.

- Meridians are spaced by 6° and the 2° apart from each center are standard lines.

- The width of quadrangles changes to 12° North of 60° N and South 60° S and again to 24° after the 76° latitudes.

- Due to the choice of standard parallels and straight meridians, any pair of neighbouring sheets may be joined with no gaps.

- The gaps cannot be avoided if sheets are joined in more than one direction at once.

- Like the ordinary and rectangular polyconics, the projection is neither conformal nor equal area.

Types of cartographic projection

Objective: At the end of this lesson you shall be able to
• **state the type of cartographic projection.**

Cartographer use projection

In a map projection co-ordinates often expressed as latitude and longitude of locations from the surface of the globe are transformed to co-ordinates on a plane projection in a necessary step in creating a two-dimensional map and is one of the essential elements of cartography.

Types of cartographic projections for mapping

Three of these common types of map projection are

UTM means → Universal Transverse Mercater

UTM projection is designed to create a rectangular cartesian grid. This allows distances and angles to be computed easily and minimize distortion.

- Many military forces uses UTM projected maps for ground operation.

- Co-ordinates are measured in metric units. It is also ideal for GIS operation.

Cylindrical, Conic and Azimuthal.

Cylindrical projection (Lambert's)

The graticula is projected on a cylindrical surface touching it on the equator (middle parallel line). Both the parallel it is recommended for Topographic mapping by the United Nation catrography committee in 1952. The UTM divide the world into 60 narrow longitudinal zones of 6 degrees. Numbered from 1 to 60. The narrow zoner of 6 degrees make the distortion so small that they can be ignored when constructing a map for a scale of 1:10,000 or smaller.

Conic projection

A conic projection is one, which is drawn by projecting the graticlue network on a conical surface which touches the globe along a parallel of latitude called the standard parallel. As the cone toucher the globe located, the position of this parallel on the globe coincide with the on

the cone is taken. That standard parallel the length of other parallel on either side of this parallel are distorted.

- It is not suitable for a world map due to extreme distortions in the parallels other than the selected standard parallel.

- It is not suitable for representing larger areas of the distortion along the pole and near the equator in larger.

- This projection is commonly used for showing middle latitude areas. Ex. A long narrow strip of land running along with the standard parallel on east to west axis.

- It is used to show railways road ways, river map, valleys, international boundries which are placed on east, west stretch in align with the standard parallel line. Ex. Canadian - Pacific - Trains - Siberial railways, international boundaries between USA & Canada, Normode valley

Azimuthal projection - Stereographic

The oldest known record of this projection its from Ptolemy in about 150 AD. It is also known as planar projection. Planar projection preserves the property of Azimuthality . Perspective is a particular case of Azimuthal projection. It is not commonly used over polar areas, but can be used for small scale maps of continents such as Australia. Small scale maps are used for general Cartographic survey, the great attraction of the projection is that the earth appears as if viewed form space or a globe.

The method uses concentric circles for parallels and their radii for meridians. It is a good projection for plotting air line connections. This is a conformal projection in that shapes are well preserved over the map, although extreme distortions do occur towards edge of the map. Directions are true from the centre of the map but the map is not equal - area.

GPS device and their uses

Objectives: At the end of this lesson you shall be able to
• **define the GPS**
• **explain what is GPS**
• **explain setup and uses of GPS equipment.**

Introduction: Where am I? Where am I going? Where are you? What is the best way to get there? When will I get there? GPS technology can answer all these questions. GPS satellite can show you exact position on the earth any time, in any weather, no matter where you are GPS technology has made an impact on navigation and positioning needs with the use of satellites and ground stations the ability to track aircrafts, cars, cell phones, boats and even individuals has become a reality.

A system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on earth by calculating the time difference for signals from satellites to reach the receiver. The Global Positioning System (GPS) is a worldwide ratio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these "Man-made stars" as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter. In a sense it's like giving every square meter on the planet a unique address. GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible to virtually everyone. Navigation in three dimensions is the primary function of GPS. Navigation receivers are made for aircraft, ships, ground vehicles, and for hand carrying by individuals. Precise positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples. Time and frequency dissemination, based on the precise clocks on board the SVs and controlled by the monitor stations, is another use for GPS. Astronomical observatories, telecommunications facilities and laboratory standards can be set to precise time signals or controlled to accurate frequencies by special purpose GPS receivers.

Definition: For thousands of years, navigators have looked to the sky for direction. Today, celestial navigation has simply switched from using natural objects to human-created satellites. A constellation of satellites, called the Global Positioning System, and hand-held receivers allow for very accurate navigation.

What is GPS?: The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defence that continuously transmit coded information, which makes it possible to precisely identify locations on earth by measuring the distance from the satellites. The satellites transmit very low power specially coded radio

signals that can be processed in a GPS receiver, enabling the receiver to compute positions, velocity and time thus allowing anyone with a GPS receiver to determine their location on earth. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock. The system was designed so that receivers did not require atomic clocks, and so could be made small and inexpensively.

The GPS system consists of three pieces. Satellites that transmit the position information, ground stations that are used to control the satellites and update the information and finally there is the receiver that you purchased. It is the receiver that collects data from the satellites and computes its location anywhere in the world based on information it gets from the satellites. There is a popular misconception that a GPS receiver somehow sends information to the satellites but this is not true, it only receives data.

After the second world war, it became obvious that we needed a solution to the problem of rapid and accurate absolute positioning. Over the next couple of decades, a number of projects and experiments were run. In the early 1970's, a bold experiment was proposed. A network of satellites, positioned thousands of miles above the earth, could provide rapid, accurate and absolute positioning anywhere. This vision became known as the Global Positioning System or GPS.

How accurate is GPS?: This is probably the most frequently asked question posed by new and potential GPS users. In practice, we have to turn this question around and ask, "How much accuracy do you need?" For example, for a hiker in the woods or a soldier in the field, a position within about 10 meters (30 feet) would usually be considered accurate enough. For a ship in coastal waters, accuracy on the order of about 5 meters (15 feet) is generally desirable. For geodetic land surveying, however, accuracy requirements are 1 centimeter (0.4 inches) or less. GPS can be used to achieve all these accuracies. For each required level of accuracy, receiver characteristics and the measurement techniques employed are different. Accuracy also depends on satellite configuration, nearby topography, distribution of buildings and trees, and even time to day.

Advantages of GPS

GPS has three advantages

   i GPS may be used to identify or define the geographical co-ordinates associated with satellite

imager. GPS is also used to reduce the distortions and to improve the accuracy of these images position. GPS receivers can be used to collect accurate geographical co-ordinates at these locations.

ii GPS can be used in the ground to get satellite images. When a particular satellite image has a region of unusual or unrecognised reflectivity the coordinates of that region can be loaded into GPS receiver.

iii GPS has developed into cost effective tool for updating GIS or computer aided design system. The GPS is an excellent user can, generally see the sky and is able to get close to the objects to be mapped.

Setup and use of GPS equipment: GPS or Global Positioning System, Devices are ubiquitous these days. They are on our phones, in our cars and attached to many of our favorite apps. Today, we can use our GPS to get directions and find new places to eat and play but learning how to use them can seem complicated thanks to the variety of different GPS styles. Luckily, all GPS devices are pretty simple to use.

Using simple GPS devices

1 **Buy a smart phone or car GPS to get directions and your location:** The GPS market is flooded with different devices, option and features. Unless you plan or using your GPS in the wilderness or for research experiments, however, your smart phone or a car GPS can provide directions and your location quickly and easily. Most have touch screens and come with a rechargeable battery.

- **Smart phones:** Most smart phones come pre-loaded with a "Maps" or "Directions" app that uses GPS. If you do not have one, search and download an app, like Google Maps, from your app store to use GPS.

- **GPS devices:** These are small, rectangular devices that specialize in driving directions and finding restaurants, airports, and other points of interest. Examples include Tom Tom, Garmin and Magellan etc.

2 **Open the "Map":** This is the basic screen for a GPS. It shows a location, usually with your current location at the center, and all of the roads and major landmarks nearby.

3 **Click on "My Location":** Some GPS use touch screens, others have keypads, and some have scroll wheels and buttons. Click on the button labeled with a compass, navigational arrow or crosshairs to show your current location.

- Your location is sometimes stored under the heading "Where am I?" "Favorite Locations" or "Current."

- iPhone users can see their current location using the built-in Compass App. Make sure you "Allow Location Services" for the compass under "Settings" "Compass."

4 **Choose your destination address:** Using the search bar found at the top of your GPS, type in the address you want to reach. Many touch screen GPS devices let you choose a location by holding your finger on the location in the map.

- Some GPS devices will prompt you with a button labeled "Get Directions." Choose this if there is no search bar to input an address.

- If you know the exact latitude and longitude of your trip, use these; they will give you the most accurate location possible.

5 **Follow the GPS instructions to get to your location:** The GPS will give you directions at every turn you need to take. Don't worry if you miss a turn - most GPS will auto-correct and give you a new route to get back on track.

- If you are struggling to keep up, check your GPS's settings and make the "Trun Warning Frequency" setting longer - giving you more time to hear the next direction.

Using GPS for research and exploration

1 **Learn to read latitude and longitude coordinates:** Latitude and longitude are represented by numbers, known as degrees, which measures your distance from two "zero lines" Longitude measures your distance East or West of the prime meridian and latitude measure your distance North or South of the equator. This is the most accurate system of measurement for your GPS.

- An example (guess where it is), is 37º 26' 46.9"N, 122º 09' 57.0"W.

- Sometimes direction is noted by positive or negative numbers. North and East are considered positive. The previous example could be written as: 37º 26' 46.0", -122º 09" 57.0"

- If there is no notation, know that the latitude always comes first.

2 **Mark your current location as a waypoint:** Waypoint are saved in the GPS to be viewed later, allowing you to take notes, draw maps and keep information on the landscape easily. On your GPS, click "Save location", "Add to Favourites," or "Mark Way point."

- Complex scientific GPS systems often let you mark specific waypoints - artifacts, streams, rock formations, etc.

- The more points you save into your GPS, the more accurate your map of the area when you get home.

3 **Set way points in advance if there are no addresses:** Plug in the longitude/latitude coordinates of water sources, compgrounds, or ranger stations under "Get Directions" or "Find Location" then save them by clicking "Add to Favourites". You can now access it anytime.

- "Add to Favourites" might be labeled by a star or flag as well.
- Click "Saved Locations" or "Favourite Locations" to see your way points anytime. You can click on them to get directions from anywhere in the world.

4. **Plug your GPS into your computer to download the data:** Most complex GPS systems come with software that lets you save your data onto your computer. The program will import your way points and use them to make a map of the area you were in, complete with elevation data and any notes you made on your GPS.

- If you are mapping a specific area, make as many way points as you can for an accurate map. Having more data the program has the better final product.

Troubleshooting your GPS

1. **Download the latest map updates if your directions are incorrect:** If you are using a phone this will happen automatically but some GPS devices need to be manually updated. This will give you the latest information, topography and directions.

- Find the "About" button, usually located in "Settings."
- Scroll down to see Map Information. If this is more than 6 months old, you will need to update.
- Plug your GPS into an internet-enables computer using the cord that came with the unit.
- Perform an internet search for "your GPS + Map Update" follow the on screen instructions.

2. **Know that GPS uses satellites to locate you:** There are over 25 satellites orbiting earth that receive signals from your GPS and use those signals to determine your latitude and longitude. Developed by the army, GPS can accurately tell your location anywhere in the world by several feet - as long as the signal can reach the satellites.

- Cell phone GPS uses cell towers and internet signals to find your location, so they won't work in the wilderness.

3. **Get into the open:** GPS needs a clear view of the sky to accurately communicate with the satellite's, so move away from overhangs or tall trees and head outside if you have issues. Generally, if you can see the sky, the GPS can as well.

- Tunnels, caves and basements may all keep your GPS from communicating to satellites and working successfully.

4. **Initialize your GPS when you buy it:** Most GPS devices are built in Asia, and are used to communicating with satellites over that area. Initializing your GPS acquaints it with your local area. To initialize a GPS, go to "Settings" and click "Initialize". Follow

your GPS's manual if you have any problems finding the setting and know that this may take up to 20 minutes.

- Turn your GPS off and restart it if you are having problems.
- Make sure you have a clear view of the sky.
- You may need to reset your GPS the first time you buy it by clearing the memory. Refer to the manual for instructions.

5. **Use "Satellite Lock" before you head out:** This is especially useful when hiking. In the parking lot, find your GPS's satellite lock setting and have it get to work - it usually takes several minutes.

- Signs that you have a bad signal changing directions, jetty locations or error messages.

6. **Know that GPS's are not replacements for maps and compasses:** Because a GPS can run out of battery, lose signal, or break, you should never rely on it completely to get around. While useful, you need to be prepared in case you cannot use it for some reason.

Getting the most out of your GPS

1. **Find shops, restaurants, and events near you:** Most GPS devices can find much more than addresses these days. Try searching "Indian Food", "Post Offices", "Gas", "Rock climbing gyms", or whatever else you are interested in and see what pops up. This can be incredibly useful when you are in a new city or if you just feel like finding the closest burrow shop.

- Apps and Internet enabled GPS (like those found on phones) will always have this feature.
- Many portable GPS devices have a section labeled "Nearby Locations" or "Find Locations" that list businesses within a short radius of your current location.

2. **Have fun Geocaching:** Geocaching is when people hide objects in the world with GPS coordinates. It is a global community that prides itself on sharing and exploration, and can be a great way to see the outdoors. To Geocache, buy a GPS and sign up for one of the many internet-based services and forums.

3. **Track your workouts:** Most modern GPS devices and apps can be turned on while you run or bike and store the information of your speed, elevation and distance for later. You will need a specific app like NikeFit, MapMyRun, or AppleHealth to get the most out of this feature.

4. **Find a lost phone:** Because smart phones are constantly hooked up to a GPS, you can use them to find lost or stolen phones if you act quickly. Download a tracking app on for your phone and sync it with your computer to always keep tabs on your phone's location.

GPS co-ordinate system & components of the GPS system

Objectives: At the end of this lesson you shall be able to
• **explain GPS co-ordinate systems**
• **describe geographic latitude and longitude**
• **explain components of GPS system**
• **describe components of GPS receiver.**

Introduction: Satellites orbit around the earth or travel in the planet system of the sun. They are generally observed from the earth. To describe the orbits of the satellites (positions and velocities), suitable coordinate and time systems have to be defined. Before starting a GPS survey, decide which co-ordinate system to use.

History: In 1884, the United states hosted the International Meridian Conference and twenty-five nations attended. Twenty-two of them agreed to adopt the longitude of the Royal Observatory in Greenwich, England, as the zero-reference line. The Dominican Republic voted against the motion, while France and Brazil abstained. France adopted Greenwich Mean Time in place of local determinations by the Paris Observatory in 1911.

GPS Coordinate system: GPS measurements are referenced to the 1984 World Geodetic System reference ellipsoid, known as WGS84. However, for most survey tasks, results in terms of WGS84 have little value. It is better to display and store results in terms of a local coordinate system. Before you start a survey, choose a coordinate system. Depending on the requirements of the survey, you can choose to give the results in the national coordinate system, a local coordinate grid system, or as local geodetic coordinates.

Geographic coordinate system (Fig 1): A geographic coordinate system is a coordinate system that enables every location on the earth to be specified by a set of numbers or letters, or symbols. The coordinates are often chosen such that one of the numbers represents vertical positon, and two or three of the numbers represent horizontal position. A common choice of coordinates is latitude, longitude and elevation.

GEOCENTRIC EARTH-FIXED COORDINATE SYSTEMS
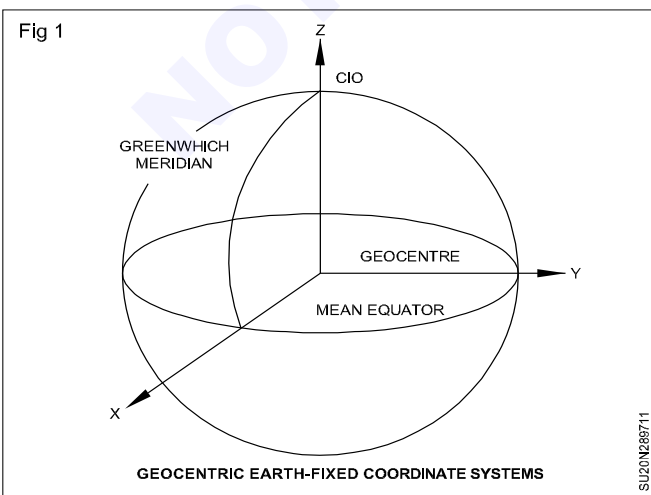
Geographic latitude and longitude (Fig 2): The "latitude (abbreviation: Lat., φ, or phi) of a point on the Earth's surface is the angle between the equatorial plane and the straight line that passes through that point and through (or close to) the centre of the Earth. Lines joining points of the same latitude trace circles on the surface of the Earth called parallels, as they are parallel to the equator and to each other. The north pole is 90º N; the south pole is | 90º S. The 0º parallel of latitude is designed the equator, the fundamental plane of all geographic coordinate systems. The equator divides the globe into Northern and Southern Hemispheres.

GRAPHIC LATITUDE AND LONGITUDE - EQUATOR
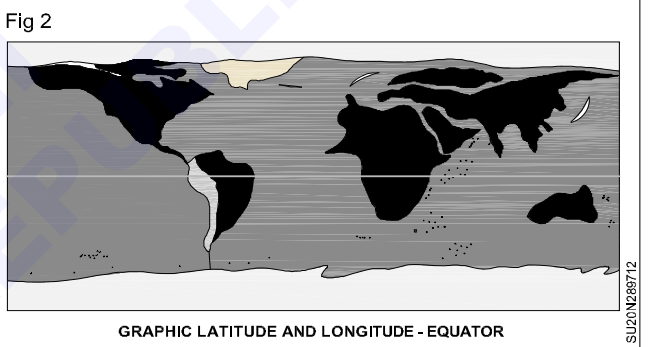
The "longitude" (abbreviation: Long., l, or lambda) of a point on the Earth's surface is the angle east or west from a reference meridian to another meridian that passes through that point. All meridians are halves of great ellipses (often improperly called great circles), which converge at the north and south poles. The meridian of the British Royal Observatory in Greenwich, a little east of London, England, is the International Prime Meridian although some organizations - such as the French Institute Geographique National - continue to use other meridians for internal purposes. The Prime Meridian determines the proper Eastern and Western Hemispers, although maps often divide these hemispheres further west in order to keep the Old World on a single side. The antipodal meridian of Greenwich is both 180º W and 180º E. This is not to be conflated with the International Date Line, which diverges from it in several places for political reasons including far eastern Russia and the far western Aleutian Islands. (Fig 3)

The combination of these two components specifies the position of any location on the surface of the Earth, without consideration of altitude or depth. The grid thus formed by latitude and longitude is known as the "graticule". The

zero, zero point of this system is located in the Gulf of Guinea about 625 km (390 mi) south of Tema, Ghana. (Fig 4)

Fig 3

GRAPHIC LATITUDE AND LONGITUDE

LONGITUDE LINES ARE PERPENDICULAR AND LATITUDE LINES ARE PARALLEL TO THE EQUATOR

Fig 4

SEGMENTS OF GPS SYSTEM
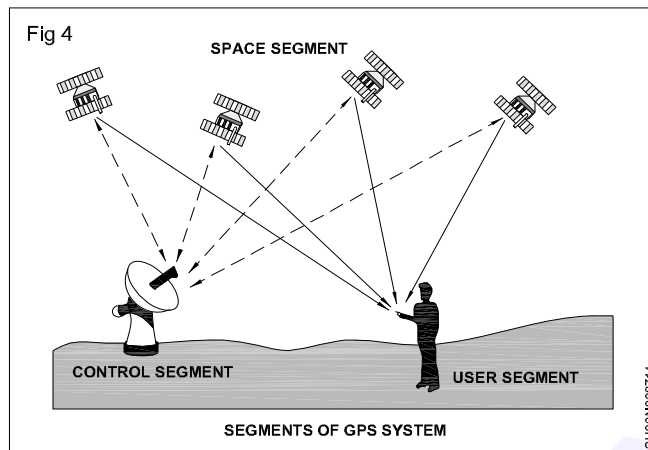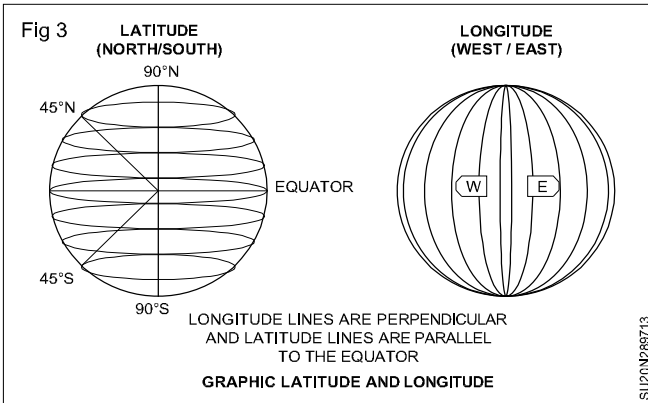
Reading coordinates: To simplify map navigation, a system of coordinates is used. Coordinates divide the map into a grid and identify a particular location by listing its relative position north / south and east/west. To choose a coordinate system, simply go to the Preferences screed. The most common coordinate systems used in GPS navigation are:

- **DMS (Degrees/Minutes/Seconds):** This is the standard way of listing latitude and longitude.

  Example: N47º 37' 12" W122º 19' 45".

  In this example, N47º 37' 12" indicates that the north/ south position is 47 degrees, 37 minutes and 12 seconds north of the equator; while W122º 19' 45" places the east/west position at 122 degrees, 19 minutes and 45 seconds west of the Prime Meridian (at Greenwich, England)

- **DDM (Degree/Decimal/Minutes):** A decimal of DMS, DDM is used by geocachers and other GPS enthusiasts. These coordinates look like this:

  Example: N47º 37.216' W122º 19.75'.

  The north/south and east/west position remains unchanged. The difference is that the seconds part of the location is converted to a decimal by dividing the seconds by 60.

- **UTM (Universal Transverse Mercator):** This military-derived grid system is not tied to latitude and longitude. It divides the map into a square grid with the grid lines all 1,000 meters apart. Most topo maps have UTM grid

lines printed on them. The system is metric-based and requires no conversion of minutes and seconds.

Example 10T 0550368 5274319.

Here, "10T" identifies the map zone, "0550368" is the east/west or "easting" number, while "5274319" is the north/south or "northing" number.

Your GPS receiver can automatically display whichever of these coordinate systems you select. It can also convert coordinates from one system to another. This is helpful if you're giving coordinates for a location in one system (e.g., UTM), but want to actually navigate in another (e.g., DDM).

Elements of the GPS/DGPS: There are 3 main components to the GPS system. These components are known as Segments, as follows:

1 Space Segment - The satellites, also known as space vehicles or SVs.

2 Control Segment - Ground stations run by the DOD

3 User Segment - All users and their GPS receivers

These three segments are illustrated schematically below:

Vocabulary/Definitions (Fig 5)

Fig 5

SEGMENT
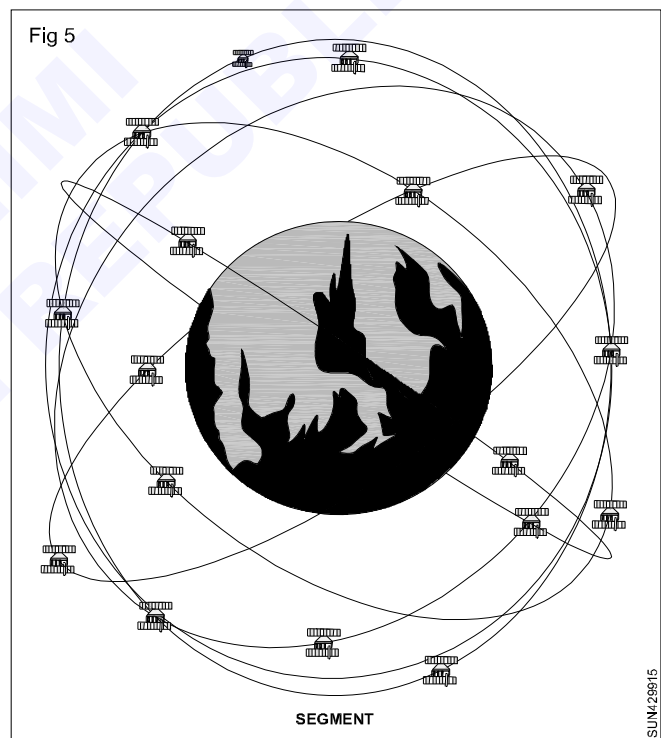
GPS	:	Global Positioning System
Satellite	:	An object launched specifically to orbit the Earth.
Receiver	:	A device that accepts (receives) incoming signals and converts them to a usable form used for transmission of radial signal from satellite to GPS receiver.
Orbit	:	The path an object in space follows as it circles the Earth.
Trilateration	:	Position determined by intersecting distances.

Triangulation : The location of an unknown point by the formation of a triangle.

Each segment is described in the following sections

1 Space segment

The space segment consists of the GPS satellites. Much of the GPS literature rears to the satellites as "space vehicles" or simply, SV's. The arrangement of GPS satellites in space is called their constellation. The minimum constellation to meet the objectives of the DOP (Dilusion of precision) is 24 operational satellites.

The orbit altitude was selected so that each satellite repeats the same track over any point on earth approximately once every 24 hours. One orbit takes a little less than 12 hours. There are six orbital planes, with nominally four satellites per orbital plane. The lanes are equally spaced 60 degrees apart inclined at about 55 degrees to the equator. The configuration was optimized to provide the best coverage between about 75 degrees north latitude and 75 degrees south latitude. This constellation provides the user between five and eight satellites visible from any point on earth at any time. (Figs 6 & 7)

TYPICAL GPS SATELLITE

BLOCK I SATELLITE
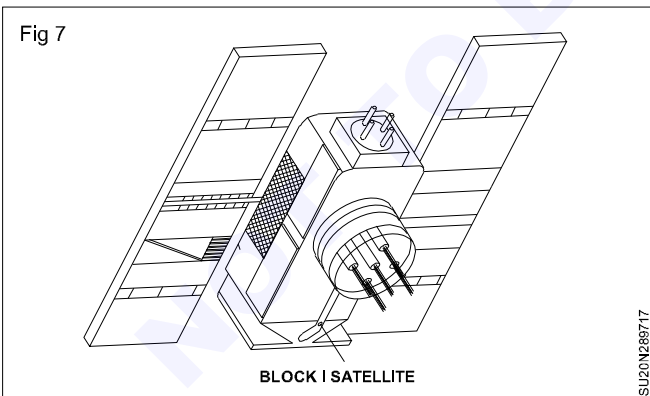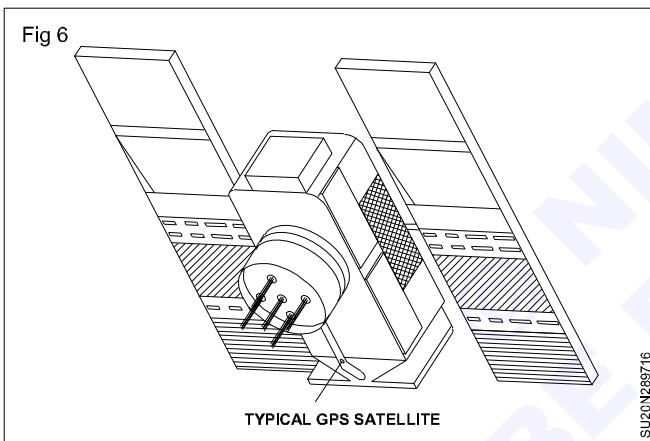
The satellite orbits are approximately 2,200 kilometers (12,000 miles) above the earth surface. The satellites travel 4km per second velocity at about 12,000 km/hour (7,000 miles per hour). Each satellite is solar powered with battery backup, and contains radio receivers and transmitters, one or more atomic clocks, small thrusters used for course corrections, special antennas, and computer equipment. The antennas on the satellites are designed to allow GPS signals to be received anywhere

from the earth's surface to about 5000 km (3,000 miles) into space. This "service volume" not only meets all civilian needs, but also provides the military with satellite tracking and missile guidance capabilities.

The first GS satellite was deployed in February 1978. By 1994, a total of 24 operational satellites were in place. Replacements and upgraded satellites have been launched on a regular basis. As of early 2001, a total of 43 satellites had been launched, and the operational constellation consists of 28 satellites. The number of satellites reported in various books, articles and internet resources varies considerably, reflecting the date that the work was prepared.

GPS satellites

Four classes (generations): blocks I, II, IIA, IIR and IIF

BLOCK IIR SATELLITE
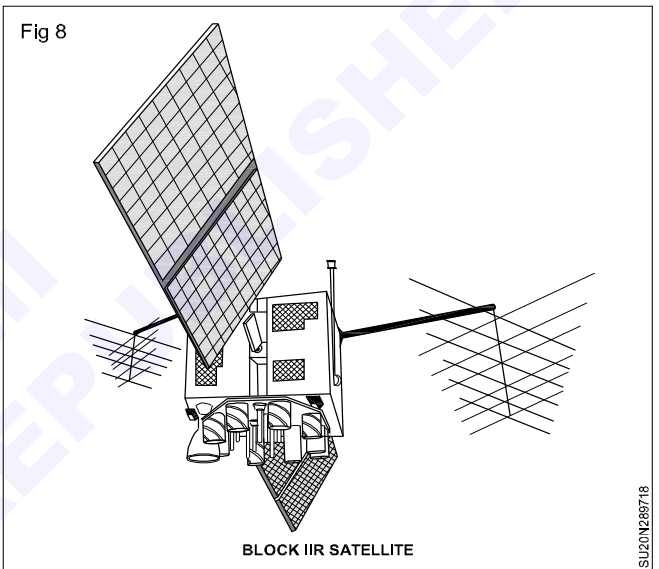
Block I (Fig 8)

- 11 satellites launched between 1978 and 1985 on Atlas F rockets.
- Life expectancy = 4.5 years, actual mean life = 7.1 years.
- Signal entirely accessible to civilian users
- Last block I satellite died on February 28, 1994

LOCATION OF THE FOUR UNMANNED STATIONS (CIRCLES)
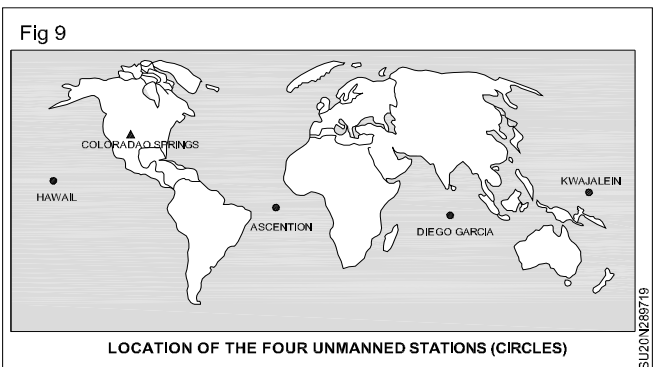
Block II (Fig 9)

- Possibility to degrade the signal for civilian users
- 1 satellite ~ 25 million dollars

- Life expectancy = 10 years
- 5 m³, 2 tons, solar panels, boosters

New launches on a regular basis

Monitored and controlled from the ground

2 Control segment

The control segment consists of a master control station in colorado springs, colorado with five monitor stations and three control up link stations located throughout the world. Monitor stations track all GPS satellites in view and collect ranging information from the satellite broadcasts. The monitor stations send information they collect from each of the satellites back to the master control station which computes extremely precise satellite orbits. The information is then formated into updated navigation message for each satellite. The updated information is transmitted to each satellite the control up link stations which also transmit and receive satellite control and monitoring signals.

The monitor stations receive all satellite signals from which they determine the pseudo range to all visible satellites and transmit the ranged data along with local meteorological data via data link to the master control station. From these data the master control station precomputes satellite ephemerides and the behaviour of the satellite clocks and formulates the navigation data. The message data are transmitted to the ground antennas and up linked via S-band to the satellites in view. Because of the global distribution of the up load antennas at least three contacts per day can be realized between the control segment and each particular satellite.

The US Military operates the control segment. There are five control stations around the world, four unmanned stations near the equator and one Master Control Station in Colorado, as shown on the following figure 9.

3 User segment

The user segment consists of all the users of the GPS signals. This includes both civilian and military users. It is important to note that GPS receivers do not send any signals back to the GPS satellites. Therefore, it is not possible to track the position of a receiver using GPS satellites. The satellites merely transmit their signals blindly throughout the service volume. In this way, the number of potential users at any one time is unlimited, and there is not interference between users.

As opposed to the space and control segments, which are maintained by the US government, the user segment is served by many commercial companies who manufacture and sell GPS receiver hardware, software and services. Anyone in the world can make and market GPS receiver equipment. There are no licenses, user fees, or any other restrictions. Allowing the private sector to design and manufacture receiver equipment has resulted in a continual reduction in size.

Components of GPS receiver

The components of a GPS receiver are:

i   Antennas with preamplifier

ii RF section with signal identification and signa processing

iii Microprocessor for receiver control data sampling, data processing.

iv Precision oscillator

v   Power supply

vi User interface, command & display panel

Memory data storage: The antenna detects the electromagnetic waves arriving from the satellites converts the wave energy into electric current amplifies the signal strength and hand over the signals to the receivers electronics. GPS signal structure requires that all GPS antennas must be circularly polarized. The antennas have to be very sensitive because of the rather weak satellite signal and the gain pattern must allow signal reception from all elevations and azimuths of the visible hemisphere.

GIS: Geographic information system: 1 Global positioning system used to find the exact location of things. GIS used to record of the map. Spatial data can be reffered to a geographic data. This data identifies the positional values and boundries of earth. This data can be analysed using GIS (or) image processing packages.

The spatal data box or geo database is the native data structure for GIS and is the primary data formed used for editing & data management.

Remote sensing is one of the method commonly used to collecting data and be integrated into GIS. A device to detect and collect this reflected or emitted electro-magnet radiation from an object is called a "Sensor". A vehicle used to carry the sensor is called a platform. (Eg. Satellites)

Main stages in remote sensing are the following

Points   -   •

Line   -   ——

Polyline -   〈

Polygon   -   ⬡

Difference between GPS and DGPS:

S.No.	GPS	DGPS
1	It means for Global positions system	It means for Differential Global positions system
2	It measure the time	It measures difference between the gaps calculated for Ground ref. & actual position of the ground
3	Accurate reading four satellites	More accurate position
4	GPS satellites are approximately 12,500 miles above the earth surface	DGPS ground ref.150 miles of target

Principle of operation of GPS & surveying with GPS

Objectives: At the end of this lesson you shall be able to
• **state principle of operation of GPS**
• **describe role of transit in GPS development**
• **explain surveying with GPS**
• **determine observation techniques of GPS**
• **describe real time GPS survey**
• **state time measurement and timing.**

Technical description (principle of operation of GPS):
The principle behind GPS is the measurement of distance (or "range") between the receiver and the satellites. The satellites also tell us exactly where they are in their orbits above the Earth. It works something like this - If we know our exact distance from a satellite in space, we know we are somewhere on the surface of an imaginary sphere with radius equal to the distance to the satellite radius. By measuring its distance from a second satellite, the receiver knows it is also somewhere on the surface of a second sphere with radius equal to its distance from the second satellite. Therefore, the receiver must be somewhere along a circle which is formed from the intersection of the two spheres. Measurement from a thrid satellite introduces a thrid sphere. Now there are only two points which are consistent with being at the intersection of all three spheres. One of these is usually impossible, and the GPS receivers have mathematical methods of eliminating the impossible location Measurement from a fourth satellite now resolves the ambiguity as to which of the two points is the location of the receiver. The fourth satellite point also helps eliminate certain errors in the measured distance due to uncertainies in the GPS receiver's timing as well. (Figs 1 & 2)

Here's how GPS works in five logical steps

• The basis of GPS is "triangulation" from satellites.

• To "triangulate", a GPS receiver measures distance using the travel time of radio signals.

• To measure travel time, GPS needs very accurate timing, which it receives with some tricks.

• Along with distance, you need to know exactly where the satellites are in space. High orbits and careful monitoring are the secret.

• Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Role of transit in GPS development

The transit system, also known as NAVSAT or NNSS (for Navy Navigation Satellite System), was the first satellite navigation system to be used operationally. The system was primarily used by the US Navy to provide accurate location information to its Polaris ballistic missile submarines, and it was also used as a navigation system by the Navy's surface ships, as well as for hydrographic survey and geodetic surveying. Transit provided continuous navigation satellite service from 1964, initially for Polaris submarines and later for civilian use as well.

Fig 1

A SINGLE MEASUREMENT PLACES THE OBSERVER SOMEWHERE ON THE SPEREH

TWO MEASUREMENTS PLACES THE OBSERVER SOMEWHERE ALONG THE INTERSECTION OF TWO SPHERES (DESCRIBED BY A CIRCLE)

Fig 2

THREE MEASUREMEMTNS PLACES THE OBSERVER AT THE INTERSECTION OF THREE SPHERES (ONE OF TWO POSSIBLE POINTS)
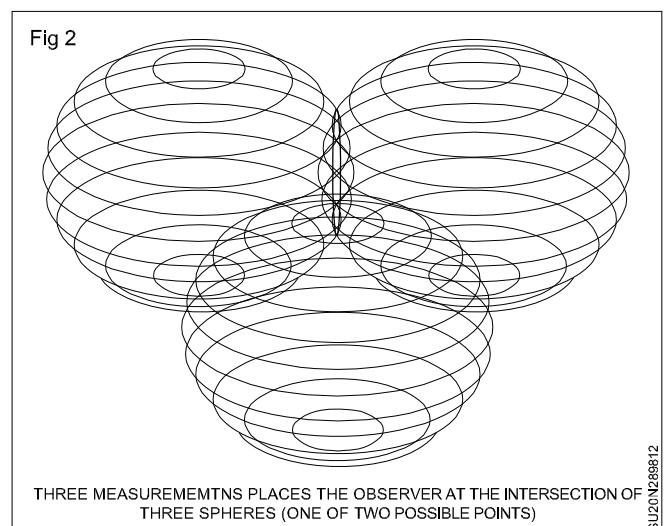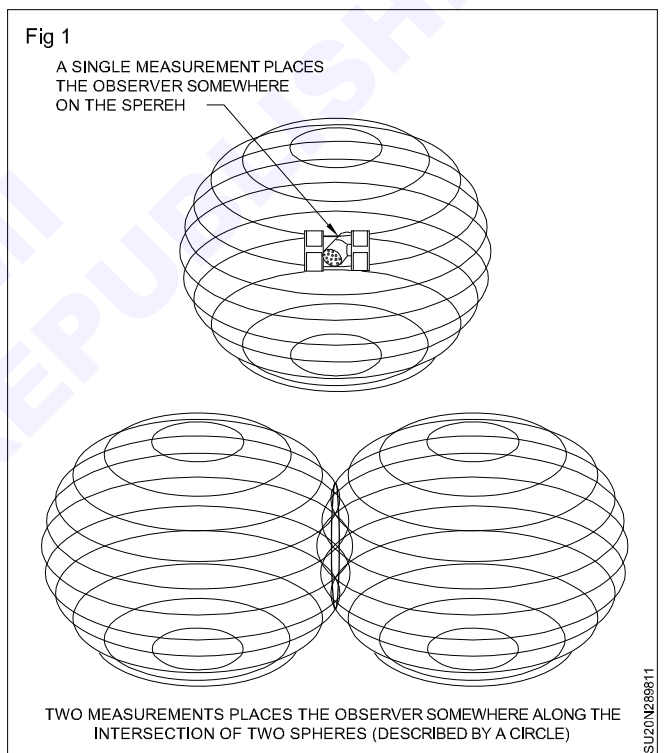
History

Development of the transit system began in 1958, and a prototype satellite, **Transit 1A**, was launched in September 1959. That satellite failed to reach orbit. A second satellite, **Transit 1B**, was successfully launched on April 13, 1960, by a Thor-Ablestar rocket. The first successful tests of the system were made in 1960, and the system entered Naval service in 1964. (Fig 3)

Fig 3

The transit system was made obsolete by the Global Positioning System(GPS), and ceased navigation service in 1996. Improvements in electronics allowed the GPS system to effectively take several fixes at once, greatly reducing the complexity of deducting a position. The GPS system uses many more satellites than were used with transit, allowing the system to be used continuously, while transit provided a fix only every hour or more. (Fig 4)

Fig 4
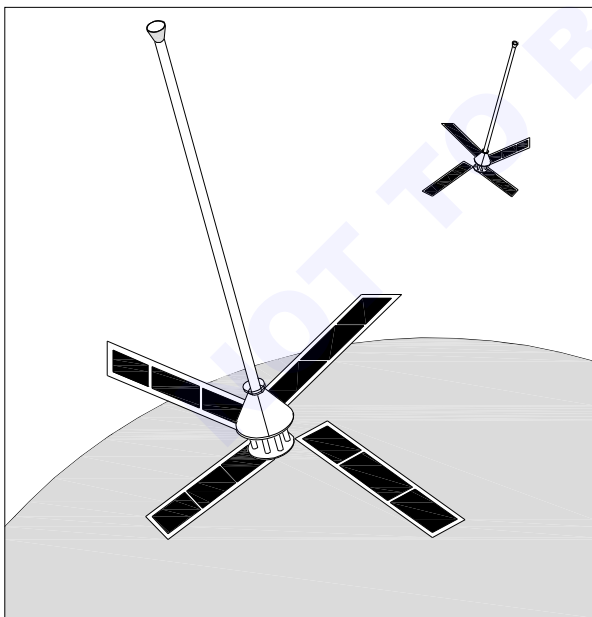
Surveying with GPS: Initially developed for military use, GPS is now part of everyday life; used in mobile phones, in-car navigation and search and rescue equipment to mention just a few. But there is a wide variety of equipment and techniques that can be used for surveying.

GPS was rapidly adapted for surveying, as it can give a position (Latitude, Longitude and Height) directly, without the need to measure angles and distances between intermediate points. Survey control could now be established almost anywhere and it was only necessary to have a clear view of the sky so the signal from the GPS satellites could be received clearly.

The first GPS instrument to be used for control surveying was the Macrometer V-1000. This instrument has the capability of determining a point's precise co-ordinates without relying on any of the special codes broadcast by the GPS satellites and is therefore often referred to as a codeless receiver. For the past year, the TI 4100 GPS instrument has also been used for precise control surveys.

Advantages of GPS surveys

- Three dimensional
- Site intervisibility not needed
- Weather independent
- Day or night operation
- Common reference system
- Rapid data processing with quality control
- High precision
- Less labour intensive / cost effective
- Very few skilled personnel needed

GPS observation techniques and methods of GPS surveying (Fig 5)

Because the X,Y,Z coordinates of each satellite are known (by computation), the coordinates of a ground point can be determined by measuring the ranges to at least three satellites. In practice, the ranges to a minimum of four satellites are measured because of the measuring techniques used. When only one receiver is used to range to the satellites, a single or point position is determined. This is why the use of a single receiver is called point positioning. The accuracy of point positioning with GPS averages ±10 meters, depending on a number of factors.

Most surveyors are interested in a second technique called differential positioning or translocation. When this method is used, one satellite receiver is placed over a point whole position is known while a second received is placed over a point whole coordinates are to be determined. The difference in coordinates between these two points can be determined to centimeter accuracy (plus 2 ppm of the distance between points) when sufficient data are observed.

Both the point positioning and translocation methods involve measuring the ranges to a number of satellites over a series of intervals from 2 seconds to several minutes. The point's coordinates or difference in coordinates are then computed by standard resection techniques.

GPS RECEIVER
KNOWN LATITUDE, LONGITUDE & HEIGHT

GPS SURVERYING
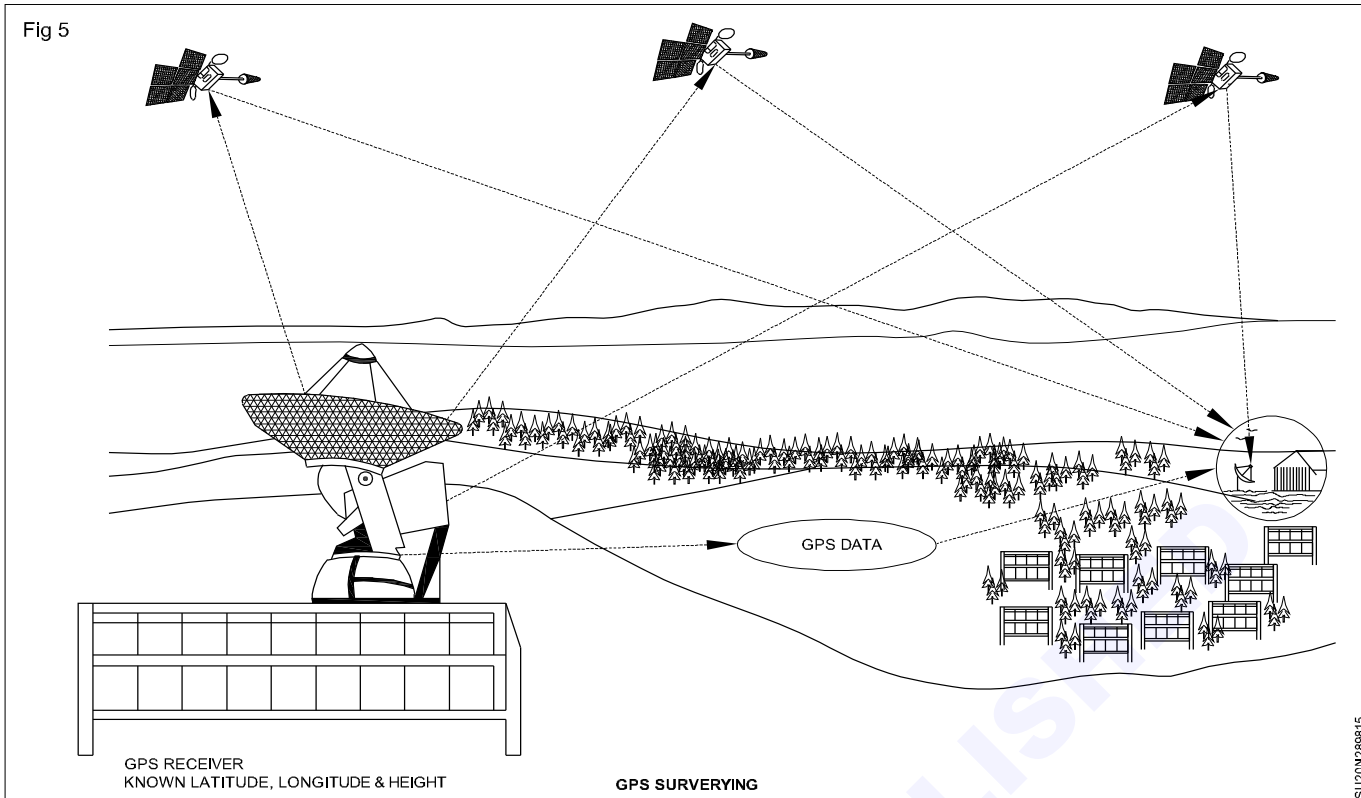
For projects requiring geodetic accuracy, National Geodetic Survey (NGS) must be contacted or NSRS database must be accessed to determine points available in the project area before the project begins.

If accurate project coordinates are needed, an accurate transformation needs to be done by including a sufficient number of points whose coordinates are known in both systems. This method is called Static Surveying, is used for surveying project that requires high accuracy.

Real time kinematic GPS surveys (Fig 6)

SURVEYED
ANTENNA
LOCATION

GPS SIGNAL

GPS SIGNAL

CORRECTION SIGNAL

REAL-TIME DGPS CONFIGURATION
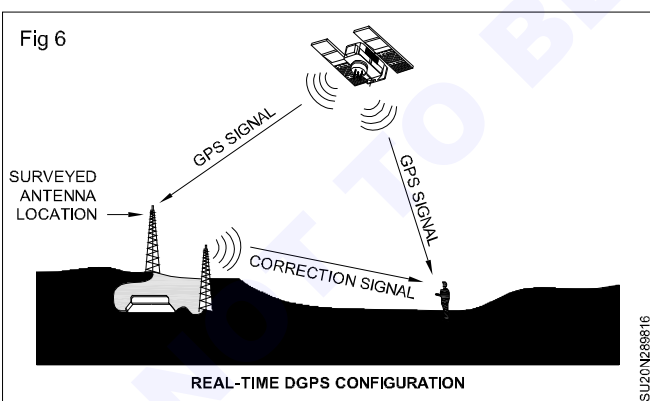
Real time kinematic (RTK) refers to a stop-gap method where the coordinates of points are available in real time using a technique called differential GPS or DGPS.

The DGPS technique is based on using at least two GPS receivers. One receiver is located at a fixed position which has been accurately located using traditional land surveying techniques. This receiver is known as the base station, and also contains a computer. The remaining receivers are roving, and are used for the surveying or navigation activity.

The base station takes GPS readings continuously and calculates its "position" based on the GPS data. The computer then compares the receiver position based on the GPS data to the actual receiver location based on the accurate land survey. The difference between the GPS calculated "position" and the real position of the receiver is the error in the GPS for that particular reading. Each reading is also time-stamped, so we know for what time of day the errors are valid.

The following figure illustrates the Real-time DGPS configuration. Note that only one satellite is shown. In reality, the base station must receive signals from all the satellites visible to the roving receiver. (Fig 7)
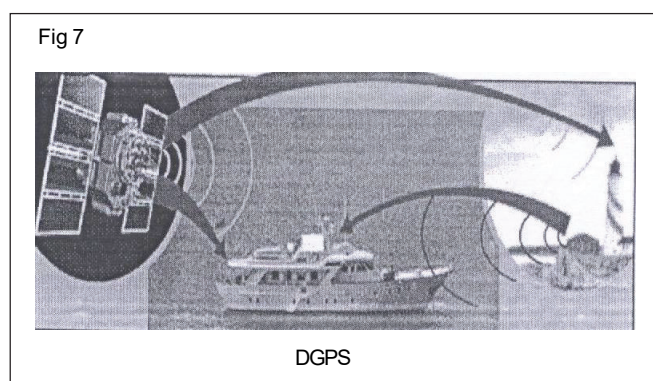
DGPS

For the highest accuracy in a local area, setting up a base station and using DGPS is the best approach. However, the US Government realized the benefit of setting up permanent DGPS base stations and radio transmitters, especially along coastal areas and around airports. The installation of permanent DGPS base stations and making the correction signals available for free or by subscription

is known as GPS Augmentation. Three augmentation systems. Beacon, WAAS and LAAS have been developed by the US Government.

Time measurement and timing in GPS: We live in a four-dimensional world and the fourth dimension is time. Without an accurate estimate of time, finding position as it is understood today is not possible. The GPS delivers time, time interval and frequency anywhere in the world with precision and accuracy more than adequate for many applications.

With GPS timing, precision of billionth of a second is now possible. A billionth of a second is called a nanosecond (ns). Such precision has opened up all kinds of opportunities.

There are several types of GPS receivers used in time and frequency metrology. The cost, size, and design of a GPS timing receiver varies significantly from model to model, but most share several common features. Most receivers use the C/A code broadcast on the L1 frequency as their time and frequency reference. Most can simultaneously track from 8 to 12 satellites, and can provide time and frequency signals derived from an average of all satellites in view. Most provide time-of-day and date information in a computer readable format.

At the hear of GPS is the timing accuracy available from atomic clocks. Albert Einstein gave us the relationship between space and time - the four dimensions of relativity. These four dimensions may be through of as latitude, longitude, altitude and time or in shorthand x, y, x and t. GPS is the first engineering implementation of relativity and would not work without it. Fortunately, an understanding of relativity is not necessary to gain an understanding of how GPS works. The realistic terms are accounted for in the design of the satellite clocks and in the receivers that properly process the data.

Ground support equipment, tracking & application of GPS

Objectives: At the end of this lesson you shall be able to
• **explain ground support equipment**
• **enumerate best personal GPS tracking devices**
• **describe differential GPS**
• **explain application of GPS.**

Ground support equipment and signals (Figs 1 & 2)

The signals the GPS receivers get from the satellites are converted into position, velocity and time estimates. Conceptually the process is one of measuring the time a signal from a given satellite takes to reach the receiver. Since the travel speed of the signal, which is the same as that of light is known, the distance of the receiver from the satellite can be computed.

Fig 1

GROUND SUPPORT EQUIPMENT & SIGNALS

Fig 2

US SPACE COMMAND

CAPE CANAVERAL

HAWAII

ASCENSION Is.

DIEGO GARCIA

KWAJALIEN ATOLL

✦ MASTER CONTROL STATION ◆ MONITOR STATION ▲ GROUND ANTENNA
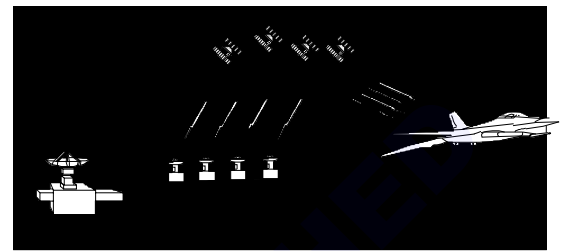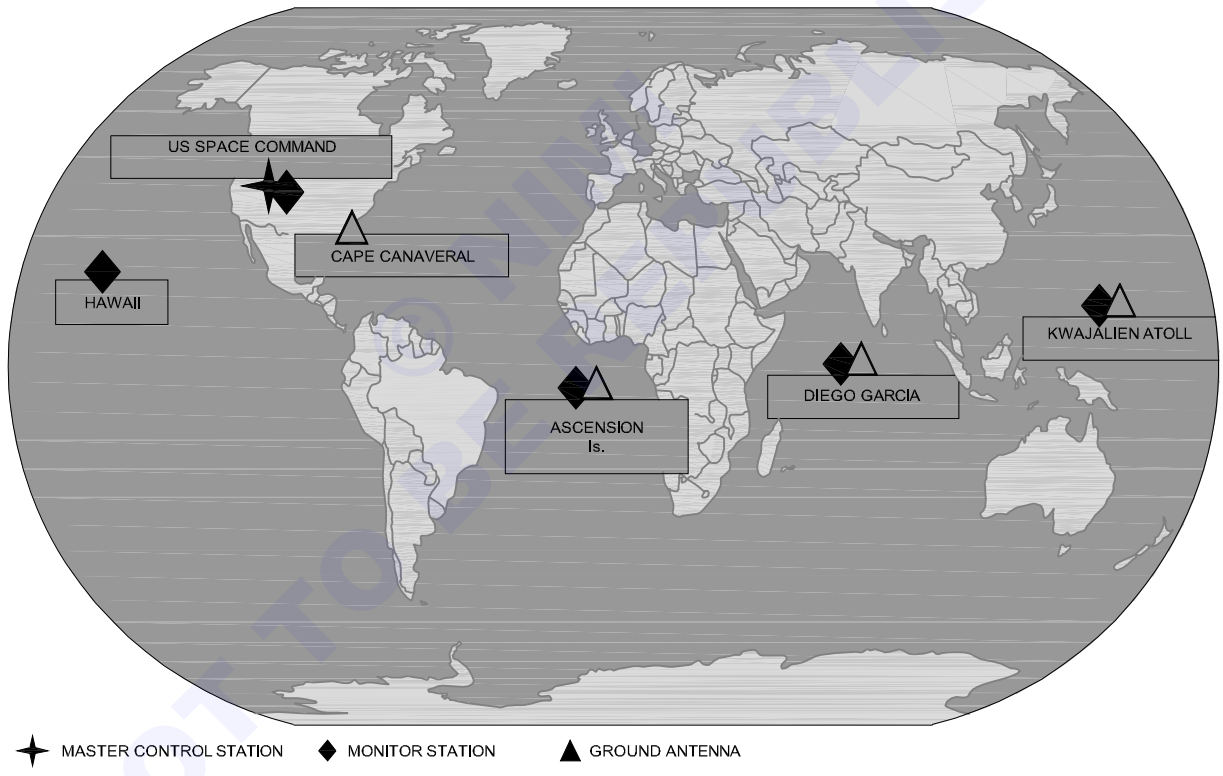
The Master Control Station receives the monitoring station tracking and ground antenna telemetry information and computes the current and predicted satellite clock offsets and satellite positions. It then converts this data to the navigation data formats described later. These rather complex satellite orbit/time filter estimating algorithms must also model the satellite solar radiation pressure, atmospheric drag on the satellite, Sun/Moon gravitational effects, including solid Earth and ocean tides, and Earth's geopotential model. Improved GPS satellite-to-satellite cross-link ranging data may also be used in the future. The navigation data are uploaded from several 10-m S-band ground antenna upload stations.

Tracking (Fig 3)

GPS tracking means to trace something or someone with the Global Positioning System. The below diagram illustrates the basic AVL system. It shows the GPS signal arriving from satellite to vehicle. The vehicle location is communicated to the PC (Control Center) via wireless network. But for thousands of years Homosapiens has had the opportunity to observe the movement and general habits of members of his own species as well as of wildlife, particularly by following their tracks. It was a hard and particular unsafe affair. Hence the development of satellite tracking by the Argos consortium was a quantum leap in

the human tracking business. Since 1994 the Global Positioning System has been available for civilian use at no cost. Nowadays GPS makes it available to everyone to track nearly everything. Objects as well as persons can be tracked if they are fitted out with a GPS receiver estimating the respective location. The GPS location data is stored on board of the GPS receiver. Modern GPS tracking systems are able to send such GPS position data from the object directly to a receiving station. A receiving station can be a stationary receiver of a tracking

service company (in case of car tracking f. ex.) or provider of a mobile phone company, or just a PC. Nowadays the GPS location data can be also received by samll mobile gadgets like laptops, handsets etc. The AVL tracking system consists of a GPS receiver inside the vehicle and a communications link between the vehicle and the control Center as well as pc-based tracking software for dispatch. The communication system is usually a cellular network similar to the one used by your cell phone.

Fig 3

GSM/SMS - GPRS - CDMA -TX
2-WAY RADIO - LTR - WAY PAGER - RE- FLOX
SATELLITE MODEM

NET WORK

1. GPS RECEIVERS IN EACH MOBILE ASSET RECEIVE SIGNALS FROM A NETWORK OF OVERHEAD SATELLITES.
2. TRANSMIT THE DATA TO THE COMMUNICATIONS CENTER VIA DIFFERENT NETWORKS.
3. THE CONTROL CENTER RECEIVE AND PROCESS THIS DATA AND SHOWS REAL-TIME PINPOINT INFORMATION OVER MAPS.
4. THE CONTROL CENTER IS ABLE TO SEND COMMANDS TO TEACH UNIT (TRIGGER ALARMS, STOP ENGINES, CHANGE DIRECTION, PERSONAL MESSAGES, ETC.)

TRACKING

Best personal GPS tracking devices

GPS trackers are getting thinner, cheaper and more useful for security and outdoor activity than over before. Infact, several excellent models may accept into the market without you realising it. Here a list of the top personal tracking devices.

1 **Trax (Fig 4):** Trax stand out by being highly consumer-oriented in its approach to GPS tracking devices. The company offers one Trax package that includes two different clips (albeit only one tracker), one for clothing and one for a collar, indicating the company's two different approaches for kids and dogs.

Fig 4

TRAX
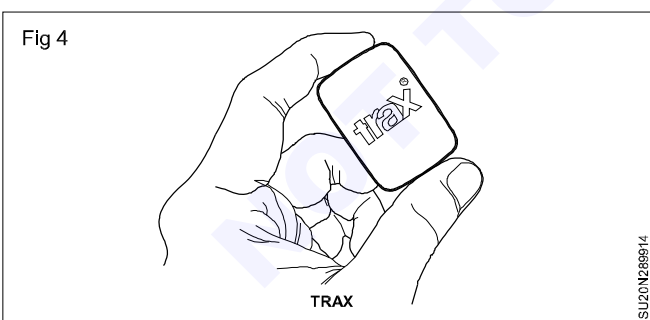
2 **Spot Gen3 (Fig 5):** Spot Gen3 takes a different approach to GPS tracking by using a personal GPA tracking device that's much more than just a tracking chip. This larger tracker comes without a screen (to be even more durable, it seems) but does have several buttons for different commands. It can track exactly where you are, record where you have been, allow to check in at specific places, and even send specific pre-planned messages or SOS signals.

Fig 5
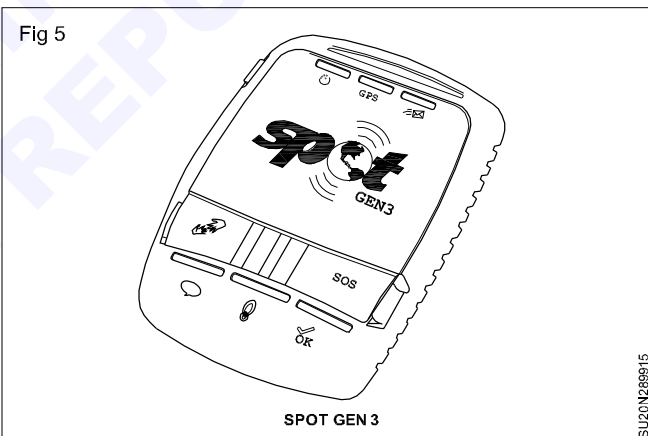
SPOT GEN 3

3 **DeLorme InReach SE (Fig 6):** DeLorme InReach SE is an excellent modern GPS tracker if you want something more social than the Spot Gen3. This device has a tiny screen and basic direction buttons you can use to tap out a text message no matter where you are or what mountain you just scaled. It also has SOS capabilities, extensive.

4 **Pocket Finder (Fig 7):** Pocket Finder is something of a supermarket in the personal tracking devices world, with options for people, pets and vehicles, each with its own characteristics. The personal GPS locator is designed for kids, teens, seniors, and anyone else who wants them. The know-like shape is a little odd compared to other offerings, but all the functionality is still present, complete with an app that overlays maps with the locations of multiple people. Geofencing also gives you important updates on location. If you aren't

quite sure what features you want in a tracker, Pocket Finder's models make a good starting place for your research.

Fig 6

DELORME INREACH SE

Fig 7

POCKETFINDER
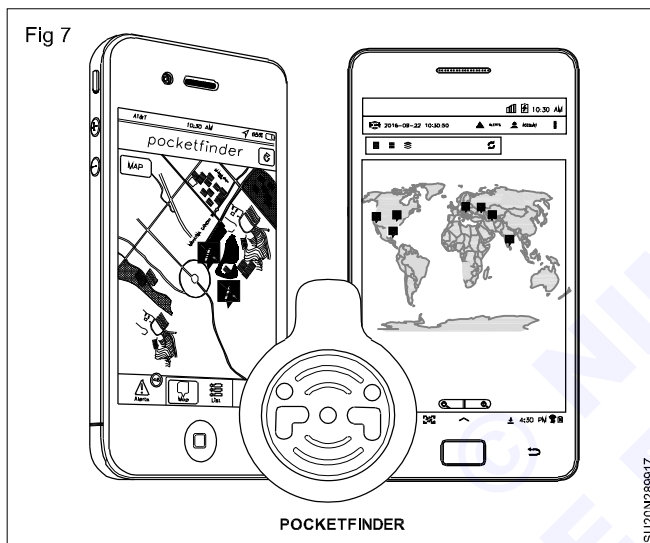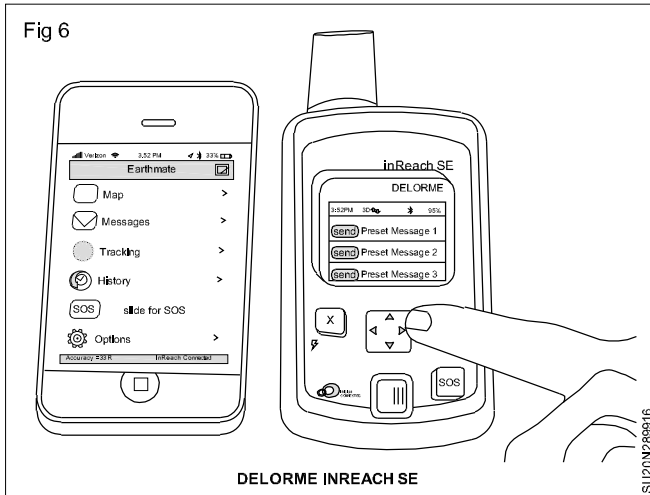
5 Real-Time Correction of Multiple Receivers - Inverse DGPS: Suppose you are interested in accurately tracking where a number of vehicles are and how fast they are moving using GPS in real-time, and you want to monitor all of them from a central location (for example, for a fleet of delivery or service trucks). Each vehicle would need a GOS receiver. That would tell the vehicle where it is, but not you. Therefore, each vehicle must transmit its own positional information, usually by radio, back to the home office. For accurate location and speed determination, you decide to use Differential GPS. To equip each vehicle with DGPS capability requires more equipment and is expensive. The better approach is to have one DGPS station at the home office, and use this single correction factor for all the data coming back from the vehicles. This tehcnique is called Inverse DGPS.

Inverse DGPS is applicable whenever there are multiple mobile receivers and the receivers themselves don't need differential GPS accuracy. This approach can be used for accurately tracking vehicles, weather balloons, semi-autonomous robots, or even real-time surveying of pre-defined points. Several companies offer inverse DGPS for public bus systems and even school buses,

so that central dispatch always knows the status of the transportation system.

Applications of GPS

GPS in marine system (Fig 8): Marine GOS receivers feature waterproof casings, marine chart plotter maps, and even fishing tables and celestial schedules. Most can also store highway map information, so you can use your marine GPS to get you to the marina and then out to the fish.

Fig 8

MARINE GPS RECEIVER
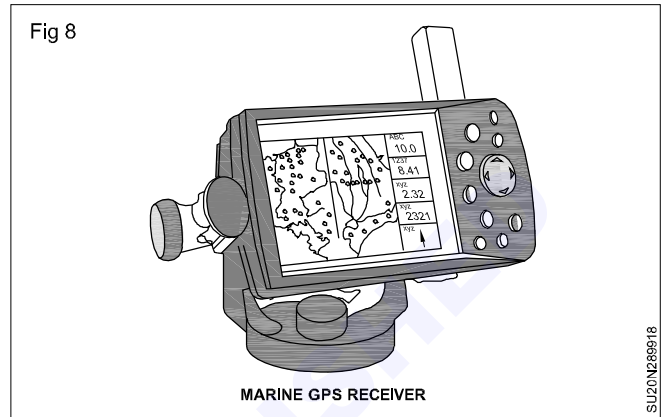
GPS for private and commercial use: The GPS system is free for everyone to use, all that is needed is a GPS receiver, which costs about $90 and up (March 2005). this has led to widespread private and commercial use. An example of private use is the popular activity Geocaching where a GPS unit is used to search for objects hidden in nature by traveling to the GPS coordinates. Commercial use can be land measurement, navigation and road construction, private and Geocatering.

GPS on air planes: Most airline companies allow private use of ordinary GPS units on their flights, except during landing and take-off, like all other electronic devices. The unit does not transmit radio signals like mobile phones, it can only receive. Note, however, that some airline companies might disallow it for security reasons, such as unwillingness to let ordinary passengers track the flight route.

GPS for visually impaired: The projects of the navigation system using GPS for the visually impaired have been conducted quite a few times. GPS was introduced in the late 80's and since then there have been several research projects such as MoBIC, Drishti and Brunel Navigation System for the Blind, NOPPA, Braille Note GPS and Trekker.

MoBIC: MoBIC means Mobility of Blind and Elderly people Interacting with Computers, which was carried out from 1994 to 1996 supported by the Commission of the European Union. It was developing a route planning system, which is designed to allow a blind person access to information from many sources such as bus and train timetables as well as electronic maps of the localtiy. The planning system helps blind people to study and plan their routes in advance, indoors.

GPS applications in agriculture

More and more producers today are using precision farming techniques that can help increase profits and protect the environment. Precision, or site-specific farming involves applying fertilizer, pesticides and other inputs only where they are needed. GPS-guided equipment is often used for variable rate and other inputs only where they are needed. GPS-guided equipment is often used for variable rate application of fertilizer (based on soil tests) or pesticides (based on pest survey). GPS can also be used to develop the initial reference maps upon which variable rate applications are based. A GPS system on a combine with a yield monitor can be used to develop an on-the-go yield map or can be used to map weed locations from the combine when harvesting. Mounted in an airplane, GPS can be used to guide aerial spraying operations.

GPS can be used to locate weed, insect or diseases infestations and monitor their spread. It can also be used to navigate back to previously mapped infestations to apply controls. A field map can be created using GPS to record the coordinates of field borders, fence lines, canals, pipelines, and point locations such as wells, buildings, and landscape features. The resulting field map might be the first layer a producer would develop for an on-farm GIS (Geographic Information System). Additional layers showing crop damage from hail or drought, and riparian areas or wetlands could be mapped using GPS. Ranchers could use GPS to develop rangeland utilization maps and to navigate back to previously mapped areas or monitoring sites.

GPS navigation - Land, Sea and Air (Fig 9)

Fig 9
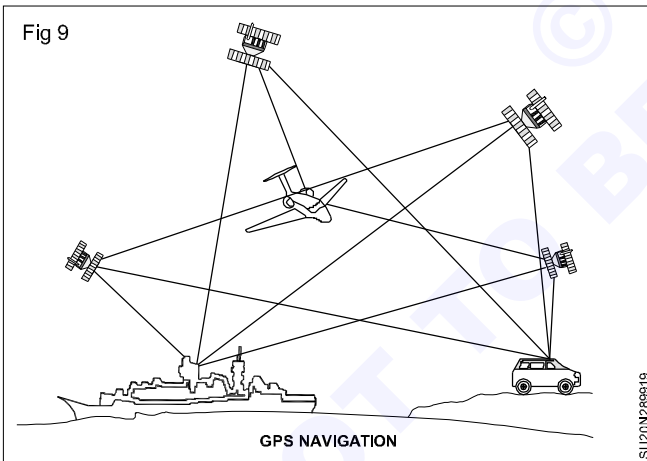
GPS NAVIGATION

GPS is being used for emergency response (fire, ambulance, police), search and rescue, fleet management (trucking, deliver vehicles, and public transportation) and for automobile guidance systems. Recreational uses of GPS include navigation while hiking, hunting, or skiing. GPS is even used on golf courses to track golf carts, and to let players know how far it is to the center of the greens.

On our nation's waterways, GPS is being used for recreational sailing and fishing and for commercial shipping fleet management. Assisted steering, risk assessment and hazard warning systems for marine navigation are being developed using GPS.

In the air, GPS is being used for en-route navigation (helicopter, airplane, hot-air balloon), aircraft landing, and air-collision avoidance systems.

GPS Applications - Mapping and Surveying

GPS applications in natural resource management include inventory and mapping of soils, vegetation types, threatened and endangered species, lake and stream boundaries and wildlife habitat. GPS has been used to aid in damage assessment after natural disasters such as fires, floods and earthquakes. GPS has also been used to map archaeological sites and for infrastructure (streets, highways and utilities) mapping, management, and planning for future growth. Engineers use GPS for surveying building roads, bridges and other structures.

Public Health and Safety - Earthquake Prediction

The occurrence of slight movements and tilting of the earth's surface often precedes moderate to large earthquakes so it requires installations of range number of earthquake prediction across the country. Historically, scientists have deployed measurement equipment only in limited areas, due mainly to cost, access, and manpower requirements. To overcome these disadvantages, the Geographical Survey Institute of Japan has deployed a permanent network of 1,000 GPS receivers across the country.

Engineering and construction - equipment control and monitoring (Fig 10)

In addition to the improvement in the speed and efficiency of precision surveying, a number of other GPS applications have been developed in engineering and construction. For example, GPS equipped earth moving equipment can now excavate and grade complex foundations with minimum operator interference. GPS technology not only guides the path of the equipment, but can also be used to automatically control the height of blades or scrapers. This capability results in significant cost savings and efficiencies, since periodic manual surveying is not required.

Fig 10

Sources of errors in GPS and their correction

Objectives: At the end of this lesson you shall be able to
• **state the sources of the errors**
• **state the methods of correcting GPS errors.**

Sources of errors

1 Satellite errors

2 Satellite orbits

3 Multi-path effect

4 Atmospheric effects

5 Clock inaccuracies and rounding errors

1 Satellite errors

• Slight inaccuracy in time keeping by the satellites can cause errors in calculating positions.

• Satellites drift slightly from their predicted orbits which contributes to errors.

Let the GPS receiver, receive signals from 4 satellites, then there are two cases:

Case 1

The satellite are at 90° to each other with reference to the GPS receiver. For demonstration purpose we will take 2 satellites. The possible positions are marked by the light green circles. The point of intersection of the two circles is a rather small, more or less quadratic field (dark green), the determined position will be rather accurate.

Case 2

The satellites are not at 90° to each other with reference to the GPS receiver, the possible intersection area of the two circles is rather larger hence less accurate.

2 Satellite orbits

Slight shifts of the orbits are possible due to gravitation forces.

• Sun and moon have a weak influence on the orbits.

• The resulting error being not more than 2 m.

3 Multi-path effect (Fig 1)

Fig 1
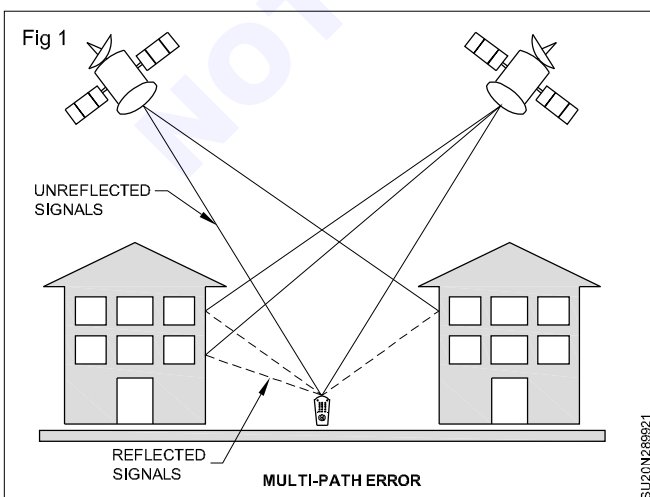
MULTI-PATH ERROR

As the GPS signal finally arrives at the earth's surface, it may be reflected by local obstructions before it gets to the receiver's antenna. This is called multi-path error as the signal is reaching the antenna in single line path as well as delayed path. The effect is similar to a double image on a tv set.

The multi-path effect is caused by reflection of satellite signals (radio waves) on objects. For GPS signals this effect mainly appears in the neighbourhood of large buildings or other elevations. The reflected signal takes more time to reach the receiver than the direct signal. The resulting error typically lies in the range of a few meters.

4 Atmospheric effects (Fig 2)

Fig 2

ATMOSPHERIC EFFECTS
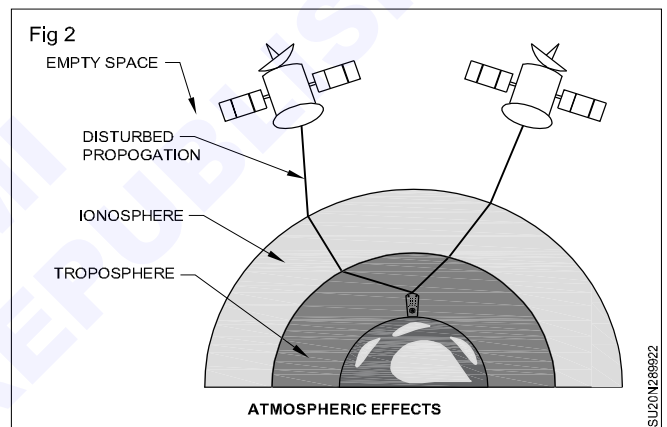
The GPS signals have to travel through charged particles and water vapors in the atmosphere which delays its transmission. Since the atmosphere varies at different places and at different times, it is not possible to accurately compensate for the delays that occur.

While radio signals travel with the velocity of light in the outer space, their propagation in the ionosphere and troposphere is slower. In the ionosphere (consisting of layers) in a height of 80 - 400 km a large number of electrons and positive charged ions are formed by the ionizing force of the sun. The layers refract the electromagnetic waves from the satellites, resulting in an elongated runtime of the signals. Since the electromagnetic waves emit in form of a sphere, therefore, inverse square law is employed and the waves are slowed down inversely proportional to the square of their frequency (I/F) while passing the ionosphere. The reasons for the refraction in troposphere are different concentrations of water vapors, caused by different weather conditions. The error caused that way is smaller than the ionosphere error, but cannot be eliminated by calculation. It can only be approximated by a general calculation model.

Receiver error

Since the receivers are also not perfect, they can introduce their own errors which usually occur from their clocks or internal noise. Despite the synchronization of the receiver clock with the satellite time during the position determination, the remaining inaccuracy of the time still leads to an error of about 2 m in the position determination. Rounding and calculation errors of the receiver sum up approximately to 1 m.

Error	Value (Approx.)
Ionosphere	4.0 meters
Clock	2.1 meters
Orbit	2.1 meters
Troposphere	0.7 meters
Receiver	0.5 meters
Multipath	1.0 meters
Total	10.4 meters

Selective availability

- Selective availability (SA) was the international error introduced by DoD to make sure that no hostile forces used the accuracy of GPS against the US or its allies.

- On May 1st, 2000, the White House announced a decision to discontinue the international degradation of the GPS signals to the public. Civilian users of GPS will be able to pinpoint locations up to ten times more accurately.

Methods of correcting GPS errors

1 Real time correction

2 Post-processing correction

3 Satellite differential services

1 Real time correction

- The base station calculates and broadcasts corrections for each satellite as it receives the data.

- The correction is received by the roving receiver via a radio signal and applied to the position it is calculating.

- As a result, the position displayed on the roving GPS receiver is a differentially corrected position.

Post processing correction

- Differentially correcting GPS data by post-processing uses a base GPS receiver that logs positions at a known location and a rover GPS receiver that collects positions in the field.

- The files from the base and rover are transferred to the office processing software, which computes corrected positions for the rover's file.

- This resulting corrected file can be viewed in or exported to a GIS.

Concept & Uses of G.P.S. Survey Software

1 Location → Determining a position

2 Navigation→Getting from one location to another

3 Tracking→Monotoring object or personal movement

4 Mapping→Creating maps of the world

5 Timing→Making it possible to take precise time measurement

Plotting the contour lines with the help of Auto civil/Civil 3D software

Objectives: At the end of this lesson you shall be able to
• **state digital terrain modeling concept**
• **state contour data**
• **define civil 3D.**

Digital terrain modeling concepts

Digital Terrain Modeling is a concept that underlies all calculations in Civil Engineering involving elevation or slope-profiles, cross sections, grading and volume calculations. The process of Digital Terrain Modeling involves the creation of a data structure that the software can instantly "touch" to retrieve elevations or slopes, representing either existing or proposed conditions.

The basic concept behind Digital Terrain Modeling is an old one in the Civil Engineering and Survey industry - interpolation.

Prior to Digital Terrain Modeling, the processing of a network of plotted spot elevations, such as those seen in Figure 1. involved the interpolation of intermediate elevations between known values as shown. The interpolation lines drawn in Figure 1 were conveniently created with the Divide command in AutoCAD®; prior to CAD, this was often accomplished with a graduated rubber band. With the interpolation complete in Figure 1 - Interpolation between Known Elevations intermediate elevation could be obtained, or contours drawn. The process is effective, but time consuming.

Digital Terrain Modeling mathematically completes all interpolation possible between the data supplied, and stores the result in a digital file for easy retrieval. Figure 2 shows the triangles that result from Digital Terrain Modeling in AutoCAD® Civil 3D®, and the Tooltip that results when the cursor is stationary over the digital surface; Civil 3D retrieves the elevation value from the digital surface and displays it in the Tooltip, instantly and anywhere on the surface.

Fig 1

Fig 2
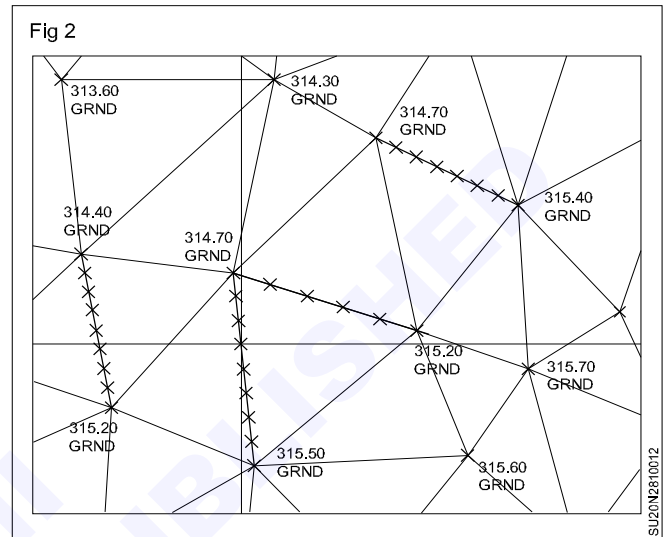
The Digital Terrain Models in Civil 3D have the advantage of many display options, through their Surface Styles. Displayed as contours, Civil 3D obligingly places a contour in the same location as the interpolated tick. (Fig 3)

Fig 3
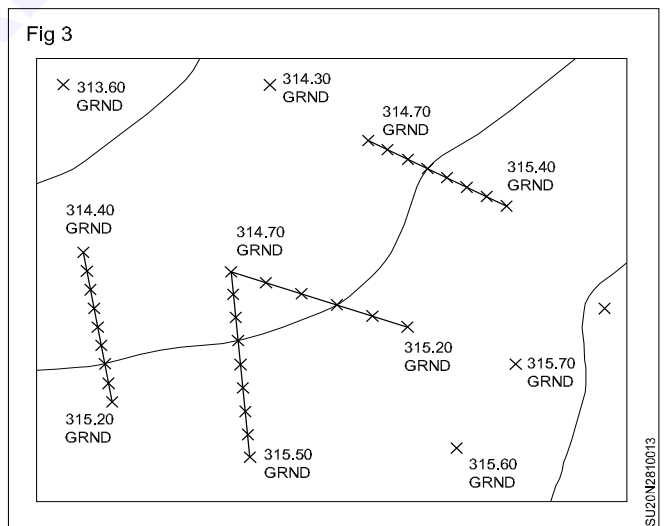
This chapter serves two purposes. The first is to introduce the Trainee to Digital Terrain Modeling in Civil 3D, a fundamental concept for both existing and proposed as mentioned above. The second objective is to serve as a detailed introduction into the operational aspects of Civil 3D, processing data and building a Civil 3D Object. The Civil 3D Surface Object is in many ways the easiest object in the program to grasp and to master, as it is readily created and displayed, and is managed by only a single Style in Civil 3D - a Surface Style. As an introduction in this fashion, the examination of surfaces in this chapter is
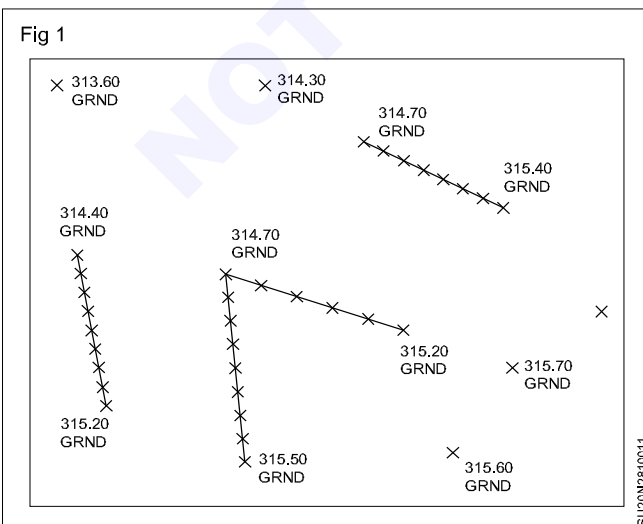
limited to the processing of Aerial or Photogrammetric data. Surfaces can certainly be produced from other data types, including point data; but a discussion of Terrain Modeling from points necessitates familiarity with Civil 3D point management and is, therefore, deferred to a later chapter.

Data Types for Digital Terrain Modeling: There are certain data types that are universally applicable to any Digital Terrain Modeling effort in Civil Engineering and Surveying. These data types are constant in any program: Civil 3D, Land Desktop, In Roads, ArcGIS, etc. The three data types which can be used in constructing a DTM are Point Data, Breakline Data, and Contour Data.

- **Point:** Data Point Data for Digital Terrain Modeling consist of individual discrete X, Y and Z locations, without connecting features between them. Typically, these will be spot elevations in a contour drawing, or the mass points themselves in a Mass Points and Breaklines drawing. Critically, the Point Data must have an elevation or Z component that can be processed in some fashion in building the elevation model. In drawing form, Point Data may be Civil 3D points, AutoCAD points or nodes, or block insertions, text or Mtext inserted into the drawing at true Z elevation. If Point Data are obtained from GIS, they can be used and processed by AutoCAD® Map 3D if an elevation attribute is present in the GIS data. Similarly, spot elevation text at elevation 0 in a drawing can be used and processed by Map into an ASCII file, and ASCII files of XYZ format can be used as well.

- **Breaking Data:** Breaklines are also referred to as Faults, or Features. Breaklines, as used in this context, represent the linear edges of site features along which there is a noticeable change in grade. Successfully applied, a breakline forces a deflection in a contour to show a grade change. Examples are edges of pavement, shoulders, toes or tops of slope, toes or tops of wall, water features, etc.

- **Contour Data:** The definition of contour Data for Digital Terrain Modeling is very specific, and not necessarily what one would expect. Contour Data are strings of point data connected by segments in complex objects; the CAD representation is a polyline. Contour Data do not have to be at constant elevation, as one typically thinks of contours. Contour Data are a fast means of selecting and processing point data, utilizing the vertices of the objects. Most Digital Terrain Modeling applications will also process the segments between the vertices as breakline data, and can filter out vertices too close together or add interpolated vertices if required. Contour Data must be at a correct Z elevation to be processed in a Terrain Model. Polylines must be at a correct Z, either constant as a 2D polyline or varying, as a 3D polyline. GIS data can again be used, and AutoCAD Map can read elevation attributes from GIS Contour Data and apply them to polylines through a Property Alteration Query.

Most Civil Engineering and Surveying applications will utilize some combination of data types in a Terrain Model; having two types present is common and all three is not unusual at all.

Critical civil 3D surface feature settings (Fig 4): Civil 3D has the advantage of being an infinitely customizable program. This advantage allows Civil 3D to be used effectively in almost any locale or units. Civil 3D has the disadvantage of being an infinitely customizable program. This disadvantage means that there are a plethora of Civil 3D settings that control the program and a concurrent risk that an important setting could be overlooked.

Every element or Feature, in Civil 3D has its own settings. This means that there are settings that control the creation, interaction and editing of surfaces, as well as points, alignments, parcels and every other portion of the Civil 3D system. Civil 3D Feature Settings determine the default styles that will be applied to each feature, various options unique to the feature's operation and then Feature Command settings that fine-tune the way Civil 3D operates.
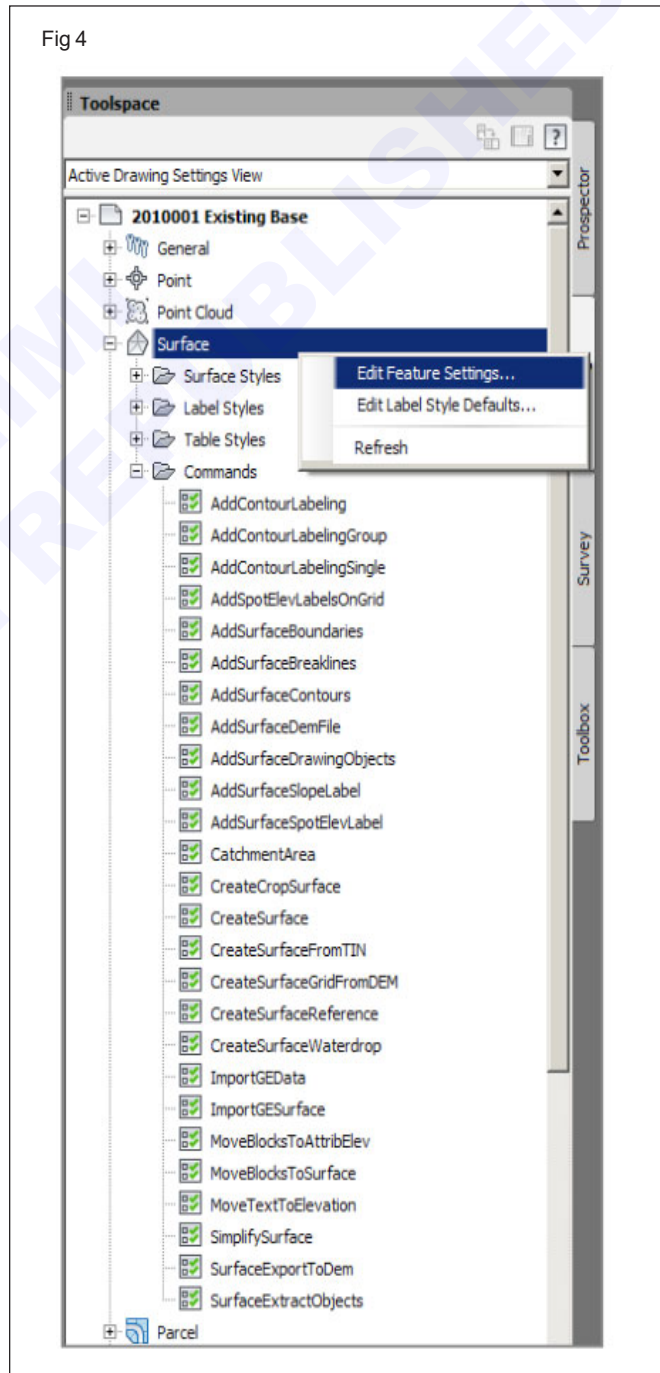
Feature Settings are among the options controlled on the Tool space's Settings tab, and are exposed under each of the various collections listed there. Many Feature Settings can be set at the time data are actually created, rather than prior to use. Some Feature Settings can be adjusted "on the fly", such as those for Point Creation. Civil 3D Surface Feature Settings are exceptional, in that certain critical Surface Feature Settings must be made before any surfaces are created in Civil 3D.

To begin examining Surface Feature settings, expand the Surface collection on the Tool space's Settings tab. Also expand the Commands collection below Surfaces.

Civil 3D Feature Settings are always found at two levels on the Settings tab: at the parent level of the collection (Surfaces in this case), and at the appropriate command level for the Civil 3D command to be used (Create Surface, which we'll get to shortly).

To examine the settings at the Surfaces parent level, right click on Surfaces and pick Edit Feature Settings from the menu.

In the Edit Feature Settings - Surface dialog, two different glyphs can be seen.

Settings with the glyph are actually inherited from the general Civil 3D Drawing Settings made earlier. Any changes made to these settings will affect Surface settings only; settings for any other feature in Civil 3D will continue to reflect the global drawing settings. An edit of this type would also result in a Child Override indication in Drawing Settings.

Settings with the drunken pentagon glyph are the settings unique to and introduced by the actual Surfaces level.

Of the three Surface Settings levels in the dialog, only one is really important at all before creating a surface, the Surface Default Style. Set to Border Only in this template, the surface will initially display only as its perimeter or border when built, and this setting can easily be overridden when the surface is built. There is clearly nothing critical here, so press OK to close the parent surface Feature Settings. (Fig 5)

Fig 5
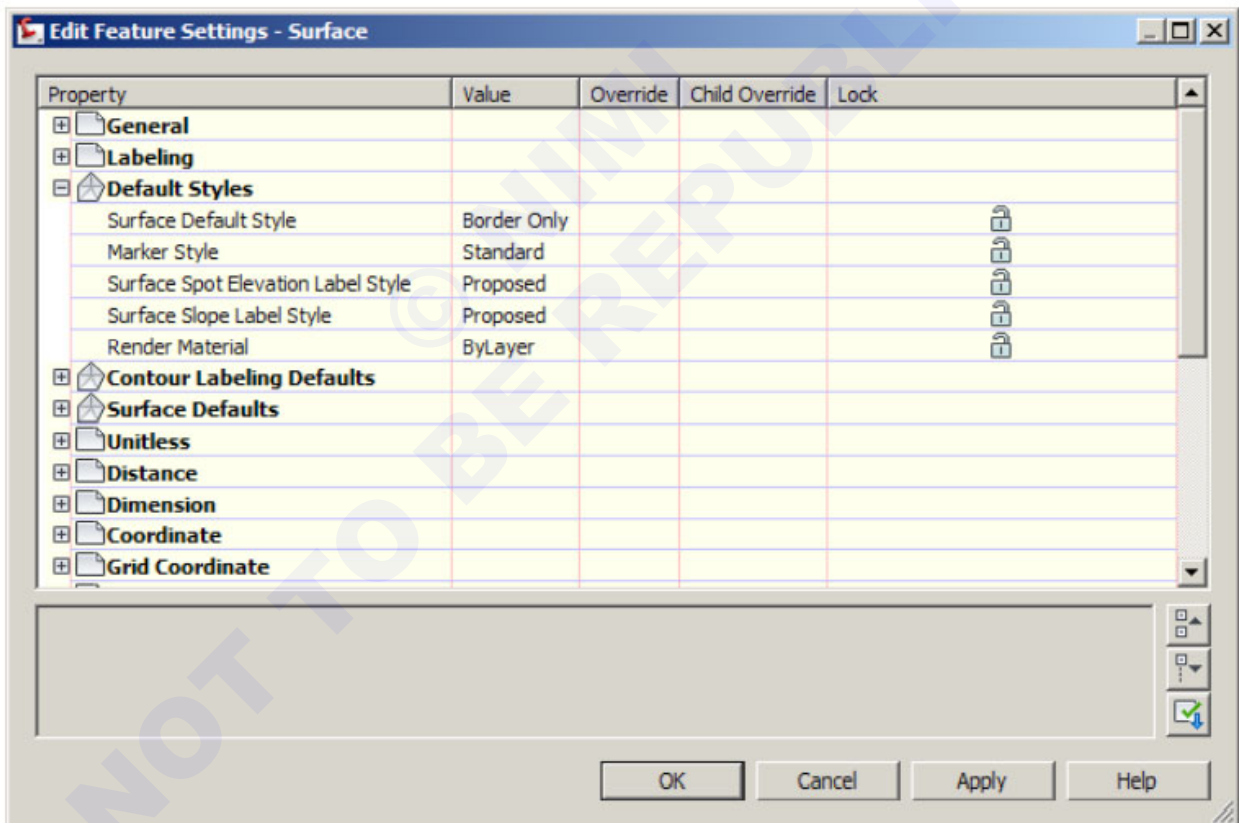
The second level of Civil 3D Feature Settings that should always be checked on the Settings tab is at the appropriate command level for the Civil 3D command to be used. In this instance, we are about to create a surface; to access the setting for this operation, right-click on Create Surface under Commands, and pick Edit Command Settings from the menu. (Fig 6)

Again, different glyphs can be seen in the Edit Command Settings - CreateSurface dialog. The and glyphs

again refer to settings inherited from the collections above, Drawing Settings and Parent Surface Feature Settings, respectively. Changes made at these levels in this dialog would again be child overrides having no effect on the drawing or feature settings above.

The new glyph pertains specifically to the operation of creating a surface, and there are two levels: Surface Creation and Build Options. (Fig 7)

Fg 6

Figure 6. Surface Command Settings on Settings Tab
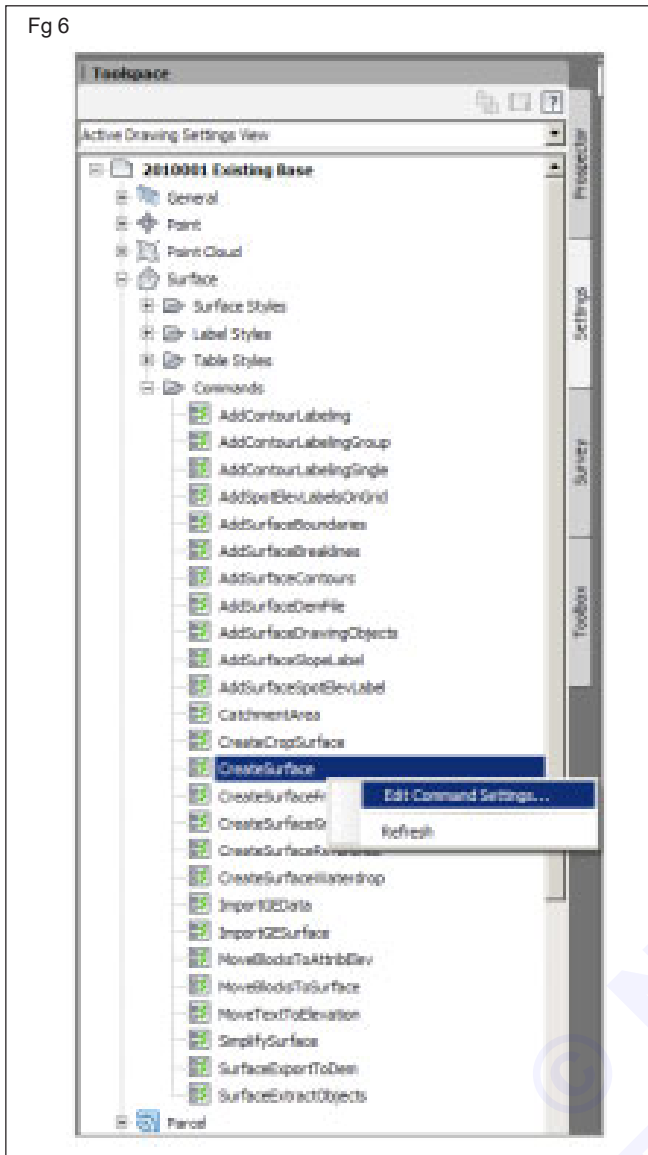
Opening the first collection, Surface Creation, the options look pretty straight forward. One option that is somewhat new is the ability to select the Surface Default Type. Civil 3D can build not only TIN Surfaces but Grid Surfaces. TINs are Triangulated Irregular Networks, a specific type of terrain model common to Land Desktop and many other Civil Engineering and Surveying applications. TINs are preferable for profiles and cross sections based on the accuracy of their triangle-based model, but they are not necessarily visually pleasing. Grid surfaces, the other type that can be produced by Civil 3D, model a surface using quadrangles.

Grid models tend to be visually smoother, but less accurate for engineering purposes. Most surfaces built in Civil 3D will be TINs so this doesn't seem that important either. The operator is being lulled into a false sense of security at this point, but a huge land mine in Civil 3D is looming.

Collapsing the Surface Creation collection and expanding the Build Options collection, things still appear reasonably familiar. Here the program can exclude data below or above a threshold value, familiar to anyone who has used Land Desktop. There are other data filters, actually restored

from earlier versions of Softdesk. One setting seems to stand out though; Allow Crossing Breaklines. Set to yes in this template, the out-of-the box setting for this value as supplied from Autodesk® is **No.** (Fig 8)

Anyone who has used any previous Civil product knows that a basic tenet of terrain modeling is that Breaklines, as already defined in this chapter, cannot cross. In Land Desktop, when one breakline crossed over another, one or both would be ignored. This rule extends even to field work - surveyors are taught that when running linework for bottom face and top face of a curb, in a curve, care must be taken to align the bottom and top shots together so the fault lines will not cross. It has always been that way. So why does this setting seem to negate a basic rule of terrain modeling, and allow crossing breaklines? And who would want to anyway?

The answer is simple: Autodesk is changing the rules - and the language - on the fly. Used in this dialog, Breaklines, does not mean Breaklines as we have defined (and used for years). Breaklines means TIN Triangles. The setting means "Allow Crossing TIN Triangles: Yes or No?"

As confusing as this seems, one must know a little more about how TINs are constructed in Civil 3D before answering the question. Unlike Land Desktop, Civil 3D does not wait until all data are selected for the surface and then perform the interpolation between all selected data. Civil 3D builds the surface interactively as each set of data are added.

As already described, many surfaces are built from a combination of data types. In this example, the aerial spot elevations will be used, the contours will be used and (true) breaklines will be developed and used. Building the TIN in Civil 3D, as soon as the spot elevations are selected, the program will build TIN triangles between them. The contour vertices will then be added to the TIN in a second step. If the "Allow Crossing TIN Triangles: Yes or No?" setting is set to No (the factory default), Civil 3D will cheerfully reject the addition of the contours to the surface. The obscure "Allow Crossing Breaklines" setting will reject them. This operation results in an unexpected occurrence of the Event Viewer, packed with warning messages, frustration and calls to tech support.

In order to build a surface from more than one type of data in Civil 3D the "Allow Crossing Breaklines" must be set to Yes.

> **The Allow Crossing Breaklines setting must be set to Yes in Civil 3D**.

Now that the "Allow Crossing TIN Triangles" land mine has been avoided, a second one appears. Setting the Allow Crossing Breaklines option to Yes enables another setting below it, Elevation to Use. This option has three choices, one of which uses the dreaded "A" word. This setting determines how triangle edge elevations should be handled when triangles already built are revaluated by the addition of another set of data: Should the elevation of the first data set be used, the elevation of the last data set be used or the elevations averaged (argh). (Fig 9)

Fg 7
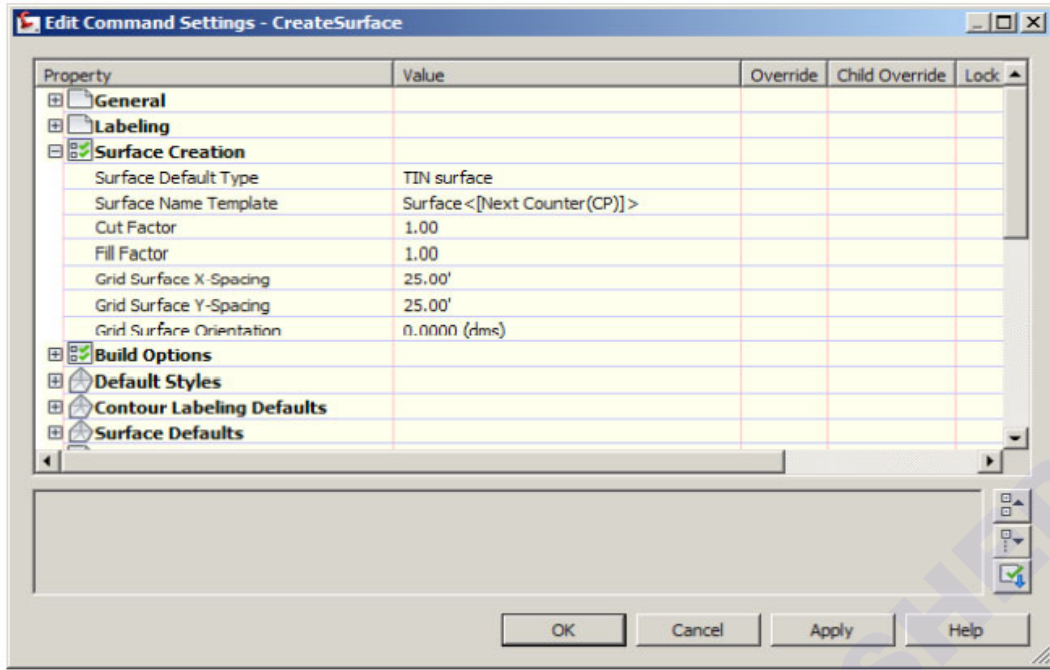
Fig 8
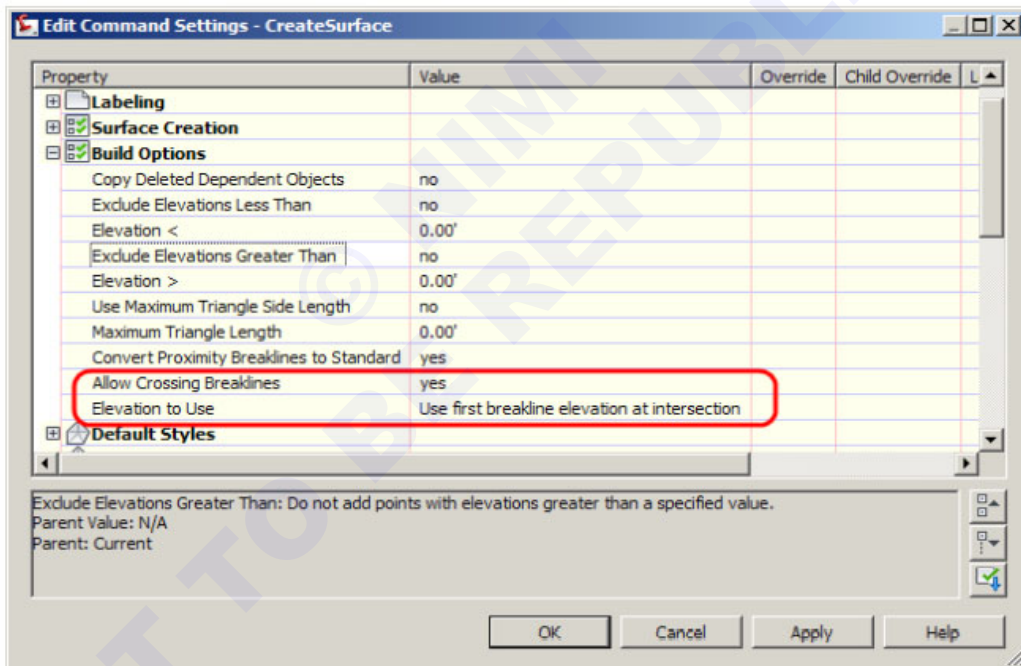
Fig 9
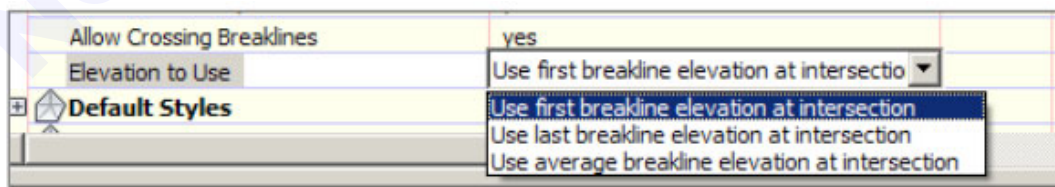
Again, some deeper analysis is required. Consider for a moment a cross sectional topographic survey of a road, and the production of a TIN from the data. The field crews set stationing, and shoot cross sections at a defined interval, for sake of example 25 feet. The road in question involves a crown, edges of pavement, and edges of shoulder. The crew runs linework for the crown, EPs and shoulders, and these lines will be used as breaklines in the surface.

Additionally, the crew also picks up other points on the road surface: manholes, inlets, water shutoffs, gas shutoffs, traffic light trip plates and the like. All of these data will be added to the TIN as points. The most reliable way to build this TIN is to set the Elevation to Use setting to Use first breakline elevation at intersection, then to select the breaklines for the surface first, then select the point group. This allows the TIN to be built first from the breaklines, which properly model the general cross sectional characteristics of the crowned road. Adding the points second then allows the TIN to deflect up or down in the areas influenced by individual points within the general shape of the road. If the point data were selected first when building the surface, the TIN would connect the manholes, inlets, water shutoffs, gas shutoffs, and traffic light trip plates, forming triangles whose elevations would not be changed by the later addition of the breaklines.

The way to use the Terrain Modeler in Civil 3D is to set the Elevation to Use setting to Use first breakline elevation at intersection, then to select data for the TIN based on its accuracy, adding the most accurate data first, and moving sequentially through data of lesser accuracy.

This concept is critical for successful use of the Terrain Modeling in Civil 3D! Civil 3D arguably has the best Terrain Modeler that has ever appeared in an Autodesk product. It has many new settings and concepts, and, once understood, can produce TINs of exceptionally high quality.

> **The Elevation to Use setting should be set to Use first breakline elevation at intersection and then data should be selected for addition to the TIN based on their accuracy, with higher accuracy data selected first.**

Set the Allow Crossing Breaklines and Elevation to Use settings as described, and press OK from Command Settings.

Starting the Surface in Civil 3D: To begin creating the existing aerial surface in Civil 3D, change to the Prospector tab. Right-click on the Surfaces collection and click Create Surface from the menu. (Fig 10)
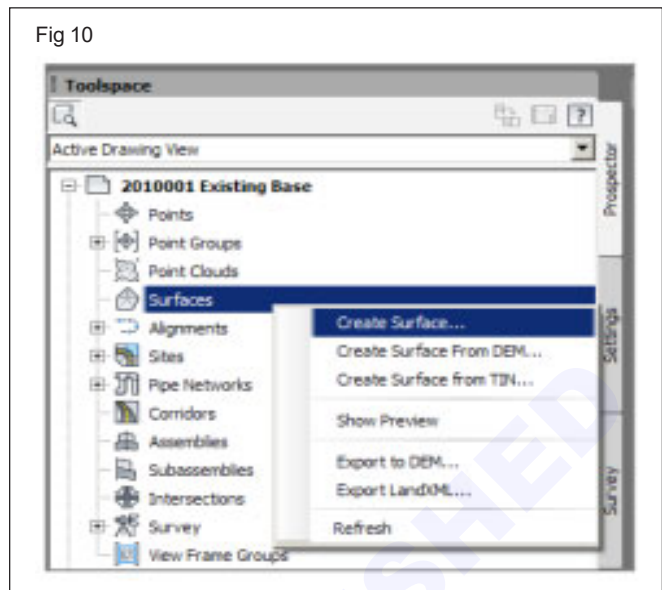
Fig 10

It should be noted that this is only one of several methods to start the surface. The process can also be started from the Home tab of the Civil 3D Ribbon, Create Ground Data Panel, Surfaces Dropdown, Create Surface. The interface used is the preference of the Trainee. In many instances, right-clicks from the Prospector will be used in these chapters; we feel these are faster in many cases and are available to readers using versions prior to Civil 3D 2010.

The Create Surface dialog appears. Taking care of the easy entries first, supply the surface Name and Description.

A less-than-obvious consideration for the surface name is the capitalization. Since the surface name will be suffixed to a layer name, be sure to type the surface name in all caps if your layer naming convention is to use capitals. (Fig 11)
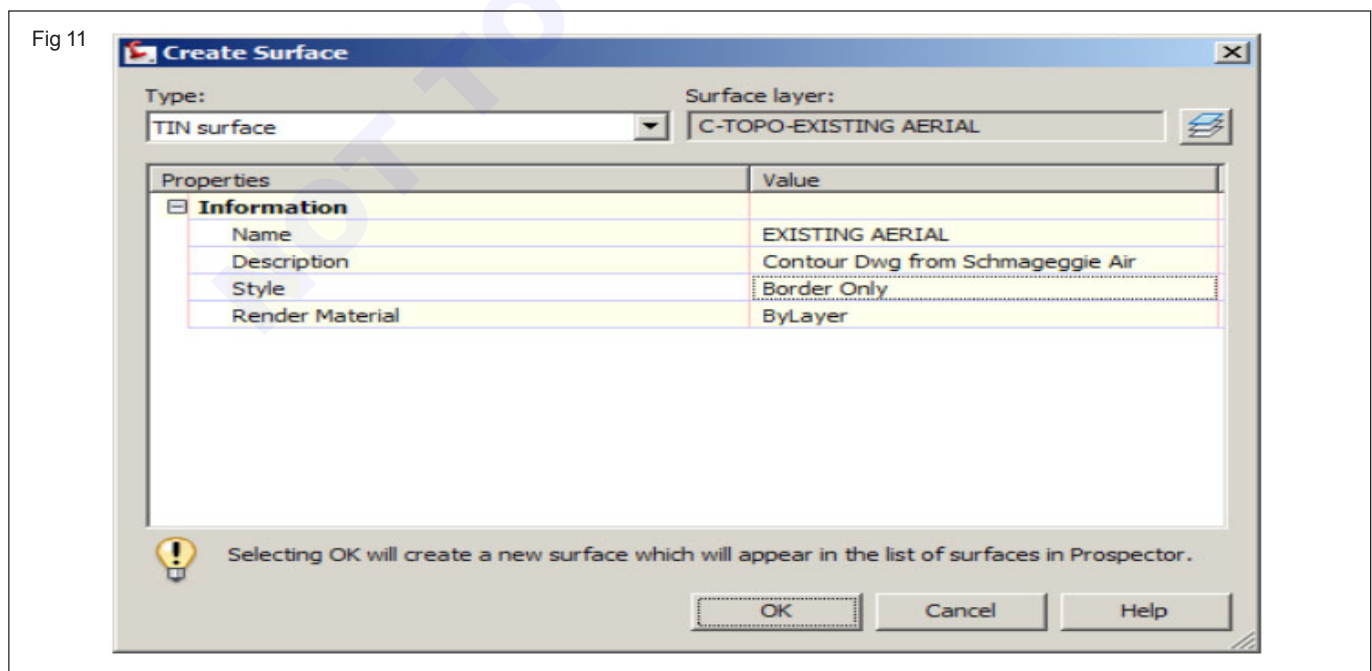
Fig 11

Introduction to hydrographic survey

Objectives: At the end of this lesson you shall be able to
• **state the application of hydrographic surveying**
• **state the uses of hydrographic surveying**
• **describe preliminary steps in hydrographic surveying.**

Introduction

Hydrographic surveying or bathymetric surveying is the survey of physical features present underwater. It is the science of measuring all factors beneath water that affect all the marine activities like dredging, marine, constructions, offshore, drilling etc.,

Hydrographic surveying is mainly conducted under authority concerns. It is mainly carried out by means of sensors, sounding or electronic sensor system for shallow water.

The information obtained from hydrographic surveying is required to bring up nautical charts which involves.

• Available depths

• Improved channels

• Break waters

• Piers

• The aids to navigation harbor facility

These survey also take part in necessary data collection relating construction and developments of port facilities, such as pier construction. This help in finding the loss in capacity due to silt and many uncertainties. (Fig 1)

Fig 1
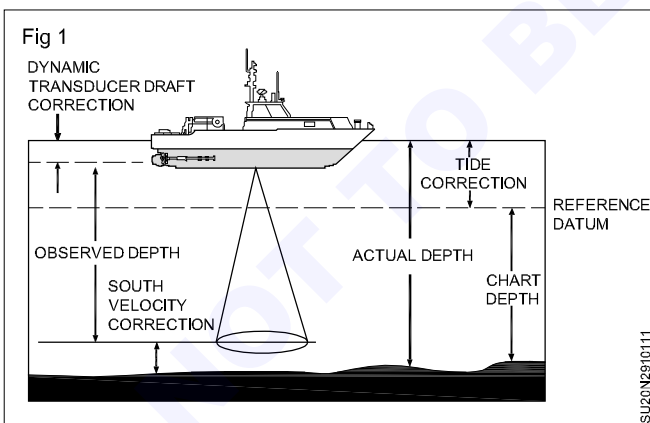
Applications of hydrographic surveying

Following are the applications of hydrographic surveying:

• Dock and harbor engineering

• Irrigation

• River works

• Land reclamation

• Water power

• Flood control

• Sewage disposal

Use of hydrographic surveying

Uses of hydrographic surveying are given below:

1 Depth of the bed can be determined.

2 Shore lines can be determined.

3 Navigation, chart preparation.

4 Locate sewer fall by measuring direct currents.

5 Locating mean sea level.

6 Scouring, silting and irregularities of the bed can be identified.

7 Tide measurement.

8 River and stream discharge measurement.

9 Massive structures like bridges, dams, harbors are planned.

Preliminary steps in hydrographic surveying

The methods starts by locating special control points along the shore line. The sounding method is employed to determine the depth at various points by means of stationary boats. Sounding locations can be either made from boat to the control points or by fixing a point in the boat and taking sounding from the control point. Before this procedure certain preliminary steps have to be made:

1 Reconnaissance

2 Locate horizontal control

3 Locate vertical control

Reconnaissance: As every project require a start-up plan to complete it effectively and economically, reconnaissance has to be undergone. A complete reconnaissance of whole survey area to choose the best way of performing the survey is needed.

This would facilitate satisfactory completion of the survey in accordance with the requirements and specifications governing such work. Aerial photographs would help this study.

Locating horizontal control: The horizontal control is necessary to locate all features of the land and marine in true relative positions. Hence a series of lines whose lengths and azimuths are determined by means of either traingulation or any other methods formed.

Tachometric and plane table survey can be conducted in order to undergo rough works. No rules are kept for establishing horizontal control as topography, vegetation, type, size of topography affect the rules.

But in general a rules can be kept for type of control say:

*   It is advisable to run traverses along each shore, connecting each other by frequent tie lines - If water body >1 km wide.

*   It is advisable to run transverse line only along one of the banks - If water body is narrow.

*   Traingulation system - If shorelines filled by vegetation.

*   Large network of traingulation system for large lakes and ocean shore lines.

A combined traingulation and traversing is shown in figure 1.

Locating vertical control

Before sounding establishment of vertical control is essential to be determined. Numerous benchmarks are placed in order to serve as vertical control, setting and checking the levels of the gauges are uses of bench marks.

Measurement of velocity of stream flow

Objectives: At the end of this lesson you shall be able to
• **describe measurement of velocity by surface flow**
• **describe measurement of velocity by velocity rods**
• **define mean velocity by empirical formulae.**

Measurement of velocity by surface floods

• The site for this measurement should be straight with steady and uniform flow for a length of 40 to 50 m.

• This distance should be equally divided.

• Floats such as partly filled bottles, wooden blocks, palmyrach fruits, etc., are released from 5m above the upstream of the reach.

• Their timings are recorded for each float as they cross the head, middle and end of the reach.

• Similarly, two more floats are released in succession from each point.

• The mean of the time of each float is calculated.

• Then the average time of all the floats are computed.

• Then the surface velocity is arrived at by dividing the run distance.

• The mean velocity is taken as 0.8 times the surface velocity.

• During the above measurement, the preveilling wind velocity and its direction with respect to the stream flow are to be recorded.

Measurement of velocity by velocity rods (Fig 1)

Fig 1

VELOCITY ROD

20 mm

0.94d

d
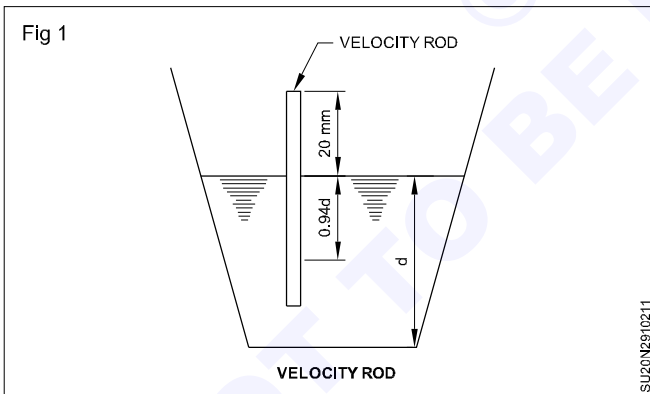
VELOCITY ROD

• Velocity rods are made of wooden rods or thin tubes of 20 to 50 mm diameter.

• The length of the velocity rod in such that they project 20 mm above the water surface level and reach 0.94 times the depth of water.

• The rods are so weighted that they float nearby vertical.

• The velocity rods are released from the straight reaches of the stream.

• The average velocity is computed, which approximately in the mean velocity.

• The mean velocity is not much affected by the wind.

• Velocity rods are suitable for artificial canals.

• In natural streams they are not used as the depth of flow varies from point to point.

Measurement of velocity by current meters

• A current meter is an instrument with a spindle mounted with cups.

• When immersed in a stream, the spindle is rotated by the force of water current.

• The number of revolutions of the spindle are recorded.

• By observing the number of revolutions of the spindle per minute, the current velocity is read from the rating curve or from the rating table.

Mean velocity by empirical formulae

1 Bazin's formulae

$$V = C\sqrt{mi}$$

Where, V = mean velocity

$$C = \frac{157.6}{1.81\left(\dfrac{k}{\sqrt{m}}\right)}$$

m = Hydralic mean depth

k = Bazin's constant

i = Bed slope

The value of 'k' depends upon the roughness of bed, but can be taken from the table for Bazin's constant.

2 Kutter's formulae

$$V = C\sqrt{mi}$$

Where

V = mean velocity

$$C = \frac{23 + \dfrac{0.00155}{i}\left[+\dfrac{i}{N}\right]}{1 + \left[23 + \dfrac{0.00155}{i}\dfrac{N}{\sqrt{m}}\right]}$$

m = Hydraulic mean depth

i = Bed slope

N = kutter's constant

The value of 'N' depends upon the roughness of bed, can be read from the table for Kutter's constant.

3 Manning's formulae

$$V = \frac{1}{n}(m)^{2/3}(i)^{1/2}$$

n = Manning's coefficient of roughness

Measurement of actual stream flow

Objectives: At the end of this lesson you shall be able to
• **define stream gauging**
• **explain the methods of stream gauging.**

Stream gauging

• For a reliable estimate of run off, the gauging stream flow is required for a number of years.

• For planning on irrigation project, the stream flow in an average bad year is required.

Methods of stream gauging

1 By erecting gauge post

2 By gauge wells

3 By gauge weirs

1 Erecting gauge post (Fig 1)

CROSS-SECTION OF RIVER WITH
POSITION OF GAUGE POSTS
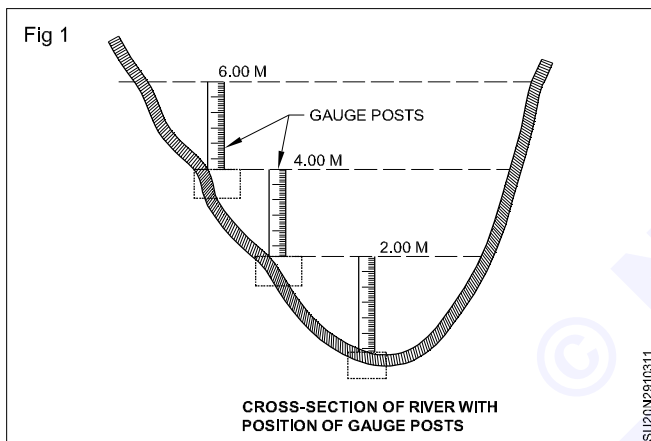
• Graduated gauge posts are erected across the stream.

• The readings observed at intervals of time from the gauge posts are recorded in a register.

• These readings given the level of water.

• The gauge posts read in metres and decimal.

• Readings are taken two to three times a day and more frequently during floods.

• Gauge posts are exposed to water and wave action.

• There are fluctuations in water level and hence the gauge readings cannot be read accurately.

2 Gauge wells (Fig 2)

• Gauge well is a well sunk on the banks of a river and provided with a gauge showing the level of water in well.

• The gauge well is usually open at top and surrounded by a steining.

• Ladder should be provided for the access to the gauge.

• The gauge well is connected by one or more pipes with river.

• Hence, the level of water in the well is kept the same as that of the stream.

SECTION OF GAUGE WELL
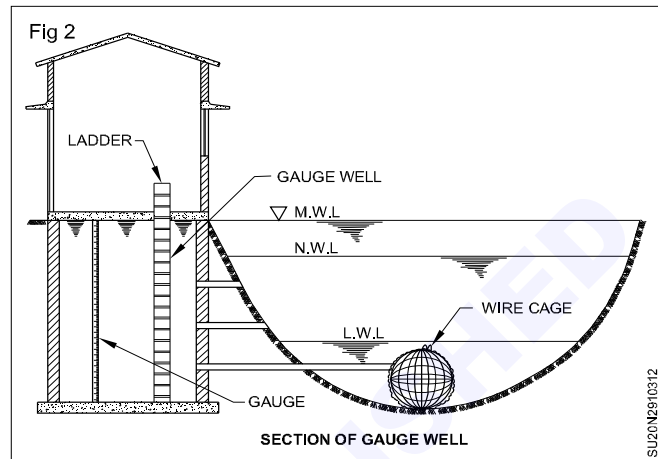
> The pipes connecting the stream and the well should have no bend.
> In case of sandy river bed, the outer end of the lowest pipe should be terminated in a lined wire gauge inside on inverted filter.

• It is better to have two gauges, one inside the well and the other outside the well in the stream of the same cross section.

3 Gauge weirs

• If small streams, weirs are constructed to measure the discharge.

• Gauge posts are fixed with the zero of the gauge at the sill level of the weir.

• Readings are recorded at regular intervals.

• The weirs may be traingular or rectangular.

• The discharge is computed by using the following formulae.

Traingular notch

$$Q = \frac{8}{15} Cd \sqrt{2g} \tan\left(\frac{\theta}{2}\right) H^{5/2}$$

Rectangular notch

$$Q = \frac{2}{3} CdL \sqrt{2g} H^{3/2}$$

Where

Q = Discharge

Cd = Co-efficient of discharge

L = Length of weir

H = Head causing flow

θ = Angle at apex of traingular notch

g = Acceleration due to gravity

Calculate the discharge of a river

Objectives: At the end of this lesson you shall be able to
• **state the measuring of stream flow**
• **explain calculating stream flow**
• **define measuring stream stage**
• **define measuring discharge**
• **define measuring stage discharge relation**
• **define handling of eco sounder and current meter.**

Measuring stream flow

While streams and rivers may be monitored for many qualities and parameters that they share with lakes, ponds and basins, they possess one quality that sets them apart from other freshwater bodies: movement. Streamflow is a keystone parameter that impacts many other aspects of a river's hydrology and water quality. Although these other aspects may be just as vital to a river's health — or just as applicable to your particular project — this chapter will focus primarily on establishing streamflow through stage discharge measurement.

Calculating stream flow

Streamflow is a measurement of the amount of water flowing through a stream or river over a fixed period of time. Streamflow cannot be measured directly, say, by plunging an instrument into a river. Instead, it must be calculated in a process known as stream gaging. The USGS has been doing this since 1889, when it established its first stream gage on the Rio Grande River in New Mexico to determine how much water was available for irrigation as the nation expanded westward. Today, the USGS operates more than 7,000 stream gages across the U.S., which provides streamflow information used widely for flood prediction, water management, engineering and research, among other uses.

The USGS splits stream gaging into a three-step process: measuring stream stage, measuring discharge and determining the stage-discharge relation.

Measuring stream stage: The first step in calculating streamflow involves measuring stage, which is the height of the water surface at a particular point in a stream or river. Stage is sometimes known as gage height, and can be measured several ways. Among the most common of these approaches uses a stilling well installed in the river bank or attached to a stationary structure such as a pier or bridge support. An underwater intake allows water into the stilling well at the same elevation of the river's surface. A float or a sensor — whether pressure, optical or acoustic — then measures the stage inside the well. An electronic recording device or data logger records stage measurements at regular intervals. A telemetry system may also be present in a stilling well, allowing data to be transmitted remotely to a host computer in real time. (Fig 1)

Fig 1

MEASURING STREAM STAGE
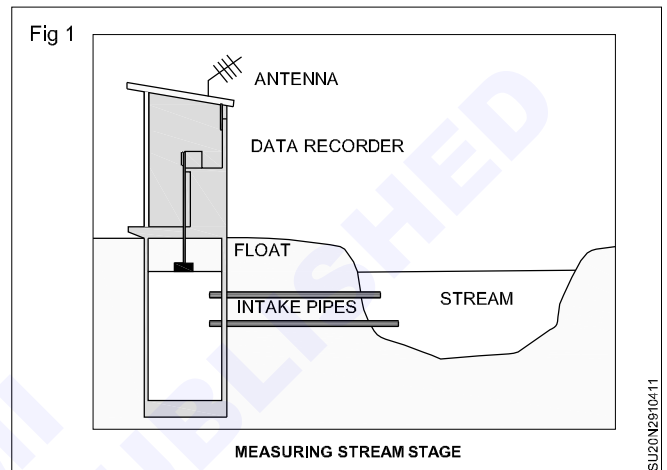
It may not always be cost-effective or space-efficient to install a stilling well where stream gaging is necessary. In these cases, stage can be measured with a vented pressure transducer installed within a PVC or metal pipe along the stream bank. In locations where a bridge or overhead structure is available for instrument mounting, a non-contact radar or ultrasonic water level sensor can also be used.

Stage must always be measured relative to a constant reference elevation, or datum. Depending on the duration of your project, it may be necessary to routinely survey the elevation of your stream gage structure and its datum, to ensure that elevations have not shifted due to settling or natural erosion.

Measuring discharge (Fig 2)

Fig 2
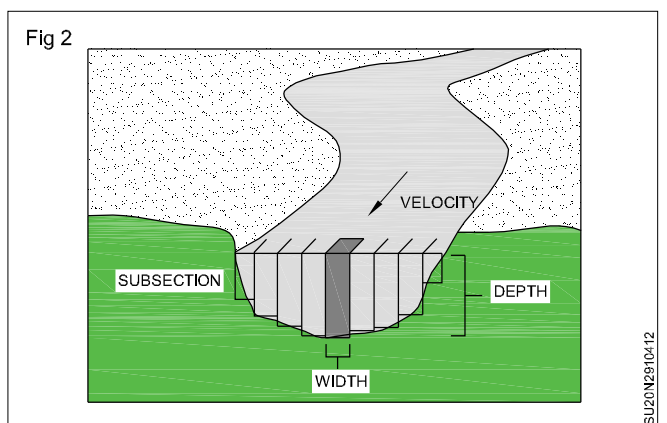
In addition to stage, discharge must also be established before streamflow information can be computed. Discharge is the volume of water moving down a waterway per unit of time. It is most commonly expressed in cubic feet per seconds or gallons per day. To calculate discharge, multiply the area of water in a channel cross section by the average velocity of water in that cross section.

In short: discharge = area X velocity

The simplest way to measure discharge is to divide the channel cross section into vertical rectangular subsections. Once the area (width X depth) of each of these subsections is established and multiplied by velocity to determine subsection discharge, the results can be added together to calculate total discharge.

Subsection width is best measured with a cable or steel measuring tape, while depth can be measured by a wading rod in shallower channels and suspended sounding weights in deeper waters. Velocity, on the other hand, should be measured with a current meter. Many current meters rely on a wheel formed of several cups revolving around an axis. Each revolution generates an electronic signal that is counted and timed by the meter, which translates to water velocity.

A faster, but more expensive method to measure velocity involves the use of an Acoustic Doppler Current Profiler (ADCP) which can be mounted in a small watercraft. The ADCP sends a pulse of sound into the water and measures changes in the pulse's frequency as it returns to the instrument. The ADCP speeds discharge calculations by measuring velocity and depth at the same time. Width is also measured as the boat-mounted ADCP is navigated across the channel. Though somewhat more limited in capability, rod-mounted Acoustic Doppler Velocimeters

allow similar functions to be performed while wading through shallow streams.

Determining the stage - discharge relation (Fig 3)
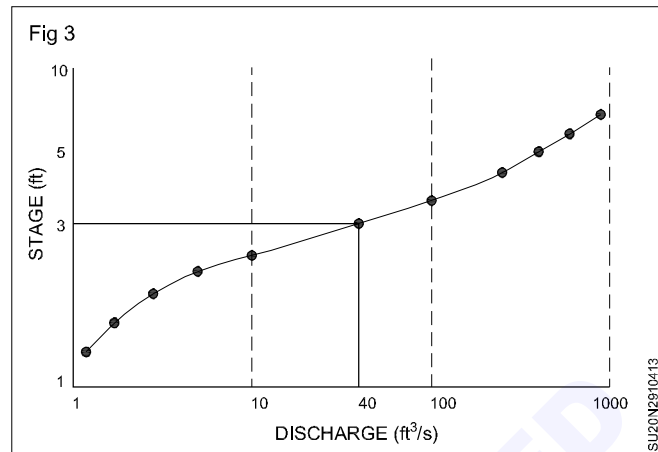
Stage-discharge relation, or "rating," is a dynamic variable that is determined by comparing stage at a stream gage to discharge at the same point. Accurate stage-discharge relations can only be developed by measuring discharge across many ranges of stage. Furthermore, channels should be continually surveyed for changes caused by erosion, sediment deposition, vegetation growth and ice formation.

When discharge has been established across enough stages, stage-discharge relation can be visualized in the form of a graph. When this relation is properly maintained through periodic updates, it can provide useful streamflow information for a given stream or river.

Handling of echo sounder, current meter

Objectives: At the end of this lesson you shall be able to
• **define echo sounds**
• **explain principle of echo sounder operation**
• **describe working of echo sounder**
• **explain transducer of echo-sounder**
• **explain recorder of echo-sounder**
• **describe setting on the echo-sounder**
• **explain the velocity of a stream flow measured by current meters.**

Echo sounder

Echo means the repetition of a sound caused by reflection of sound waves.

Principle of echo sounder operation

• Echo sounder measures the depth of water by measuring the time for a pulse of energy to travel to the sea bed and back and work on the principle of reflection of acoustic energy.

• Short pulse of sound energy is transmitted vertically down from the ship.

• The pulse having been reflected from the sea bottm returns to the ship in the form of an echo.

• Travel time (t) taken for its return depends upon the depth of water (d) and on the velocity of sound (v) through the water.

• Time taken (t) = (2xd)/v or d = (vxt)/2

• Performance of a sonar system depends on the accuracy with which the velocity of sounds propagation is measured.

The velocity of propagator is a function of temperature of water, pressure and salinity. The velocity is usually taken as 1500 meters/second for sea water at 13°C and atmospheric pressure.

Working of echo sounder: The recorder sends a signal to the pulse generator which triggers a pulse and simultaneously starts the recorder trace.

The rate may be between 5-600 pulses a minute depending upon the depth to be measured.

Lesser the depth scale, faster the pulse repetition frequency.

The pulse from the pulse generator activates the transmitter which sends a powerful electric pulse to the transducer.

The transducer converts the electric energy into sound energy producing a pulse.

The sound energy travels to the bottom, hits the bottom and gets reflected back to the transducer.

The transducer converts the received sound energy of the echo into an electric pulse and sends it to the receiver.

In the receiver the received pulse is processed and then amplified and sent to the recorder.

At the recorder, the stylus which has been at a speed proportional to the speed of sound, creates a physical mark on a paper or a visual blip or a digital signal for the recorder.

Transducer of echo sounder

Magnetic striction is an effect which occurs in all ferromagnetic material, but particularly pronounced in iron, nickel and cobalt.

These items when placed in a magnetic field change their length.

Conversely, when subjected to physical stress they generate an emf means electro motive force.

When alternating current is used to create a magnetic flux, the transducer will vibrate producing a sound pulse.

Sighting of the transducer.

Away from noise sources and areas of turbulence like the propeller and discharges.

Away from aeration which is caused due to bubbles generated by the bow wave or irregularities on the hull, log tubes and discharge orifices.

Recorder of echo sounder: This is the component of the echo-sounder, a mariner would be using on the bridge.

Earlier, the echo of the location used to be recorded as a mark on paper.

Currently the old style paper recorder has been replaced by electronic displays showing the bottom echo as blip.

However, IMO regulations require that a ship must have hard copies of past depth soundings which can only be done on paper.

A paper recorder consists of a stylus which a made to move across electro-sensitive paper.

When the transmitter fires its pulse, the stylus marks the paper at the zero of a graduated scale.

While the pulse travels to the bottom the stylus moves in tandem across the paper but at a speed proportional to half the speed of sound.

On detection of an echo, the stylus again marks the paper which shows depth of water.

Even after marking the depth, the stylus will continue travelling towards the end of the paper.

On reaching the end, the stylus files back to the zero signifying next transmission and the paper moves down providing a fresh surface for the next echo.

The process above will be repeated.

A trace can be seen to be developing on the paper with time on one axis and the echoes on the other building a profile of the sea bottom on paper.

The speed of the stylus will move depending upon the chosen range scale.

Setting on the echo sounder

Range switch of echo sounder

Could be between 0-10M, 0-20M, 0-50M, 0-100M, 0-200M, 0-1000 etc.,

Check the approximate depth in the vicinity of your fix.

Start at a range which is just little more than this depth. (If the depth is 8M, choose 0-100M)

Lock out for an echo blip or a marking.

To coax out the echo, you may have to manipulate other controls.

Once observed, shift to one range scale higher.

Observe the echo against the enhanced range scale marking.

It should be the same as the earlier readings.

Draught setting of echo sounder.

The E/S transducer is fitted at the keel of the ship.

It means that the depth will be measured below the keel.

To obtain the depth of water, the draft of the ship will have to be added to the measured reading. This can be achieved by setting this control which is known as setting the zero line to the ships draught.

In modern echo sounders, the display automatically adjusts to the chosen scale.

If you are on Meter scale and the depth shown is 10M.

It will show 33 ft. in fathom scale 5.5 Fathom is shown. Fathom scale is used to measure the depth of the water in the ocean.

Paper speed control (Fast/Show) of echo sounder.

Faster the paper clear the record trace which is essential to appreciate the shape of the sea bottom. This visual display is a great help when sounding is used to fix a ship.

Gain & sensitivity of echo sounder.

To make echoes darker on the paper. Best set to when the echoes become just about discemible.

Dimmer of echo sounder

Keep to optimum settings or else it will affect your night vision.

Measurement of velocity by current meters

- The velocity measured with the aid of the current meter is more reliable and accurate.

One point method & Two point method (Figs 1 & 2)

- The velocity measurement of 0.6 depth of flow using current meters is called one point method.

- The measurement of velocities at 0.2 and 0.8 depths of flow at the same section using current meter is known as two point method.

- The average of the velocities measured at two points is taken as the mean velocity.

Current meter measuring the velocity of flow.

Fig 1

ONE POINT METHOD

Fig 2

TWO POINT METHOD
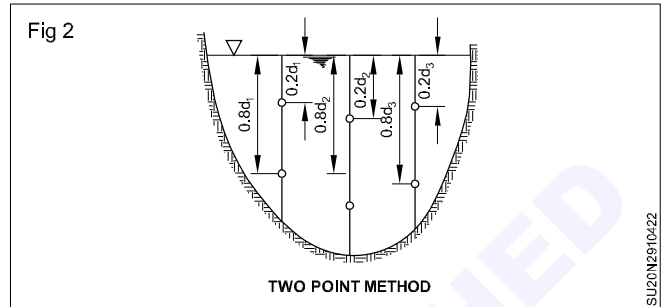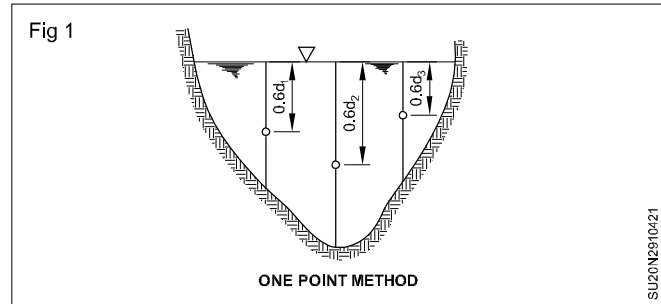
Constructing new transmission line

Objectives: At the end of this lesson you shall be able to
• **state the features of constructing transmission line**
• **explain site preparation**
• **describe foundation construction**
• **define structure construction**
• **explain wire stringing operations**
• **state about guard poles or gourd structure.**

Definition: Transmission line: In an electronic system the delivery of power require the connection of two wires between the source and the load.

Types

1 Transmission line design involves route selection

2 Reconnaissance survey

3 Preliminary survey

Construction of transmission lines involves the following activities

•   Site Preparation

•   Foundation Construction

•   Structure Construction

•   Wire-Stringing Operations

Site preparation (Fig 1): Tower locations are cleared of vegetation prior to construction of the towers. Access roads may need to be upgraded or new roads constructed to accommodate construction vehicles and equipment access to each tower site.

Fig 1

Foundation construction (Fig 2): Most structures have a concrete foundation. The size of the foundation depends on the type of structure and the terrain. Foundation construction begins with the auguring of holes for footings (four for lattice steel towers [LSTs] and one for tubular steel poles [TSPs]). For LSTs, each hole is usually 3 to 4 feet wide and 15 to 30 feet deep. TSPs require one hole that is up to 8 to 12 feet wide and 40 to 60 feet deep.

Regardless of the structure type, foundations typically have a slight projection above the ground.

Fig 2

After the footing holes are excavated, they are reinforced with steel and then concrete is poured into the holes. Once the concrete has cured, crews can begin the construction of the structure itself.

Structure construction (Figs 3 & 4): Generally, structures are built from the ground up. Structures are assembled in sections near the new tower location and a crane is used to lift the sections into place. Crews then bolt the sections together.

The method used is determined by terrain and available space next to the structure site.

Helicopters are used in areas that are inaccessible to large ground-based construction equipment.

Wire-Stringing Operations (Fig 5): Wire stringing includes all activities associated with the installation of the primary conductors onto the transmission line structures. These activities include the installation of conductor, ground wire, insulators, stringing sheaves (rollers or travelers), vibration dampeners, weights, suspension and dead-end hardware assemblies for the entire length of the route. Wire stringing involves the following four operations.

•   **Stringing the pilot line to install the conductor.** A light-weight sock line (pilot line) is flown from tower to tower by helicopter, threading the sock line through

99

wire rollers attached to the insulators on each structure. A clam lock device secures the sock line in the rollers.

Fig 3

Fig 4

- **Pulling:** The sock line is attached to a conductor pulling rope/cable, which is connected to a tensioning machine on a truck. The conductors are then pulled through by

a puller machine. The puller and tensioner work together during the pulling operation to ensure that the conductor maintains the proper ground clearance at all times. Wire set-up sites or pulling stations, where the associated pulling machinery and equipment are staged, are located at intervals along the span.

Fig 5

- **Sagging and dead-ending:** Once the conductor is pulled through the length of the line, the tensioner is then used to sag the conductors to the proper tension. Conductors expand and contract with changes in temperature (they are longest at high temperatures), so they need to be installed at the proper tension such that they do not sag too low when temperatures are at a maximum. All phases (or bundled phases) between two towers must be sagged to the same tension.

- **Splicing:** Once the conductor is pulled in and the proper tension of the conductor is reached, mid-span splicing is performed at dead-end tower locations to connect or splice segments together. Any temporary pulling splices are removed and replaced with permanent splices. Implosive sleeves may be used for splicing, which involves placing a layer of explosives around an aluminum sleeve. The layer of explosive is designed to create the required compression of the sleeve around the conductor. After splicing and sagging, conductors are affixed to dead-end towers. (Fig 6)

Fig 6

- **Clipping-in, spacers:** After the conductors are spliced and affixed to dead-end towers, they are "clipped in", or attached to tangent towers. This process involves removing the rollers and replacing them with clamps and other final insulator hardware to secure the conductors to the insulators. Vibration dampeners, weights, and spacers between the conductors of a bundled phase are then installed. Once construction is complete, crews cleanup work areas and restore disturbed areas. (Fig 7)

- **Guard poles or guard structures** may be installed at transportation, flood control, utility crossings, parks, and other sensitive locations to protect these underlying areas during wire stringing operations. The guard structures intercept wire not to drop below a conventional stringing height, preventing damage to underlying structures. These guard structures are temporary and are removed after conductor installation is complete.

Fig 7

Making of tentative alignment on existing topographical map

Objectives: At the end of this lesson you shall be able to
• **state what is topographical survey**
• **state the topographical surveys plans or map**
• **state the topographical surveys involvement**
• **state purpose of the second type topographical survey**
• **state planning of topographical survey**
• **state main methods used in plan surveying.**

What is a topographical survey?

1   A survey to make a map to help you plan your work; or lay out marks on the ground that will guide you as you work.

2   Topographical surveys will help you to make plans or maps of an area that show: (Figs 1, 2 & 3)

Fig 1

SITE

Fig 2

MAP

Fig 3

VERTICAL PROFILE
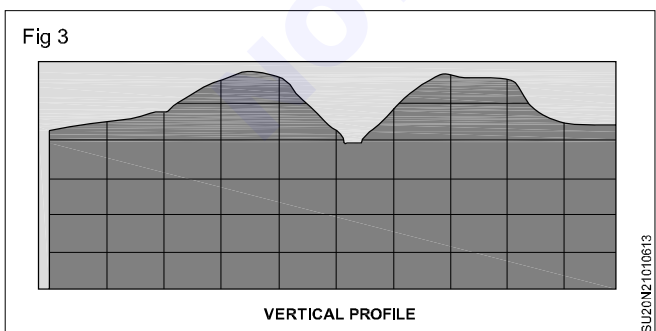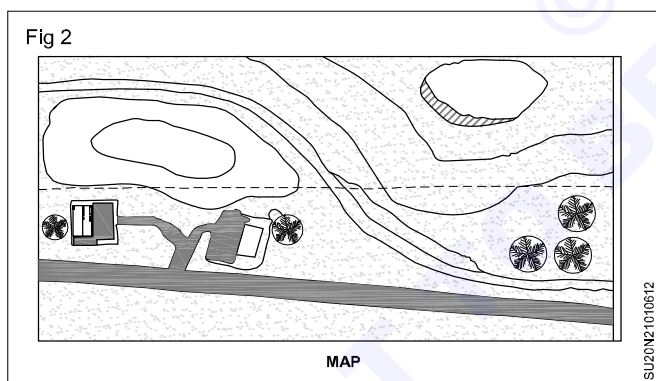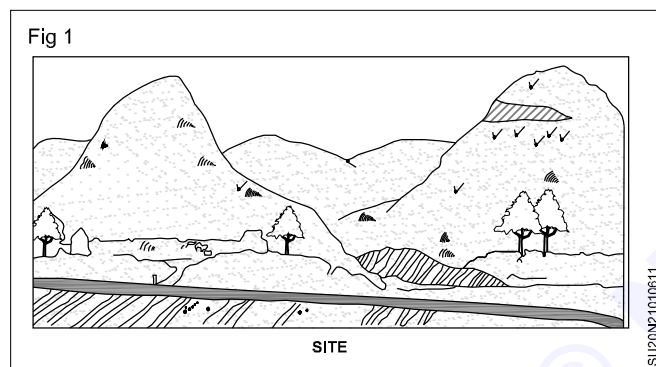
• The main physical features on the ground, such as rivers, lakes, reservoirs, roads, forests or large rocks; or ponds, dams, dikes, drainage ditches or sources of water;

• The difference in height between land forms, such as valleys, plains, hills or slopes; or the difference in height between the features site. These differences are called the vertical relief.

What do topographical surveys involve?

3   The purpose of the first type of topographical survey is to establish, on a horizontal plane, the position of one or more points in relation to the position of one or more other points. To do this, you will measure horizontal distances and horizontal angles or directions. You will use a method called plan surveying.

4   The purpose of the second type of topographical survey is to find the elevation (or vertical height) of one or more points above a definite horizontal plane. To do this, you will measure horizontal distances and height differences; you may also need to lay out contour lines. You will use a method called direct levelling.

5   You will learn how to make plans and maps based on the results of plan surveying and direct levelling. (Figs 4, 5 & 6)

Fig 4

SITE

Fig 5

MAP

CONTOUR MAP
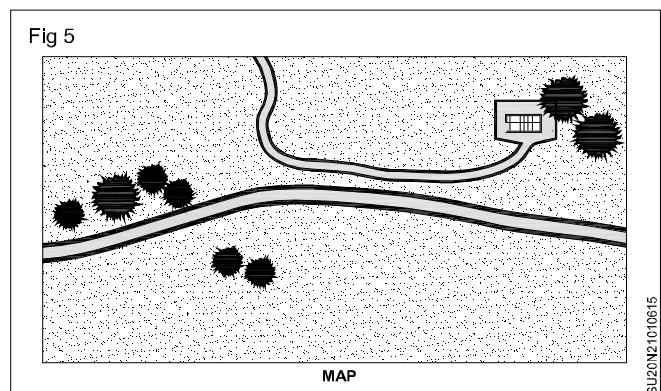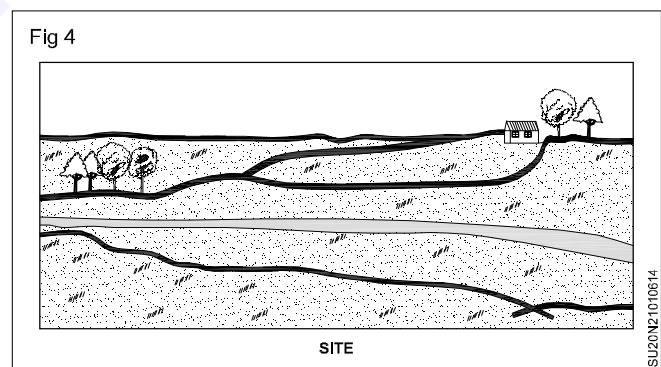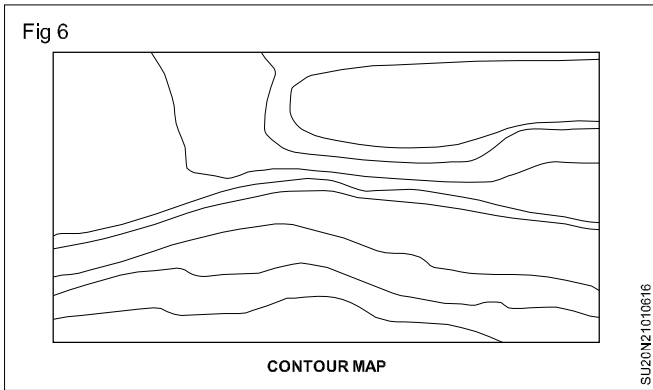
Planning of topographical surveys

6 When you plan a topographical study, the most important rule to remember is that you must work from the whole to the part, keeping in mind all of the work you will need to do as you begin the first steps. Different types of survey require different levels of accuracy, but you should lay down the first points of each survey as accurately as possible. You will adjust all the work you do later to agree with these first points.

Example

You need to plan survey a fish-farm site.

a First, you must make a perimeter survey ABCDEA. Besides these summits and boundaries, add several major points and lines, such as AJ and EO. They run across the interior to create right angles, which will help you in your calculations. This survey gives the primary survey points, which you should determine and plot very accurately. (Fig 7)

PRIMARY POINTS
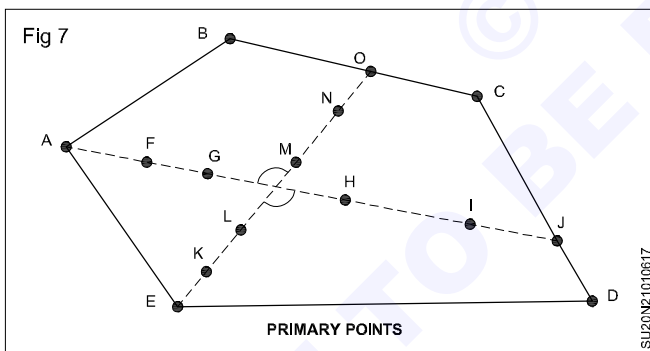
b Then, lay out minor lines such as FP and TN. They go between the major lines to divide the area into blocks. This gives you the secondary survey points, which you may determine less accurately. (Fig 8)

c Finally, survey details in each block using tertiary points, for which less accuracy is also acceptable. (Fig 9)

7 The way you plan a topographical survey will also depend on its purpose. You will use a planning method similar to the one described for soil surveys.

   • First make a preliminary or reconnaissance survey, You can use quick methods without worrying too much about high accuracy.

SECONDARY POINTS
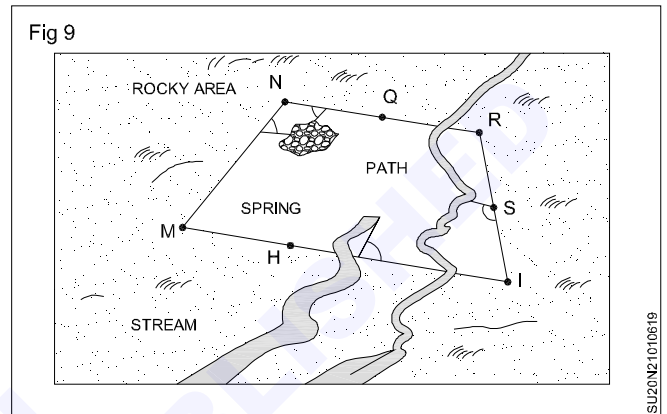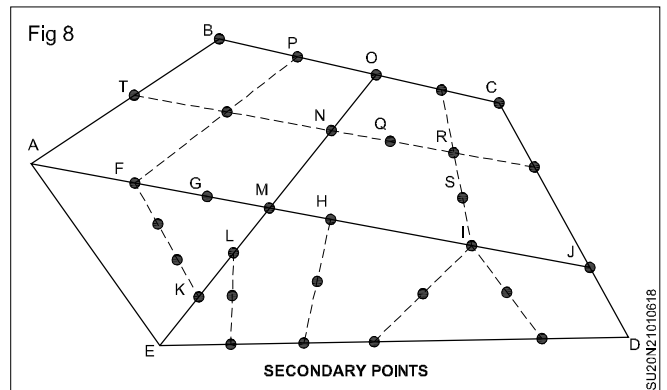
   • Based on the results of this survey you can plan and carry out more detailed and accurate surveys, such as location surveys and, last of all, construction surveys.

8 The way you plan a topographical survey will depend on the subject you need to survey, such as:

   • A straight line defined by at least two points, such as the centre-lines of supply canals, pond dikes, and reservoir dams. (Fig 10)

CENTRE-LINE OF A DIKES
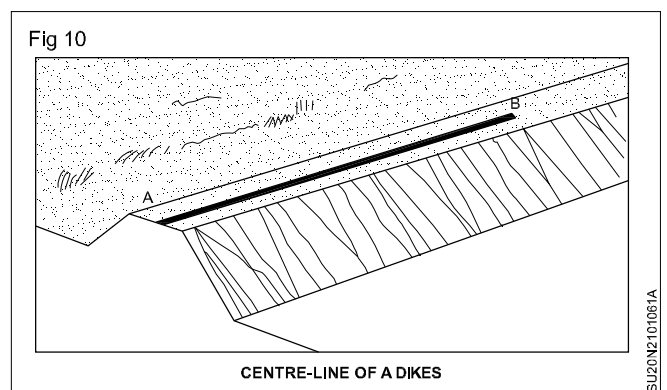
   • A series of lines related to each other by horizontal angles and horizontal distances, such as the center-lines of pond dikes in a fish-farm.

   • An area of land such as a site chosen for the construction of a fish-farm. (Figs 11 & 12)

9 In open country, you will have no problems in plan surveying with the methods explained in the next sections. Any of the following methods should work well. In country with thick forests, however, you will

not be able to use methods for which you need to see several points at the same time. In such areas, you will also need to rely on existing paths and roads much more than usual, and you might even need to clear lines of sight through the vegetation. (Fig 13)

Fig 11

ADJACENT POND DIKES

Fig 12

POND AREA

Fig 13

What are the main methods used in plan surveying?

10 There are four main methods used in plan surveying. You can fix the position of a point on the horizontal plane. (Fig 14)

Fig 14

OPEN TRAVERSE
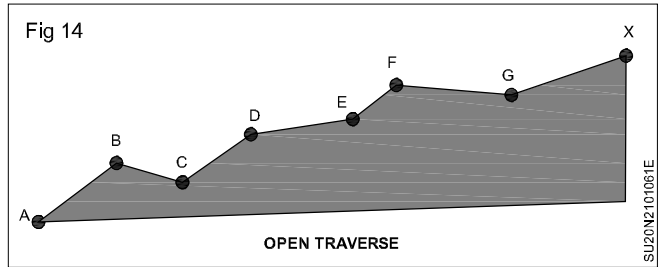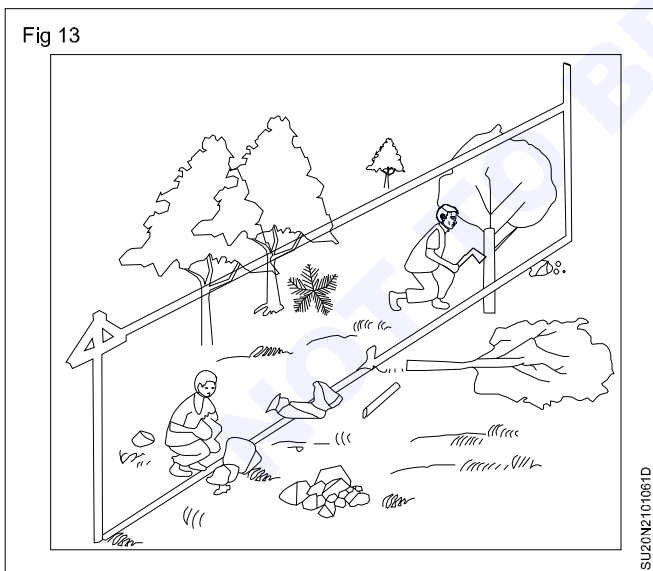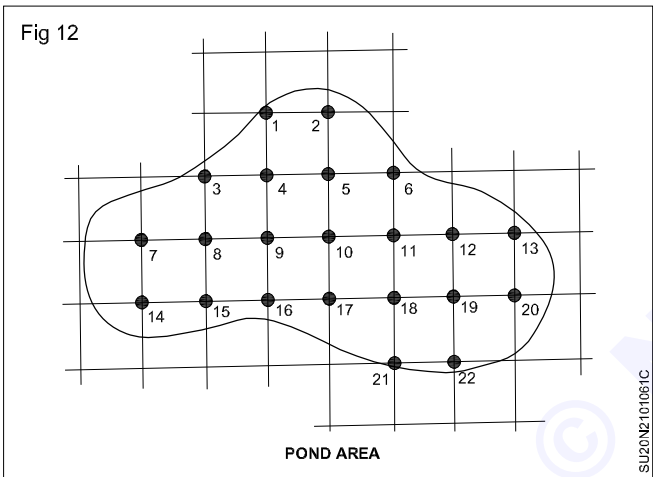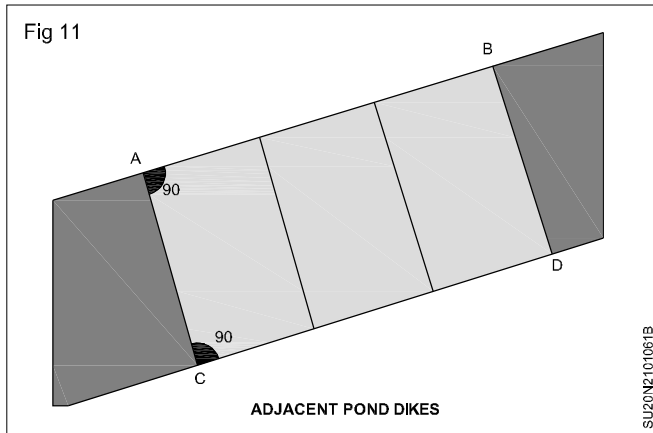
- From a single known point, by traversing, a method in which you measure horizontal distances and azimuths along a zigzag line.

- From a single known point, by radiation, a method in which you measure horizontal distances and azimuths, or horizontal angles. (Fig 15)

Fig 15

RADIATION SURVEY
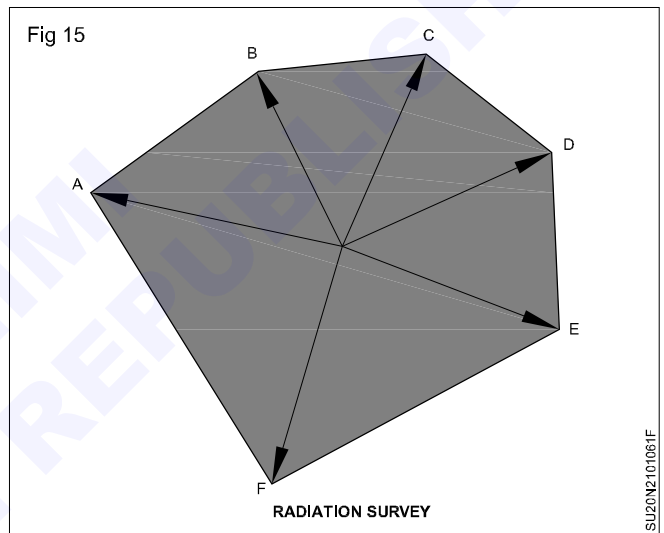
- From a known line, by offset, a methods in which you measure horizontal distances and set out perpendiculars.

- From two known points, by traingulation and/or intersection, methods in which you measure horizontal distances and azimuths or horizontal angles.

Each of these methods will be explained in the next sections. When you are choosing a method, you will also need to consider which methods are the kind of information you need from your survey and the type of terrain you are surveying.

Reconnaissance/preliminary survey

Objectives: At the end of this lesson you shall be able to
• **state the definition of reconnaissance survey**
• **state design of reconnaissance survey**
• **state preliminary survey**
• **state the method of preliminary survey.**

Preparation and Scope

Definition of Reconnaissance Survey

The reconnaissance survey is an extensive study of an entire area that might be used for a transmission alignment. Its purpose is to eliminate those routes or sites which are impractical or unfeasible and to identify the more promising routes or sites.

So let's go and read about "What is Reconnaissance Survey in Civil Engineering". Existing maps and aerial photographs may be of great help. Contour maps show the terrain features and the relief of an area. Aerial photographs show up-to-date planimetric details.

The reconnaissance survey must include all possible routes and sites. The reconnaissance survey report should summarize all the collected information, including a description of each route or site, a conclusion on the economy of its use, and, where possible, appropriate maps and aerial photographs.

Design of Reconnaissance Survey

• Design and military characteristics should be considered during the reconnaissance survey. Keep in mind that future operations may require an expanded road net.

• A study of the route plans and specifications is necessary. If these are unavailable, use the following as guides.

• Locate portions of the new alignment or over existing alignment, railroads, or trails, whenever possible.

• Locate the alignment along ridges and streamlines, keeping drainage structures to a minimum. Keep the grade well above the high waterline when following a stream.

• Select a route as near to sources of construction material as practical, and locate the road along contour lines to avoid unnecessary earthwork.

• Locate the road alignment on the sunny side of hills and canyons and on that side of the canyon wall where the inclination of the strata tends to support the road rather than cause the road to slide into the canyon.

• Locate alignment in forwarding combat zones so that they are concealed and protected from enemy fire. This may at times conflict with engineering considerations.

• Select locations which conserve engineering assets, avoiding rock work and excessive clearing.

• Avoid sharp curves and locations which involve bridging.

Collection of data

Upon completion, the reconnaissance survey should support the routes surveyed and provide a basis of a study showing the advantages and disadvantages of all routes reconnoitered. Typical data collected in a reconnaissance survey are following

• Sketches of all routes recommitted.

• Reports of feasible routes. Data on clearing and grubbing.

• The number of stream crossings involving bridge spans exceeding 20 feet or 6 meters.

• The approximate number of culverts and spans less than 20 feet or 6 meters.

• Descriptions and sizes of marsh areas and other natural obstacles.

• Unusual grade and alignment problems encountered.

• Anticipated effects of landslides, melting snow, and rainfall.

• Soil conditions and stream and substrate conditions at proposed bridge sites.

• Discrepancies noted in maps or aerial photographs.

• Availability of local materials, equipment, transportation facilities, and labor.

• Photographs or sketches of reference points, control points, structure sites, terrain obstacles, and any unusual conditions.

Use of maps

After the Collected Data next step is Use of Maps in the reconnaissance survey. The procurement of maps is a very important phase of the reconnaissance. The surveyor should locate and use all existing maps, including up-to-date aerial photographs of the area to be reconnoitered.

Large scale topographic maps are desirable because they depict the terrain in the greatest detail. The maps, with overlays, serve as worksheets for plotting trial alignments

and approximate grades and distances.

The surveyor begins a map study by marking the limiting boundaries and specified terminals directly on the map. Between boundaries and specified terminals, the surveyor observes the existing routes, ridge lines, water courses, mountain gaps, and similar control features.

The surveyor must also look for terrain which will allow moderate grades, the simplicity of alignment, and a balance between cut and fills.

After closer inspection, the routes that appear to fit the situation are classified. As a further study shows the disadvantages of each route, the surveyor lowers the classification. The routes to be further reconnoitered in the field are marked using pencils of different colors to denote priority or preference.

Taking advantage of the existing terrain conditions to keep excavation to a minimum, the surveyor determines grades, estimates the amount of clearing to be done on each route, and marks stream crossings and marsh areas for possible fords, bridges, or culvert crossings.

The survey of transmission line can be completed in four Stage (map study, reconnaissance survey, preliminary survey, final location and detailed survey), the third stage is known as the Preliminary Survey.

Preliminary Survey

The art of finding the details of alternative alignments found suitable during the reconnaissance survey is called preliminary survey.

In this survey, the routes selected during the reconnaissance survey, are actually located on the ground. The highway engineer collects necessary data in the field and prepares drawings and approximate estimates to compare the alternative routes and to finalize the best alignment from all consideration.

Method of preliminary survey

The preliminary survey is carried out by anyone of the following methods.

1 Conventional Method

In the conventional method, a survey party carries out surveys by using the field equipment like a chain, metallic tape, prismatic compass, levelling instrument, plane table, theodolite etc.

The survey party takes measurements, collects topographical and other data and also conduct soil survey.

2 Modern Approach

In this method, necessary topographic and other maps including details of soil and geographical features of the area are obtained by Arial survey.

Important Point to be Followed during Preliminary Survey

1 The angle of traverse should be very accurately measured by theodolite.

2 The length of the centre line should be measured by using very good and accurate chaining method or by tachometry or by modern instruments.

3 Cross-section levels should be taken at suitable intervals.

4 Supporting structure and hydrological data are to be collected carefully so as to estimate the type, number and approximate size of cross drainage structures.

5 Soil survey is to be carried out very carefully.

Conduct detailed survey prepare a profile drawing using of template

Objectives: At the end of this lesson you shall be able to
• **detail of survey**
• **state how to move sag template for tower spotting**
• **define sag template.**

Detailed survey

•   The detailed work over survey shall be carried out using GPS, total stations, digital theodolites etc., along the approved route alignment.

•   As an alternative, may also use ALTM (Airborne Laser Terrain Modeling) techniques of equal or better accuracy for the detailed survey and plotting on topo sheet to fix up angle point.

•   Soil resistivity along the route alignment shall be measured in dry weather by four electrode method keeping inter-electrode spacing of 50 m.

•   For calculating soil resistivity formulae 2π ar (where, a = 50 m and r = megger reading in ohms) shall be adopted.

•   In case of soil changes within 2 to 3 km, values shall be measured at intermediate locations also.

•   Megger reading and soil should also be indicated in the soil resistivity results.

Route marking

•   The route of the transmission line shall be recorded using GPS of positional accuracy less than 3 m.

•   The co-ordinates of all the angle points as well as other important crossings, land marks etc., shall be recorded using GPS for easy relocating.

•   At the starting point of the commencement of route survey the co-ordinates shall be recorded.

•   The co-ordinates of the location of the survey instrument shall be recorded.

•   Further the co-ordinates at prominent position at intervals of not more than 750 m along the transmission line to be surveyed up to the next angle point shall be recorded.

•   Wherever the line alignment crossed the EHT line, railway line, P and T line or roads shall record co-ordinates on the points of crossing.

•   Wherever line route alignment passes over permanent land marks such as rock, boulders, culverts etc., shall be marked and co-ordinates recorded.

Profiling

•   The complete profiling along the route shall be carried out using surveying equipments viz., total stations, GPS, digital theodolite, along range scanners etc.,

•   Reference levels at every 20 meters along the route are to be recorded.

•   R.L of other undulations along the route as well as in the route plan and other enroute details viz., crossings, building and structures, trees and other infrastructures etc., shall be recorded.

•   Areas along the route not suitable for tower spotting shall be marked.

•   The complete profiling details shall be digitilized and the data shall be prepared and stored in the format compatible to computer aided tower spotting software.

Sag template curve

The sag templates is used for allocating the position and height of the support correctly on profile.

•   If required for tower spotting shall be prepared by the contractor on acrylic sheet indicating cold curve, hot curve, ground clearance curve and support footing curve.

•   Tower spotting while profiling and spotting the towers.

The following shall be borne in mind

•   The number of consecutive spans between the section points shall not exceed 12 spans or 4.5 km in plain terrain and 10 spans or 3 km in hilly terrain for 220 kv line.

•   A section point shall comprise of tension point with minimum angle of deviation type towers as applicable.

Extension

•   Extension/truncation an individual span shall be as near to the normal design span as possible. Incase, of an individual span becomes too short with normal support on account of undulations in ground profiles, one or both the supports of the span may be extended by inserting standard body/leg extension.

Loading

•   Loading shall not be any upward force on suspension towers under normal working conditions.

•   The suspension towers shall support atleast, the minimum weight span as provided in the designs.

Road crossing

•   At all important road crossings, the tower shall be fitted with double suspension or tension insulator strings depending on the type of tower.

- Ground clearance of the conductor from the road surfaces will not be les than 7.015 m for 220 k.v lines.

- At all National Highway tension towers shall be utilised and crossing span shall not be more than 250 m.

Railway crossings

- The railway crossings shall be finalized as per the regulation laid down by the railway authorities.

- The crossing shall normally be at right angle to the railway track.

- The minimum distance of the crossing towers shall be atleast, equal to the height of the tower plus 6 meters away measured from the centre of the nearest railway track

- No crossing shall be located over a booster transformer traction switching station, traction sub-station or a track cabin location in an electrified area.

- Minimum ground clearance above rail level of the lowest portion of any conductor under conditions of maximum sag shall be maintained at 15.40m for 220 k.v line and 14.60 m for 66 k.v lines.

River crossing

- In case, of major river crossings, towers shall be of suspension type.

- Clearance required by navigation authority shall be provided.

- For non-navigation river, clearance shall be reckoned with respect to highest flood level.

Power line crossing

- Power line is to cross over another line of the same voltage or lower voltage.

Telecommunication line crossings

- The angle of crossing shall be as near to 90° possible.

- However, deviation to the extent of 30° may be permitted under exceptionally difficult situations.

- When the angle of crossing has to be below 60°, the marks will be referred to the authority incharge of the telecommunication system.

How to make sag template for tower spotting (Fig 1)

Fig 1

Route plan and profile

It is assumed by now that you already have a "route profile" or simply "profile" that depicts the elevation of the ground level from a reference datum. Details of all crossing such roads, rivers, forest area, ponds, railway lines and power lines along the route should be included. Objects within the width of Right of Way (ROW) shall be noted.

Typical right of way width

Normal phase-to phase voltage	69KV	115KV	138KV	161KV	230KV	345KV	500KV
Single circuit row	75 to 100 (22.9 to 30.5)	100 (30.5)	100 to 150 (30.5 to 45.7)	100to 150 (30.5 to 45.7)	125 to 200 (38.1 to 61)	170 to 200 (52 to 61)*	200 to 300 (61 to 91.4)

Incase, of overhead crossing, the height above ground of the earthwire or OPGW should be measured. Likewise, for crossing under existing power lines.

Typical scale in plotting of the route plan and longitudinal profile is 1cm = 20m horizontal and 1cm= 2m vertical. The sag template should have the same scale with the route plan.

What is a Sag Template?

A sag template is a tool in spotting manually the position of towers or poles on the route profile. Today, transmission design engineers are using sophisticated design softwares - CADD

A sag template is specific for the particular line voltage, the conductor used and local weather conditions. It consist of a set of curves drawn on a transparent celluloid or acrylic clear sheet. The set of curves in the sag template consist of:

- **"Cold or Uplift Curve":**

  - Showing sag of conductor at minimum temperature and still wind.

- **"Hot or Maximum Sag Curve":**

  - Showing maximum sag of conductor may experience. It may be due to creep or heavy loading due to ice and wind loads or due to maximum temperature.

- **"Ground Clearance Curve":**
  - Which is drawn parallel to the "Hot or Maximum Sag Curve" and at a distance equal to the specified minimum ground clearance for the relevant voltage.
- **"Tower Footing Curve":**
  - Which is drawn parallel to the "Ground Clearance Curve" and separated by a minimum distance equal to the maximum sag at the ruling span. (Fig 2)

Fig 2
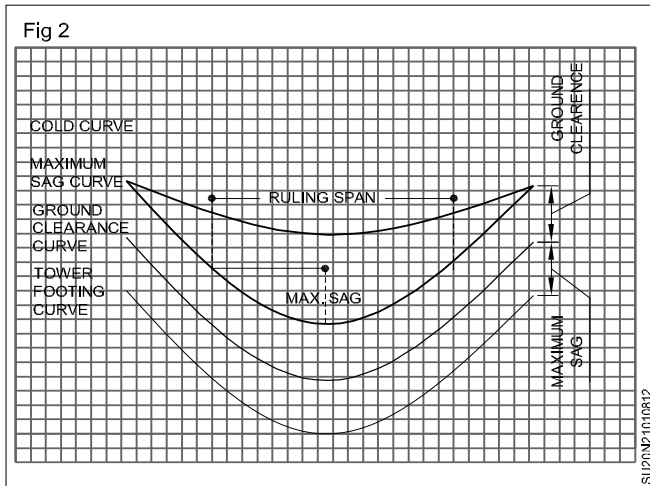
This method can provide the following:

- Maintenance of proper clearance from conductor to ground and to crossing conductors.
- Economic Layout.
- Minimum possibility of errors in design and layout.
- Proper grading of structures.
- Prevention of excessive insulator swing or uplift at structures.
- Exact and correct quantity of materials purchased and delivered to the proper site.

The primary goal of this post is how to make a sag template. Then the succeeding articles on how to use this template in locating transmission towers or commonly called "tower spotting".

How to make a Sag Template?

Step 1: Gather the design data

The design data will include the following:

- The scale of the route plan or profile used.

- Appropriate ruling span.
- Conductor data for sag and tension calculations.
- Stringing tension limits of the conductor.
- Ground clearance standards for different voltage levels.

Step 2: Determine the weather conditions that may affect your conductor.

These data are necessary for calculating the characteristics of conductor curves.

- **Cold Curve:** minimum temperature at no ice and still wind.
- **Maximum Sag Curve**
  - Maximum temperature of the conductor due to electrical loading.
  - Maximum ice loading with no wind.
  - Maximum ice loading with concurrent wind and maximum ice loading with no wind.

For areas in the US, refer to the NESC loading zone. Otherwise, refer to the local standard in your area. For example, here in the Philippines we don't experience ice loading hence maximum sag will be determined by the maximum temperature due to electrical loading.

Step 3: Calculate the sag and tension of the conductor

It is recommended to include the plastic elongation factors in the calculation. However, for simplicity in our examples, we will use the linear elongation model which do not include this factors. We will use the excel spreadsheet file that I developed for sag and tension calculations.

Calculate the sag and tension at different weather conditions and tabulate them.

Step 4: Plotting of the parabolic/catenary curve.

Plot the four curves into a graphing paper with the same scale with the route profile. Take note of the offset of the "ground clearance curve" and "tower footing curve" as described above. The usual practice is using a parabolic curve.

Step 5: Transfer the plotted curve to a transparent paper or celluloid

Photocopy the plotted curved to transparent paper or celluloid.

Final location survey

Objectives: At the end of this lesson you shall be able to
• **explain surveying is important**
• **define system planning stage**
• **define project sensibility stage**
• **define project execution stage**
• **define probable solution for fast and reliable surveying**
• **define power grids experience in new surveying tools satellite imaginary**
• **explain survey by photography**
• **explain power grid requirements**
• **define product conceptualization stage**
• **define product feasibility stage**
• **define conclusion.**

Why Surveying is important?

Surveying is an important aspect of transmission line due to the following:

The objective is to optimize the cost of transmission line based on following considerations:

• Shortest route clearing various objects.

• Minimum number of river crossing towers.

• Accessibility i.e from approachability for construction as well as from law and order point of view.

• Selection of optimum foundations based on following information.

• Type of soil.

• Type of terrain: Benching and rivetment requirements, requirements of leg extensions.

• Loose hills especially in young Himalayan region, areas prone to landslides.

• Area of submergence as well as prone to river meandering.

It helps in ensuring the statutory clearances with respect to following:

• Power line crossings, Railway crossings, road crossings etc.

• Clearances from habitation

• Environmental clearances

• Minimum forests, minimum forests density

• Historically important areas and monuments

• National Parks and wild life sanctuaries

The surveys to collect the above information are carried out progressively at different stages of the project due to various reasons.

The various stages in a transmission line project requiring map study/ surveying and the type of surveys associated are detailed below:

System Planning Stage

The transmission system planning is done considering the load demand and the projected additions in power generation capacity at various places of the country. For effective power transfer with good reliability, security and economy different alternatives are studied at the system planning stage; for example, different voltage level of transmission lines, different routes of transmission lines, different connecting points etc. Therefore the routing and the cost of transmission line projects depends on factors like terrain conditions (plain, hilly), soil conditions, river crossings, power line crossings, railway crossings, reserved forests, agricultural fields etc through which the line traverses. At present, general routing and estimation of cost of each alternative at planning stage is done with reference to certain empirical rules as well as forest and physical maps. As these maps are not updated frequently, percentage error in assessment may be large. Even though this may not largely affect the selection of alternatives it will be prudent to identify more accurate and faster methods of collecting details at planning stage itself so that a large number of possible alternatives can be examined. The requirement generally would be to have updated information on maps so that the planning engineers can study various line routes and then identify and recommend cost effective solutions.

Project Feasibility Stage: After system planning studies and identifying suitable transmission system Feasibility Reports for the transmission line projects are to be submitted for techno-economic clearance from the CEA and investment approval from the Government. At the project feasibility stage, detailed elaboration of the project is done for the technical details, BOQ, cost and implementation schedules of the project. Presently, reconnaissances involving the following types of studies/ surveys are carried out prior to submission of feasibility reports:

The types of surveys adopted at feasibility stage are generally ruled by time constraints for fast track projects. Reconnaissance forms the most important aspect of transmission line survey as the cost of the transmission

line is influenced to a great extent by the route chosen. Selecting the best possible route can derive the following benefits:

- Line construction cost can be brought to the minimum.

- Material Estimation and procurement can be done fairly on realistic basis.

- Any possible delay/hindrance likely to come during the execution of the work can be avoided after taking due care of various statutory provisions during the course of selecting route alignment.

- Proper planning can be done for termination of lines at switchyards keeping provision for future lines etc.

- Approvals from PTCC, Railways, Civil Aviation, Forest authorities etc. can be obtained faster.

- Preparation of Master Network and fixing construction/ erection targets can be done on realistic basis, which will help in the judicious planning of materials flow, cash flow and manpower requirements.

- Appreciable time can be saved during construction of line, if selection of River Xing points, route along hill sections and power line xings etc., are properly made.

Map study: After drawing various feasible alternative routes of transmission line within 10kms of the bee line on the topographical maps (1:50000 scale) of Survey of India, a comparative study is done on the basis of the following data:

- Route length.

- Nos. and type of angle points in each proposal indicating the angle of each deviation as measured on the map.

- Nature and number of major crossings.

- Deviation in the line due to civil/military aerodromes and other industrial installations.

- Approach to the line in general for construction.

- Reaches through protected or Reserved Forests

- Continuously long stretches in paddy fields.

- Close parallelism with telecom and Railway block circuits.

Walk-over survey is carried out on these routes. Walk over survey means going over the area associated with the alternative routes proposed and collecting features observed other than those existing on the map. In addition the indication on following features are also checked.

- Communication lines

- Power lines

- Expanding villages and towns

- Rich gardens and plantations

- Reserved forests and high tree areas

- National Parks & Wild life sanctuaries

- Archaeological monuments

- Aerodromes, radar centers etc.

- Steep sloping terrain, Areas prone to land slides, soil instability etc.

- Prohibited areas declared under statutory regulations.

Preliminary survey: On completion of walkover survey proposal of the most suited route is further studied before taking preliminary survey. The main objective of preliminary survey is to transfer the route to the ground with such deviations as may be necessary as per field constraints. It involves generally fixing of angle points of the towers, route alignment, identification of major crossings, general classifications of soils, measurement of route length etc. Conventional instruments like tapes and theodolites do these. Based on these results, the Bill of Quantities (BOQs) of a transmission line are estimated and cost estimates are prepared. The preliminary survey does not include detailed soil investigations for locations along the route.

Project Execution Stage: On completion of preliminary survey and approval of Feasibility report, the detailed survey of the route is carried out . The detailed survey consists of accurately determining the number and types of towers along with extensions, special towers required, number and types of foundations, special foundations required etc. It generally involves the following actions:

- Leveling

- Plotting and profiling on a scale of 1:200 (vertical) and 1:2000 (horizontal)

- Final alignment and pegging of locations

- Trial pit excavations

- Detailed soil investigations wherever required

The final output of the detailed survey is in the form of tower schedule showing the type of tower with associated angle of deviation, span length, wind and weight spans, associated foundations along with its classifications, geological and geotechnical, data and any crossing involved in that span.

Limitations of Conventional methods of map study/ surveying: Apart from the considerable time involved, the following limitations are generally associated with conventional methods of surveying:

- The topographical maps used for walkover survey and preliminary survey can be very old and do not contain recent changes in inhabitation pattern, vegetation coverage and water bodies etc.

- The process of elimination is done at the ground itself which increases the number of angle towers and length of line.

- The surveying staff do not have birds eye view of the present ground condition This may particularly result in large inaccuracies in estimation of civil works (benching and revetment) quantities in terrain involving large undulations.

- There is every possibility of error in recording the ground data and subsequent transfer on the route map.

Probable solutions for fast and reliable surveying: As a first step following procedure can be explored at each stage of transmission line project:

Route planning and fixing of alignment: This can be achieved through the following procedure

- Data Input: Survey of India maps, Satellite data, railway maps, land use maps, settlement maps etc are used as input for data base preparation

- GIS: Above inputs through GIS are used to update the Survey of India topo sheets. Other specific maps may also be created.

- Using computer run algorithms or linear programming techniques optimal transmission line route may be finalized.

- On this output from GIS domain post field work is done and locational latitude and longitude of the deviation points are identified on ground using Geographical position system (GPS).

Further in terrain having large undulations, stereoscopic satellite imageries may be used selectively to interpolate the contours and digital terrain model can be used to select the route in hilly regions

Detailed survey: Aerial photography can be used as a reliable tool to record the precise elevations and plan measurements of the selected route. This may involve taking following actions.

- Requesting Ministry of Defence for granting permission for carrying out aerial photography

- Arrangement of flight on selected route

- Transferring of photographs to studios for processing and detailed measurements

- Authentication through ground verification

It is said that camera never speaks lie. That is precisely the greatest advantage of aerial photography in detailed survey application w.r.t traditional methods. Further once the ground profile in digital form is obtained the estimation of various types of earthworks involved viz. Benching, revetments etc. can be made using software.

Appropriate techniques for obtaining soil conditions, sub soil conditions, water tables, treacherous

terrain conditions etc for accurate estimation of civil works needs to be explored.

POWERGRID's experience in new surveying tools

Satellite Imagery

POWERGRID in its effort to use new surveying tools had taken a trial project with National Informatics Centre (NIC) for use of satellite imagery in preliminary survey for 400kV D/C Monubulu (near Nellore) to Sriprembdur transmission line (line length of approx. 184 kms). The major objective was to develop a methodology to use the satellite data using IRS LISS (resolution of 23.5 metres), and PAN

(resolution of 5.88 metres), datasets, in conjunction with topographical maps on a single platform, in order to update the natural and cultural features of the routing of transmission line.

Three alternatives routes were identified by NIC using satellite imagery. These routes were then compared with the other three alternative routes identified by POWERGRID using conventional surveying methods (map study and walkover survey). Various algorithms and weightage techniques were used for comparison purposes with environmental impact being a major factor taken in account for comparison purposes. It was found that a saving of 1.5 kms (approx.) that is around 1 % could be achieved after comparing the best route from conventional and new method. Being first case of its kind to be given to NIC, the time taken was around six months instead of three months as expected earlier. The work with NIC gave the following additional important points to be looked into for further applications:

- There may be some error involved in using satellite imagery for preliminary survey due to the "shadow effect". In the above case it was found sometimes difficult to differentiate between forests and other greenery. Thus exact boundaries of forests could not be demarcated

- Resolution plays an important part in interpreting satellite images. Power line crossings could not be identified in the satellite imageries of 23.5m/5.88m resolution. Higher resolution may improve the visual content and may reveal ground realities more closely.

- Ground profile and subsoil data cannot be accessed through satellite imageries.

- Digitisation of complete topographical maps rather than selecting features would provide a complete replica in integrated environment.

- Satellite data of resolution of 1 metre will be preferable. However, the overall cost economics shall have to be worked out since this data will be more costly but will completely avoid field works.

- Symbols of physical features in satellite imageries are not easily recognizable by transmission line engineers.

Survey by Photogrammetry

POWERGRID also has undertaken a pilot project along with National Remote Sensing Agency (NRSA) for survey of 10 kms. Stretch of 400kV D/C Kolhapur-Mpausa transmission line on a trial case. The NRSA has taken up the survey and generated 1:15,000 scale maps with 1 mtr. contours for 10 kms.section of the line using 1:10,000 scale aerial photographs for 1 km corridor width. The output has been taken as digital data on topographical maps on 1:15,000 scale with 2 mtr. contour interval. The digital mapping of the corridor with the accuracy specified above has been achieved by the survey, however, appropriate software and tools for using the contours for tower spotting, estimation of civil works quantities etc. would be further required. One of the major constraints has been the exercise has taken more time than a conventional survey.

Power grid Requirements

POWERGRID in its endeavor for an accelerated power development and formation of national grid in the country has been instrumental in adopting various ways and means to reduce project implementation time. Over the last decade, it has been demonstrated that a transmission line project can be constructed with 30 per cent less time than the time taken in the last decade through standardization of designs at project conceptualization stage itself. POWERGRID's present endeavor is to reduce the total time involved from project conceptualisation to project approvals and to commissioning. The major constraints observed during conceptualization of the project is that the conventional ways of surveys and estimation of project costs consume considerable time by which the system planning, project feasibility and their approvals are taking more time. One of the major requirements at project conceptualisation and feasibility stage is to draw-up correct project definition, cost and implementation programme for which elaborate survey inputs within limited time would be of great help. The modern methods of survey using GIS, GPS etc. will be of more help in defining the project requirements precisely at project feasibility stage itself. With accurate project definition at feasibility stage itself, it would be possible to do correct project cost estimation, optimum resource planning, accelerate construction programme etc. Further, the cost and time overrun of projects can be kept minimum. In this connection, the following are identified as the major requirements.

Project Conceptualization Stage

Techniques are required to be developed to evaluate various line routes using inputs from digital topographical maps.

Project Feasibility Stage

Detailed mapping of the right of way, ground profiling, identification of tower locations along with geographical and geo-technical details of the location, site constraints etc. for evolving project definition in finer details.

Project Construction Stage

Detailed contouring of undulated terrain for estimation of benching and revetment quantities.

Conclusions

The basic concepts of an Extra High Voltage (EHV) transmission line specifically relevant to surveying, type of surveys presently done at various stages of a transmission line project, their limitations and probable solutions for faster and more accurate surveying have been presented. Further POWERGRID's experiences in adopting satellite imagery, photogrammetry and GIS to surveying have also been presented.

Mark tower foundation pit point

Objectives: At the end of this lesson you shall be able to
• **state the requirements for tower foundation**
• **state team members training**
• **explain tools and equipments**
• **define weather condition**
• **state personnel protective equipment**
• **state house keeping**
• **define access roads**
• **explain tower foundation**
• **state working time**
• **state environmental measures**
• **explain visitors and vendors on sites.**

The purpose of this methodology is to establish a methodology on the construction of the tower foundation required for the construction of 35kV transmission lines for the medium voltage transmission grid. This procedure establishes descriptions and guidelines for works performed during the construction of the tower foundation required to access the tower locations.

It explains the duties of each worker, machinery used, and methodology based on international standards.

Requirements

Before the Contractor starts foundation work below listed requirements shall be addressed and completed.

1 All the crew must be trained for such activity

2 Risk Assessment (RA) and Job Hazard Analysis (JHA) must be done before any activity starts; this document must be read and signed by all the members of the crew.

3 Equipment must be in good condition and all safety devices functional and active all the time.

4 Tools must be in good shape and not damaged.

5 Visitors or vendors must have permission to get in on-site, they must attend a brief about the HSE rules and sign the attendance sheet.

6 Housekeeping and clean working area.

7 Communication

8 Working time

9 Work organization and team coordination

Team Members Training

Team members must be trained in different disciplines to perform in this activity.

• General induction training

• Tools and equipment training

• PPE training

• Work at height training

• Spill prevention

• Excavation works

• Concrete works

• First aid training (at least two for each team).

Tools and Equipment

• Tools must be in good condition and free from any damage.

• Only proper tool is allowed to use in this activity.

• Equipment must be in good condition and checked periodically.

• The only authorized operator must use them and be sure that the equipment to be well maintained.

• Where the equipment is settled, the area should be barricaded by high visible safety tape, and also warning signs must be put in order to inform the public about the work activity.

Weather Condition

It is not allowed to perform any activity during bad weather conditions.

• Storm

• Ice

No activity will be performed if it is anticipated that can result in a fatality or a very Lost Time Incident (LTI).

The work activity can be stopped on-site due to bad weather conditions when any of the following persons decide so: (see point.7 Contractor Organization)

• Site Manager

• HSE Lead

• Site Civil Engineer

Personal Protective Equipment: In order to prevent any injury or accident during the working time, referred to HSE plan and Albanian Labor Low, Contractor has to use the personal protective equipment during all the time on site.

- Hard hat
- Gloves
- Safety shoes
- High visible vest
- Protective glasses
- Safety harness

All these PPEs shall be used and wore by everyone that will be part of the working site.

Housekeeping

In order to prevent incidents or accidents on-site, the working area must be in good shape. Ground-level must be flat and free from holes, mud, and ice. Also, materials must be stored in the proper way. Timbers, tools, or any other material must be store in order to have better access and aggress.

Access Roads

Before the work starts the access points to the tower shall be identified and then start the opening of the road. While performing construction of access roads we must maintain good environmental conditions and prevent any environmental incident. They must be maintained in good conditions due to heavy machinery and weather conditions.

Tower Foundation

During the opening of the foundation, we must check the stability of the excavation, also the workers that work inside the foundation structure must be trained and well secured with slope and slide protection if need.

Excavations in uninhabited areas shall be fenced with an orange net in order to prevent falls and excavations in residential areas shall be hard fenced with wooden or metal scaffolding. The Site shall be clearly marked (Red Fencing) with clearly placed signage in the community language informing that the area is a construction site and that unauthorized personnel is denied access.

Access & aggress point in the foundation must be in good shape and ladders must be used if the access point is not at ground level. Ladders shall extend 1m above ground level and be secured. The foundation excavation must be in such a way as to prevent instability of the ground or to put a box or to make protection wall on the side. Concrete Pouring In Foundation;

Before pouring concrete the workers must check the stability of the formwork and then only the authorized people will take part in this activity. All the workers must have proper PPEs during this activity.

This work may be performed in the proper light condition during nighttime. Luminance must be minimum of 54 lux. These can be measured by a luminance – meter.

Working Time

In order to have a safe work condition, tower foundation activity will be performed during the official working time, except when pouring concrete work is continuous.

If this activity will be longer than 8 hours workers must be in shift with other workers in order to be able to have a safe condition and performance.

Environmental Measures

In order to keep a good environment on-site, spill prevention must be present on-site, garbage and waste of food will be removed from the site and deposited in the safe waste area.

All the areas must be clean and in good environmental condition after the final work activity. For any emergency, a vehicle will be in place for immediate transport.

Visitors or vendor on site

Visitors or Vendors are not allowed to enter on site until they have permission, however, visitors and vendors must have a brief training before they go on-site, and also they should sign the attendance list.

Railway line site survey - I

Objectives: At the end of this lesson you shall be able to
• **state the parts of Railway Track**
• **state types of gauges.**

Railway line project survey

Basic terms

Component parts of railway track the typical components are (Fig 1)

Fig 1
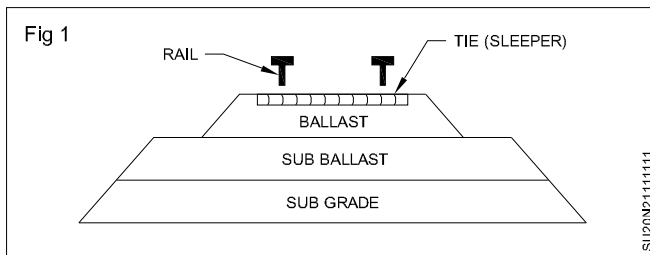
Rails

Rails are the members of the track laid in two parallel lines to provide an unchanging. Continious and level surface for the movement of trains. To be able to withstand stresses, they are made of high carbon steel.

Sleepers

Sleepers are the transverse ties that are laid to support the rails. They have an important role in the track as they transmit the wheel load from the rails to the ballast. Several types of sleepers are used on Indian Railways.

Ballast

Ballast is a layer of broken stones, gravel, moorum or any other granular material place and packed below and around sleepers for distributing load from the sleepers to the formation. It provides drainage as well as longitudinal and laternal stability to the track.

Sub Grade

Sub grade is the naturally occuring soil which is ready to receive the ballast, along with sleepers and rails, is called the formation. The formation is an important constituent of the track, as it supports the entire track structure.

Gauge

The clear minimum horizontal distance between the inner (running) faces of the two rails forming a track is known as gauge.

Various gauges on Indian Railways

Broad gauge - 1.676 m

Standard gauge - 1.435 m

Meter gauge - 1m

Narrow gauge - 0.762 m

Fig 2
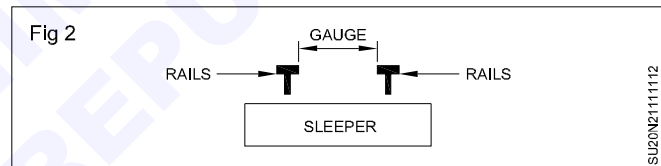
Railway line site survey - II

Objectives: At the end of this lesson you shall be able to
• **state the selection of good alignment.**

Selection criterial for good alignment

- A good alignment is always short and economical.

- A good alignment can generate considerable amount of revenue.

- A good alignment consists minimum number of bridges (or) culverts in its way.

- Earth filling or earth excavation is minimum as possible along good alignment.

- Alignments consisting vertical curves should be eliminated.

- Construction material and labour availability is new as possible.

- A good alignment should connect all the important and rush areas in that region.

- Location of station yards should be easily reachable for passengers.

- Cost of construction and expected revenue should be estimated along the good alignment.

Preliminary survey of alignment

Objectives: At the end of this lesson you shall be able to
• **state preliminary survey of alignment.**

After selecting good alignment. Then it's time to decide only one alignment finally. But before this final step, preliminary survey is conducted for all the good alignments. The preliminary survey consists:

- A pillar is constructed at the starting point of alignment and this point is connected to near by GTS bench mark using fly levelling.

- Longitudinal levelling with an interval of 20 or 40 meter is carried out along the alignment.

- Crossing levelling with an interval of 100 meter is carried out.

- Magnetic bearing of each line of traverse is noted in level book.

- A route survey map in prepared which give the details of 100 m land on both sides of alignment. This can be done by plane table surveying (or) prismatic compass surveying.

- At every 2 km or with regular interval permanent bench marks are established.

- Bearing capacity of soil and water table level is recorded.

- A map is prepared for the marked station yards using plane table surveying.

- At river crossing, the details of river like its cross section, width, water level, HFL scour depth etc., are noted for a distance upto 1000 meters on the both sides crossing with an interval of 100 m.

- The river is bored to find out the depth of foundation required.

- With all the recorded readings, a drawing is prepared for the whole alignment.

- For the drawings, an approximate estimate, which includes earthworks, compensation cost of culverts, bridge structure etc.,

Conduct reconnaissance preliminary survey & select good alignment

Objectives: At the end of this lesson you shall be able to
• **state types of surveys**
• **state selection of good alignment**
• **explain zig zag alignment**
• **explain switch back method**
• **explain spiral or complete loop method.**

Railway preliminary survey: The preliminary survey consists of a detailed instrumental examination of the route to be selected as a result of the reconnaissance survey in order to estimate the cost of the proposed railway line.

Types of Surveys: Once a decision has been taken during preliminary investigations about the general feasibility and desirability of a railway line, surveys are undertaken before the construction of the new line. The following types of surveys are normally conducted.

a   Traffic survey

b   Reconnaissance survey

c   Preliminary survey

d   Final location survey

The details of these surveys are discussed in the following sections.

Preliminary Survey

The preliminary survey consists of a detailed instrumental examination of the route to be selected as a result of the reconnaissance survey in order to estimate the cost of the proposed railway line. Based on the preliminary and traffic survey reports, the railway administration decides whether or not the proposed railway line is to be constructed.

1   Instruments for Preliminary Survey

The instruments to be used for a preliminary survey will depend on the topography of the country and its flora. The survey instruments normally used are the following.

a   Theodolite for traversing and pegging the centre line.

b   Tacheometer for plotting the main features.

c   Dumpy level for taking the longitudinal and cross levels.

d   Plane table for getting details of various features.

e   Prismatic compass for measuring the magnetic bearings of a particular alignment.

2   Field Survey

The route selected is surveyed in greater detail in the preliminary survey. The survey normally covers a width of 200 m on either side of the proposed alignment. The following survey work is carried out.

a   An open traverse is run along the centre line of the proposed alignment with the help of a theodolite, tacheometer, or a compass.

b   Longitudinal and cross levelling on the proposed route for a width of 200 m on either side in order to make an accurate contour map.

c   Plane tabling of the entire area to obtain various geographical details.

d   Special survey of station sites, level crossings, and bridges using the plane table.

3   Data

The following information should normally be collected during a preliminary survey.

a   Geological information such as type of soil strata and the nature of rocks.

b   Source of availability of construction materials such as sand, aggregate, bricks, cement, and timber.

c   Facilities for construction such as the availability of labour and drinking water.

d   Full details of the land and buildings to be acquired.

e   Details of existing bridges and culverts along with information about proximity of tanks, bunds, etc., which may affect the design of bridges.

f   Details of road crossings along with the angles of crossing and the traffic expected on the level crossings.

g   High flood level and low water level of all the rivers and streams falling on the alignment.

h   Full details of station sites along with the facilities required.

4   Preparation of project report

A report based on the preliminary survey is prepared after obtaining an estimate of the cost. The project report should contain the following details.

a   Introduction

b   Characteristics of the project area

c   Standard of construction

d   Route selection

e Project engineering including cost estimate and construction schedule

f Conclusions and recommendations

5 Cost estimate

The report should be accompanied by cost estimate. The estimate based on the preliminary report should be sufficiently accurate to enable a competent authority to take a decision regarding the construction of the new line. The estimate should contain the following details.

a An abstract cost estimate of the line surveyed accompanied by an abstract estimate of junction arrangements.

b Detailed estimates of land, tunnels, major bridges, minor bridges, one kilometre of permanent way, rolling stock, and general charges.

The report and estimate should be accompanied by the following drawings.

a Map of the area (scale 20 km = 1 cm)

b Index plan and section (scale 0.5 km to 1 cm horizontal and 10 m to 1 cm vertical)

c Detailed plans and sections Plans of station yards

d Plans of junction arrangements

Selection of a Good Alignment: Normally, a direct straight route connecting two points is the shortest and most economical route for a railway line, but there are practical problems and other compulsions which necessitate deviation from this route. The various factors involved is the selection of a good alignment for a railway line are given below.

Choice of Gauge: The gauge can be a BG (1676 mm), an MG (1000 mm), or even an NG (762 mm). As per the latest policy of the Government of India, new railway lines are constructed on BG only.

Obligatory or Controlling Points: These are the points through which the railway line must pass due to political, strategic and commercial reasons as well as due to technical considerations. The following are obligatory or controlling points.

Important cities and towns: These are mostly intermediate important towns, cities, or places which of commercial, strategic, or political importance.

Major bridge sites and river crossings: The construction of major bridges for large rivers is very expensive and suitable bridge sites become obligatory points for a good alignment.

Existing passes and saddles in hilly terrain: Existing passes and saddles should be identified for crossing a hilly terrain in order to avoid deep cuttings and high banks.

Sites for tunnels The option of a tunnel in place of a deep cut in a hilly terrain is better from the economical viewpoint. The exact site of such a tunnel becomes an obligatory point.

Topography of the Country: The alignment of a new railway line depends upon the topography of the country it traverses. The following few situations may arise.

Plane alignment: When the topography is plane and flat, the alignment presents no problems and can pass through obligatory points and yet have very easy gradients.

Valley alignment: The alignment of a railway line in valley is simple and does not pose any problem. If two control points lie in the same valley, a straight line is provided between these points with a uniform gradient.

Cross-country alignment: The alignment of a railway line in such terrain crosses the watersheds of two or more streams of varied sizes. As the levels vary in cross-country, the gradients are steep and varying and there are sags and summits. The controlling or obligatory points for cross-country alignment may be the lowest saddles or tunnels. It may be desirable to align the line for some length along the watersheds so that some of the drainage crossings may be avoided.

Mountain alignment: The levels in mountains vary considerably, and if normal alignment is adopted, the grades would become too steep, much more than the ruling gradient (allowable gradient). In order to remain within the ruling gradient, the length of the railway line is increased artificially by the 'development process'. The following are the standard methods for the development technique.

Zigzag line method: In this method, the railway line traverses in a zigzag alignment (Fig 1) and follows a convenient side slope which is at nearly right angles to the general direction of the alignment. The line then turns about 180° in a horseshoe pattern to gain height.

Fig 1

ZIGZAG LINE ALIGNMENT
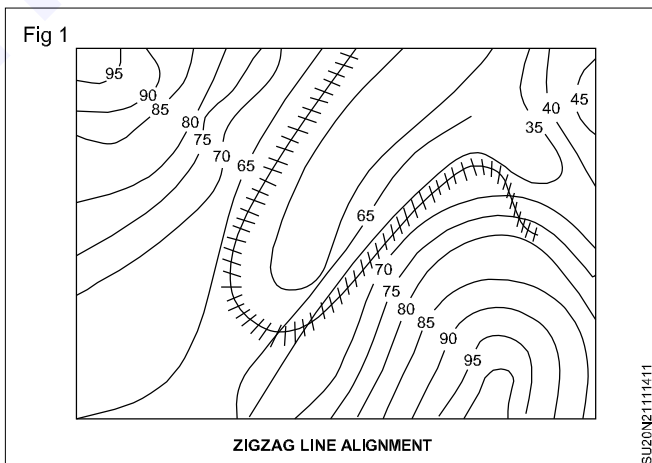
Switch-back method In the case of steep side slopes, a considerable gain in elevation is accomplished that is the switch-back method (Fig 2). This method involves a reversal of direction achieved by a switch, for which the train has to necessarily stop. The switch point is normally located in a station yard. In Fig 2, A and B are two switches and A1 and B1 are two buffer stops. A train coming from D will stop at B1 and move in back gear to line BA. It will stop at A1 again and then follow the line AC.

Fig 2

SWITCH-BACK ALIGNMENT
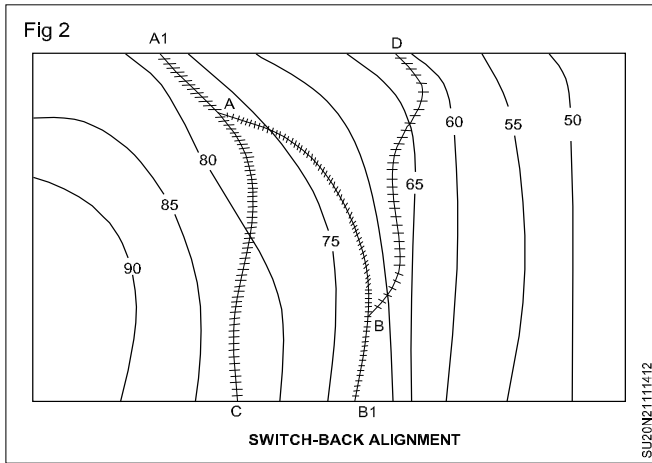
Spiral or complete loop method This method is used in a narrow valley where a small bridge or viaduct has been constructed at a considerable height to span the valley (Fig 3). In this case, normally a complete loop of the railway line is constructed, so that the line crosses the same point a second time at a height through a flyover or a tunnel.

Fig 3

SPIRAL or COMPLETE LOOP METHOD
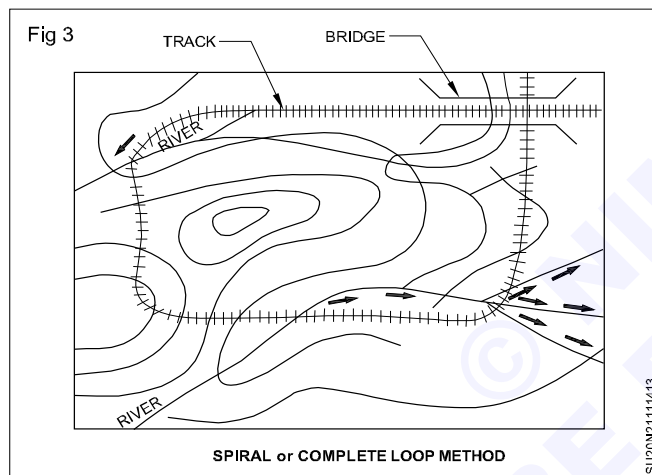
Geometrical Standards: Geometrical standards should be so adopted as to economize as much as possible as well as provide safety and comfort to passengers. This can be done by adopting gradients and curves within permissible limits. Transition as well as vertical curves should be used to provide better comfort and safety.

Geological Formation: The alignment should be so selected that it normally runs on good and stable soil formation as far as possible. Weak soil and marshy land present a number of problems including those of maintenance. Though rocky soil, provides a stable formation, it is a costly proposal.

Effect of Flood and Climate: The alignment should normally pass through areas which are not likely to be flooded. The climatic conditions should also be taken into consideration for alignment. In hot climate and sandy areas, the alignment should pass by those sides of sand dunes that face away from the direction of the wind. Similarly, in cold regions, the alignment should pass by those sides of hills that face away from the direction of the wind. A sunny side is more desirable.

Position of Roads and Road Crossings: A railway line should cross a road at right angles so as to have a perpendicular level crossing and avoid accidents.

Proximity of Labour and Material: The availability and proximity of local labour and good and cheap building material should also be considered when deciding the alignment.

Location of Railway Stations and Yards: Railway stations and yards should be located on level stretches of land, preferably on the outskirts of a town or village so as to have enough area for the free flow of traffic.

Religious and Historical Monuments: The alignment should avoid religious and historical monuments, as it is normally not possible to dismantle these buildings.

Cost Considerations: The alignment should be such that the cost of construction of the railway line is as low as possible. Not only the initial cost of construction but also the maintenance cost should be as low as possible. For this purpose, the alignment should be as straight as possible, with least earthwork, and should pass through terrain with good soil.

Traffic Considerations: The alignment should be so selected that it attracts maximum traffic. In this context, traffic centres should be well planned; so that the railway line is well patronized and the gross revenue arising out of traffic receipts is as high as possible.

Economic Considerations: Keeping in mind the various considerations, it should be ensured that the alignment is overall economical. For this purpose, various alternate alignments are considered and the most economical one, which is cost effective and gives the maximum returns is chosen.

The maximum annual return (y) is calculated by the formula y = R-E

where R is the gross revenue earned by the railway line and E denotes the annual running expenses.

It may be noted here that R depends upon the route that proves to be advantageous when taking traffic into consideration and, therefore, should be given due weightage. The other way to maximize the annual return is to have sound and economical construction work so as to reduce the annual running expenses. A suitable balance has to be achieved between construction cost and operating expenses.

Final location survey

Objectives: At the end of this lesson you shall be able to
• **state final location survey**
• **state the arrangement of documents in the report.**

Final Location Survey

Once a decision has been taken for a particular railway line to be constructed, a final location survey is done. The instruments used are generally the same as in the case of the preliminary survey. Final location survey is done to prepare working details and make accurate cost estimates in certain cases. The principal differences between the preliminary survey and the final survey are as follows.

a   In the final location survey, the alignment is fully staked with the help of a theodolite, whereas it is not obligatory to do so in the case of preliminary survey.

b   In the final location survey, a more detailed project report is prepared and submitted.

c   All working drawings are prepared in the final location survey.

Survey Alignment

The following tasks are carried out in the final location survey.

a   The centre line is fully marked by pegs at 20 m. At each 100 m, a large peg should be used.

b   Masonry pillars are built at tangent points of curves and along the centre line at intervals of 500 m.

c   Longitudinal and cross levelling is done to ascertain the final gradient of the alignment. All gradients are compensated for curves.

In the final location survey, the following set of drawings is prepared.

a   General map of the country traversed by the project at a scale of about 20 km to 1 cm

b   Index map, scale about 2.5 km to 1 cm

c   Index plan and sections

d   Detailed plans and sections

e   Plans and cross section

f   Plans of station yards

g   Detailed drawings of structures

h   Plans of junction arrangements

The following broad objectives should be kept in mind when selecting the best possible alignment in the final location survey.

a   Correct obligatory points

b   Easy grades and flat curves

c   Minimum cost of construction

d   Minimum adverse effect on environment

e   Ease of construction

f   Potential for high speeds

g   Avoidance of constraints for future expansion

h   Minimum maintenance cost

Project Report

A final project report is prepared based on the final location survey. The report consists of the following.

Introduction

In this segment of the report, the following details are covered.

i   Object of investigation and background

ii   Programme and methodology of investigation

iii Special features of investigation

Characteristics of the Project Areas

In this segment the topographical outline of the areas and geographical features of the country are given to the extent to which these are likely to affect the alignment, probable stability of the line, cost of construction, working expenses, or future prospects of the proposed line. Climatic and rainfall characteristics and environmental characteristics such as the presence of corrosive factors, pollution, etc., which may have an effect on the design and maintenance of structures and bridges, are also brought out.

Standard of Construction

This segment gives details of the following.

Gauge

The gauge adopted for the proposed line and the reasons, if any, for adopting it.

Category of line

The category of the line, the maximum speed potential of the line, the maximum axle load, the loading standard of bridges, and the basis for adopting the same.

Ruling gradient

The gradient adopted and the basis for its selection.

Curves

The sharpest degree of curvature adopted, the basis for its adoption, and its impact on the projected speed compatible to the category of line.

Permanent way

The rail section adopted, the decision as to whether welding of the rails will be carried out or not, and the type and density of sleepers provided in the project estimate.

Ballast

The type and depth of ballast cushion provided.

Stations

Spacing of stations in the case of new lines, provision for future intermediate stations, and the scale of facilities contemplated at stations.

Signalling and telecommunication

The standard of signalling adopted and the scale of communication facilities provided.

Traction

The type of traction proposed.

Other details Road crossings, station machinery, residential accommodation, service and maintenance facilities, etc.

Route Selection

This segment provides relevant information and data related to the various alternative routes examined and gives an insight into the factors influencing the choice of the route adopted for the project.

Project Engineering

This section furnishes information and data for the project manager to enable him to understand the scope and extent of the project and to assist him in formulating the strategy for the execution and management of the project. It must focus on the problems likely to be encountered, identify the areas requiring special attention, and place the knowledge and information gathered at the investigation stage for evolving optimal solutions.

Estimation of Cost and Construction Schedule

This segment gives a cost estimate of preliminary expenses, land, formation, bridges, permanent way, station building and residential quarters, road crossings, station equipment, signaling and interlocking, rolling stock, etc. The schedule of' construction as well as investment is also given. A network should be developed for projects costing above Rs.5 million.

Project Organization

This section details the organizational structure for the execution of the project, the proposed headquarters of the project manager and other construction officers, as well as the allocation of the various construction activities. Health and hygienic conditions provided to the staff as well as the provision of necessary medical establishments may be indicated, along with suggested plans providing the housing of staff and labour and the construction of temporary office buildings. Comments regarding the availability of water for construction purposes and its suitability for drinking purposes may also be given. The purpose and final cost allocation of such plans may also be indicated.

Tabulated Details

The report is accompanied by tabulated details of curve abstract, gradient abstract, bridge abstract, important bridges, stations, machinery, stations, and station sites.

Arrangement of Documents in the Report

All the documents pertaining to a final location survey report should be in the following order.

1 Covering note

2 Index

3 Report

4 A list of drawings accompanying the report

5 Appendices to the report

   a Historical and geographical aspects

   b Location report

   c Rates for construction work

Specification

Objectives: At the end of this lesson you shall be able to
• **define and describe the importance of specifications**
• **classify the specification**
• **describe the general specification**
• **explain the detailed specification**
• **calculate the area and volume at irregular boundary.**

Specification: Specification specifies or describes the nature and the class of the work, materials to be used in the work, workmanship, etc. and is very important for the execution of the work. The cost of a work depends much on the specifications. Specifications should be clear, and there should not be any ambiguity anywhere. From the study of the specifications, one should easily understand the nature of the work and what the work shall be. The drawings of the building or structure show that arrangement of the rooms and various parts and the dimensions - length, breadth and height with brief descriptions of different parts. Drawings do not furnish the details of different items of work, the quantity of materials, proportion of mortar and workmanship which are described in specifications. Thus the combinations of drawings and specifications define completely the structure. Drawings and specifications form important parts of contract document.

During writing specification attempts should be made to express all the requirement of the work clearly and in a concise form avoiding repetition. As far as possible, the clauses of the specification would be arranged in the same order in which the work will be carried out. The specifications are wirtten in a language so that they indicate what the work should be, and words "shall be" or "should be" are used.

Specifications depend on the nature of the work, the purpose for which the work is required, strength of the materials, availability of materials, quantity of materials etc.

Specifications are of two types

1   General specification or brief specification and

2   Detailed specification

General or brief specification: General specification gives the nature and class of the work and materials in general terms, to be used in the various parts of the work, from the foundation to the super sturcture. It is a short description of different parts of the work specifying materials, proportions, qualities, etc. General specifications give general idea of the whole work or structure and are useful for preparing the estimate.

For general idea, the general specifications of different class of the buildings are given below. These will of course vary according to the necessity and type of works.

General specifications of different class of buildings are as follows:

1 **First class building:** The first class building specifications are as follows.

S. No.	Items	Details
1	Foundation and Plinth	It shall be of first class brickwork (or random rubble masonry) in lime mortar or 1:6 cement mortars over lime concrete or 1:4:8 cement concrete
2	Damp Proof Course	It shall be 2.5 thick cement concrete 1:1.5:3 mixed with water proofing materials and painted with two coats of bitumen
3	Super Structure	It shall be of 1st class brick with lime mortar or 1:6 cement mortar. Lintels shall be of R.C.C.
4	Roofing	Roof shall be of R.C.C. slab with an insulation layer. Height of rooms not less than 3.7 m.
5	Flooring	Drawing and dining room floors shall be of mosaic, bath room and W.C. floors and dado shall be of mosaic. Bedroom shall be coloured and polished of 2.5 cm cement concrete over 7.5 lime concrete. Floor of others shall be of 2.5 cm. Cement concrete 7.5 cm. Lime concrete polished.
6	Finishing	Inside and outside walls shall be of 12 mm. Cement lime plastered 1:1:6 Drawing, Dining and Bed rooms inside shall be distempered and other inside white washed 3 coats. Outside shall be coloured snow cem washed 2 coats over 1 coat of white wash

S. No.	Items	Details
7	Doors and windows	Frame shall be teak wood.
		Shutters shall be teak wood 4.3 cm, thick panelled or partly glazed with additional wire gauge shutters.
		All fittings shall be of brass.
		Doors and windows shall be varnished or pained two coats with enamel paints over one coat or priming. Windows shall be provided with iron grills.
		Rain water pipes, 1st class sanitary and water fittings and electrical installations shall be provided.
		1 metre wide 7.5 cm, thick c.c. 1 : 3 : 6 aprons shall be provided all around the building.
8	Miscellaneous	

2 Second class buildings: The second class building specifications are as follows:

S. No.	Items	Details
1	Foundation and plinth	Foundation and plinth shall be of 1st class brickwork cement mortar over lime concrete
2	Damp proof course	It shall be of 2 cm. thick cement concrete 1 : 2 : 4 mixed with standard water proofing materials.
3	Superstructure	It shall be of 2nd class brick with lime mortar. Lintels shall be of R.B.
4	Roofing	Roof shall be of R.B. slab with 7.5 cm. Lime concrete terracing above. Verandah roof may be of A.C. sheet or Allahabad tiles.
5	Flooring	Floor shall be 2.5 cm. cement concrete over 7.5 L.C. verandah floor shall be of brick tiles finished cement pointed.
6	Finishing	Inside and outside walls shall be of 12 mm. Cement mortar plastered 1 : 6 ceiling shall be cement pastered 1 : 3.
7	Doors and windows	Frame shall be of R.C.C. or well seasoned sal wood, shutter of deodars wood 4 cm. thick panelled or partly glazed. Doors and windows shall be painted two coats over one coat of priming.
8	Miscellaneous	Rain water pipes shall be provided. Electrification, sanitary and water fittings may be provided if required.

3 Third class buildings: The specifications for the third class building are as follows

S. No.	Items	Details
1	Foundation and Plinth	It shall be of sun dried bricks and mud mortar. Opening shall be provided with superstructure arch of 2nd class brick work in lime mortar or with wooden planks. Inside and outside wall shall be water proof mud plastered.
2	Roofing	It shall be of tiles, over bamboo, and wooden support.
3	Flooring	If shall be earthen floor finished with gobris washing (cow dung lapping)
4	Doors and Windows	It shall be of chir or mango wood or country wood.

Detailed specification

The detailed specification is a detailed description and expresses the requirements in detail. The detailed specification of an item of work specifies the qualities and quantities of materials, the proportion of mortar, workmanship, the method of preparation and execution and the methods of measurement. The detailed specifications of different items of work are prepared

separately, and describe what the works should be and how they shall be executed and constructed. Detailed specifications are written to express the requirements clearly n a concise form avoiding repetition and ambiguity.

The detailed specifications are arranged as far as possible in the same sequence of order as the work is carried out. The detailed specifications if prepared properly are very helpful for the execution of work. The detailed specifications form an important part of contract document.

Every engineering department prepares the detailed specifications of the various items of works, and get them printed in book form under the name "Detailed Specifications." When the work or a structure or project is taken up, instead of writing detailed specification every time. The printed Detailed Specifications are referred.

Example - The detailed specifications of Earth Work Excavation is given below.

1 **Earthwork in excavation in foundation:** Excavation-Foundation trenches shall be dug out to the exact width of foundation concrete and the sides shall be vertical. If the soil is not good and does not permit vertical sides, the sides should be sloped back or protected with timber shoring. Excavated earth shall not be placed within 1 m (3") of the edge of the trench.

2 **Finish of trench:** The bottom of foundation trenches shall be perfectly levelled both longitudinally and transversely and the sides of the trench shall be dressed perfectly vertical from bottom up to the least thickness of loose concrete so that concrete may be laid to the exact width as per design. The bed of the trench shall be lightly watered and well rammed. Excess digging if done through mistake shall be filled with concrete at the expense of the contractor. Soft or defective sports shall be dug out and removed filled with concrete or with stabilized soil. If rocks or boulders are found during excavation, these should be removed and the bed of the trenches shall be levelled and made hard by consolidating the earth. Foundation concrete shall not be laid before the inspection and approval of the trench by the engineer-in-charge.

Finds: Any treasure and valuables or materials found during the excavation, shall be property of the Government.

Water in foundation: Water, if any accumulates in the trench, should be bailed or pumped out without the extra payment and necessary precautions shall be taken to prevent surface water to enter into the trench.

Trench filling: After the concrete has been laid masonry has been constructed the remaining portion of the trenches shall be filled up with earth in layers of 15 cm (6") and watered and well rammed. The earth filling shall be free from rubbish and refuse matters and all clods shall be broken before filling. Surplus earth not required, shall be removed and disposed, and site shall be levelled and dressed.

Measurement: The measurement of the excavation shall be taken in cu. m. (cu. ft.) as for rectangular trench bottom width of concrete multiplied by the vertical depth of foundation from ground level and multiplied by the length of trenches even though the contractor might have excavated with sloping side for his convenience. Rate shall be for complete work for 30 m (100 ft.) lead and 1.50 m (5') lift, including all tools and plants required for the completion of the works. For every extra lead of 30 m and every extra lift of 1.5 m separate extra rate is provided.

Excavation in saturated soil: Excavation in saturated soil or below sub-soil water level shall be taken under a separate item and shall be carried out in the same manner as above. Pumping or bailing out of water and removal of slush shall be included in the item. Timbering of the sides of trenches if required shall be taken under a separate item and paid separately.

Foundation

Objectives: At the end of this lesson, you shall be able to,
• **define foundation**
• **state types of foundation**
• **explain purpose of foundation**
• **explain various loads on foundation**
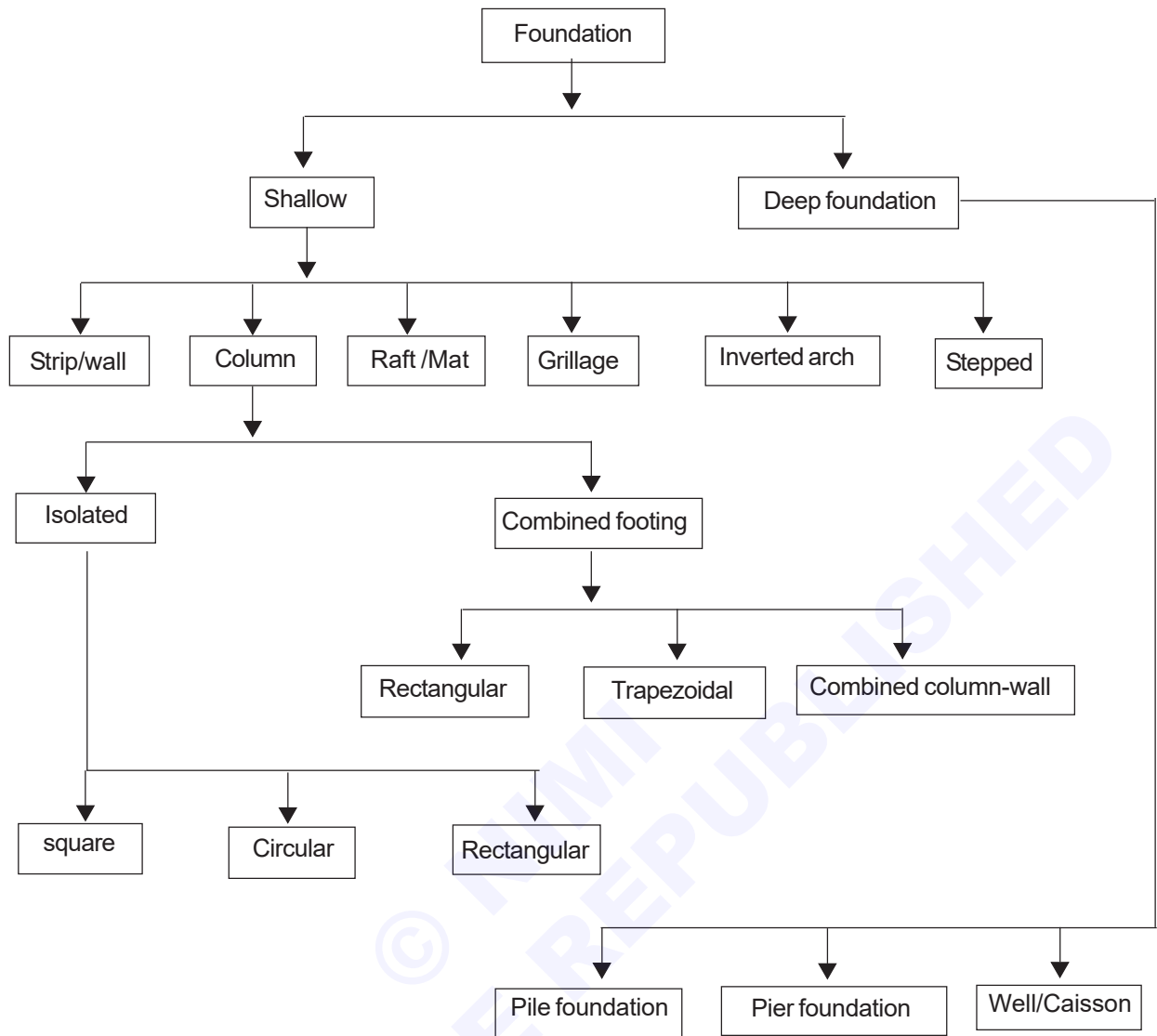• **describe causes of failure of foundation and its remedies.**

Introduction: Every structure consists of two parts, namely foundation and super structure. Foundation is the lowest part of a structure which transmits the weight of the structure, together with the effect of live loads and pressure, to the material on which the structure rests in such a manner that the underlying material is not stressed beyond its safe bearing capacity.

Definition: The lowest artificially prepared part of the structure, usually located below the ground level, which transmit the load of the superstructure to the ground is known as substructure or foundation.

Types of loads

1 Dead load

2 Live load

3 Wind load

4 Snow load

Types of function

Foundation
- Shallow
  - Strip/wall
  - Column
    - Isolated
      - square
      - Circular
      - Rectangular
    - Combined footing
      - Rectangular
      - Trapezoidal
      - Combined column-wall
  - Raft /Mat
  - Grillage
  - Inverted arch
  - Stepped
- Deep foundation
  - Pile foundation
  - Pier foundation
  - Well/Caisson

Causes of failure of foundations and its remedies

S.No.	Causes	Remedies
1	Unequal settlement of the subsoil	Foundation should rest on rigid strata. Design of foundations should be appropriate to the nature of subsoil.
2	Unequal settlement of the masonry	Using mortar of proper strength. Masonry work should be raised evenly. Proper Curing.
3	Withdrawal of moisture from the subsoil	Provide drive piles up to the hard rock.
4	Lateral pressure on the superstructure	Provide sufficient wide base.
5	Horizontal movement of the earth	Construct retaining walls to prevent the escape of earth.
6	Transpiration of trees and shrubs	Foundations should be sufficiently deep. Trees should not be planted near the building.
7	Atmospheric action	Provide suitable underground drains. Providing gentle ground slope away from the wall.

Shallow foundation

Objectives: At the end of this lesson you shall be able to,
• define shallow foundation
• explain various types of shallow foundation
• describe setting out of building on ground.

Definition

The depth of foundation is equal or less than its width, is known as shallow foundation.

Setting out of building on ground

1 Clear the Site.

2 Prepare a plan of setting out on paper.

3 Centre lines of walls to be marked on plan

4 This is to be marked on ground.

5 Mark the centre lines of walls by stretching a string between wooden pegs.

6 Cross walls set by 3, 4,5 method.

7 Corners of building are laid and sides checked by measuring diagonals.

8 Entire width of foundation marked

9 For big projects reference pillars of brick may be constructed.

Shallow foundation

Foundation having its depth less than or equal is its width are known as shallow foundation. Since such foundation are constructed by open excavation.

Hence those foundation having its depth even greater than its width but are constructed by way of open excavation are also come under shallow foundation.

Design of shallow foundation

Following data are required before design of a foundation

a The total load to be transmitted by the wall or pier to the foundation bed.

b The results of trial pit and the corresponding bearing capacity of each strata of soil.

The design of foundation required the three terms

a Width of foundation.

b Depth of foundation below ground level.

c Depth of concrete block below the masonry footing.

Width of foundation

The width of foundation should be sufficient enough to bear the super imposed load per unit length on the foundation bed. The width of foundation is obtained by

i Dividing the total load per unit length on foundation bed by safe bearing capacity of the soil.

Thus, width of foundation = $\dfrac{w}{p}$

Where, w = total load in tonne/metre

p = safe bearing capacity of soil in tonne/m²

ii Width of foundation = 2 (T+J)

Where,

T = thickness of wall above the plinth level.

J = the projection of concrete block on the either side of the lower most of the masonry footing. which should be atleast 10cm -15cm.

Depth of foundation below ground level

This is generally determined by the rankine's formula. Which gives the maximum depth.

Depth of foundation below the ground level,

$$d = \frac{p}{w}\left[\frac{1-\sin\theta}{1+\sin\theta}\right]^2$$

Where p = total load on soil in kg/m²

w = wt of soil in kg/m³

θ = Angle of repose of the soil.

In order that all the shallow foundation should be taken to a minimum depth of 80cm below the natural ground level. Unless hard soil is available within 80cm.

Angle of repose

Angle of repose is the angle between 0° to 90° the loose soil will make with the horizontal, if allowed to remain free in loose condition. The angle of repose of the soil varies with the type of earth.

Depth of concrete block

The depth of concrete block below the masonry footing is calculated by using the formula

$$d = \sqrt{\frac{3PJ^2}{m}}$$

Where, P = the load on soil in kg/m²

J = The projection of concrete on either side of the lowermost masonry footing which should be at least 10-15cm.

m = modulus of rupture of concrete in kg/m

The depth of concrete block below the masonry footing is also determined by the formula

$$d = \frac{5}{6}T$$

Where T = thickness of wall above the plinth level.

Types of shallow foundation

A Spread footing

The total load of the structure is transmitted to the base of the structure is spread out to a large area by spread footing.

a Strip footing
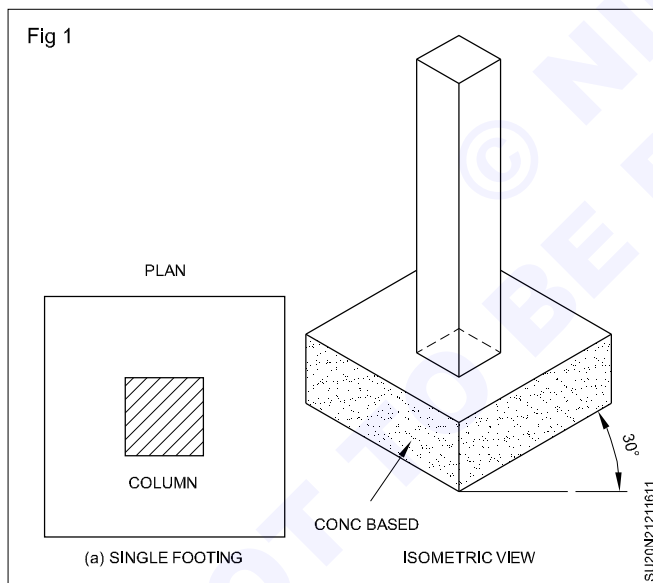
Spread footing for a wall is known as strip footing.

b Pad footing

The spread footing for a single column is known as pad footing or isolated footing.

The spread footing may be of the following types

i Single footing

Fig 1 shows the single footing for a column in which the loaded area (bxb) of the column has been spread to the size (BxB) through a single spread.
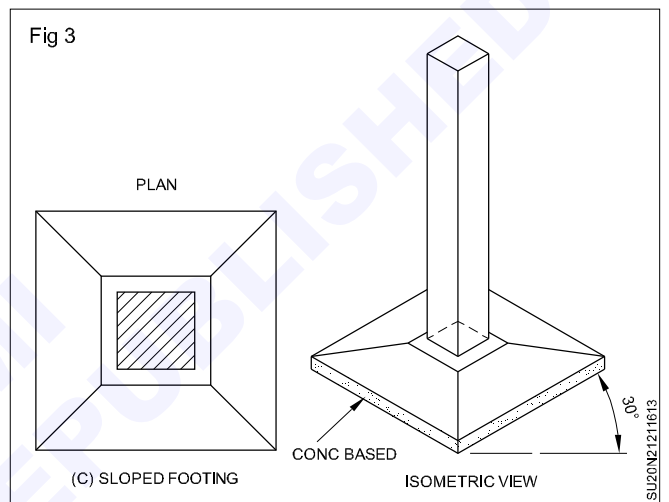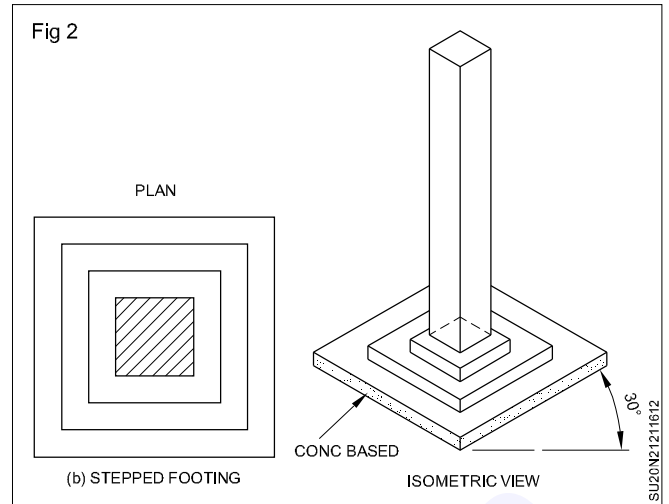

ii Stepped footing

The Fig 2 shows the stepped footing for a heavily loaded column which require greater spread. The base of the column is made of concrete.
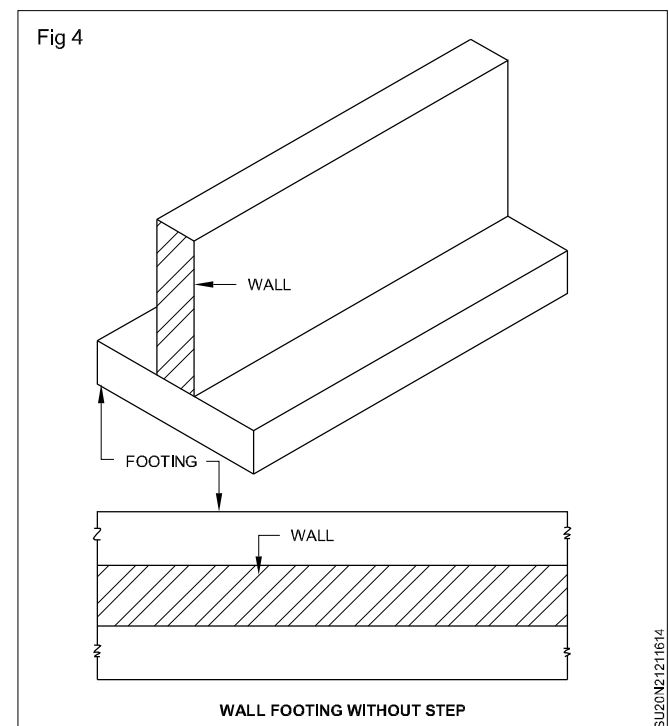
iii Sloped footing

Fig 3 shows the sloped footing made in concrete base of non uniform thickness. Greater thickness at its bottom, smaller thickness at the top.
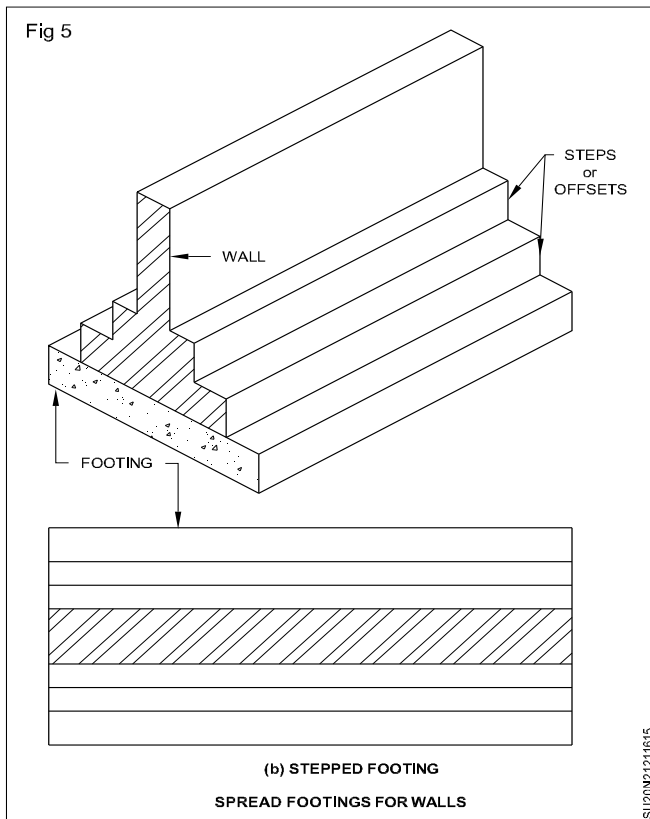

iv Wall footing without step

Fig 4 shows the stepped footing for a wall consisting of concrete base without step.

v Stepped footing for a wall

Fig 5 shows the masonry wall have stepped footing with a concrete base.

(b) STEPPED FOOTING

SPREAD FOOTINGS FOR WALLS

vi Grillage foundation

A grillage foundation is a special type of isolated footing. Generally provided for heavily loaded steel stanchions or column, specially in those location where bearing capacity of soil is poor. The depth of foundation is limited from 1-1.5m. The load of the column or stanchion is distributed or spread to a very large area by means of layers of tiers of joist, each tier being placed at right angle to the next tier.

Grillage foundation are of two types:-

Steel grillage foundation

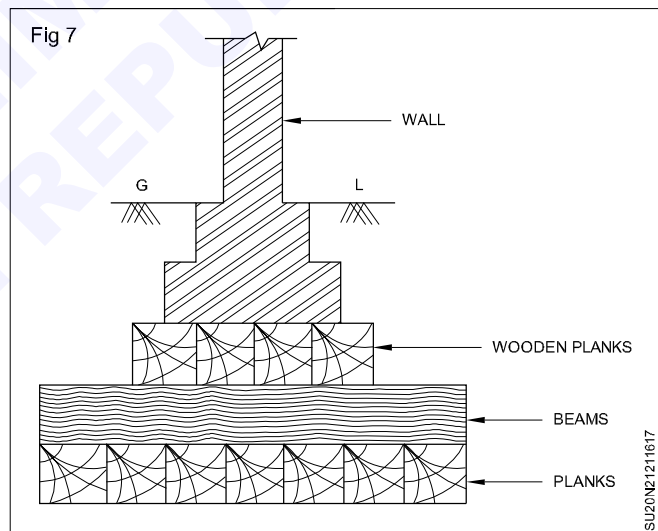**Timber grillage foundation.**

Steel grillage foundation

Steel grillage foundation is constructed of steel beams, structurally known as rolled steel joist (RSJ) provided in two or more tiers. In case of double tier grillage (which is commonly provided) the top tier of grillage beams is laid at right angle to the Bottom tier. The joists or beams of each tier are held in position by 20mm diameter pipe separators (tie rod 20mm diameter) as shown in Fig 6.

The grillage beams are embedded in concrete. Generally, the minimum clearance of 8cm is kept between the grillage beams. So that the concrete can be easily poured ,properly compacted. However the distance between the flanges should not exceed 30cm or $1\frac{1}{2}$ times the flange width. So that the filled concrete acts monolithically with the beams. It should prevent their corrosion. A minimum concrete cover of 10cm is kept on the outside of the external beams as well as upper flanges of top tier.

SECTION ON A-B

GRILLAGE FOUNDATION
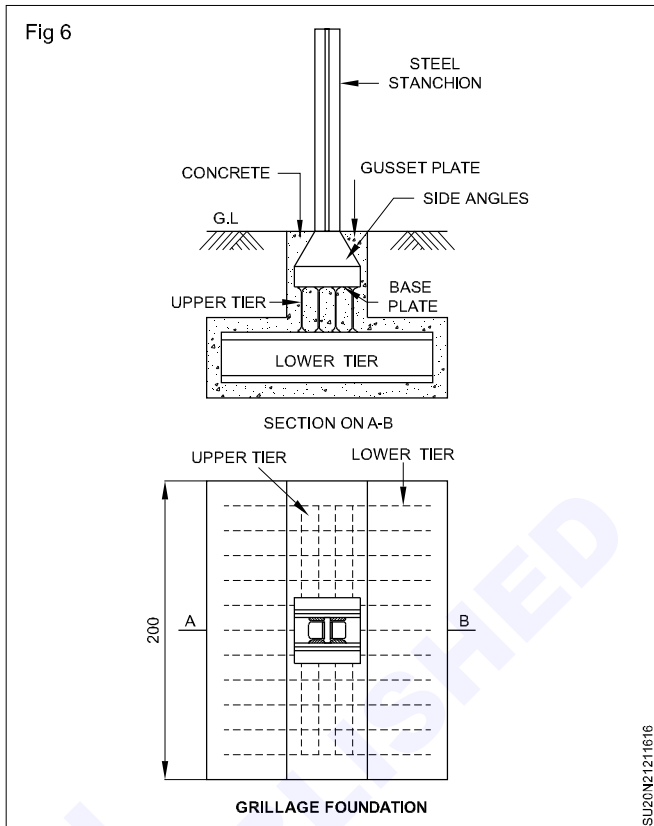
Timber grillage foundation (Fig 7)

Temporary grillage foundation in the form of timber beams may be provided to timber columns, posts or walls etc. They can be designed for supporting light building. In water logged areas. The loading on the soil is limited is 5.5 tone/m. The grillage takes the form of a platform of wooden planks arranged in 2 layers at rectangle to each other. The two layers of planks are separated by rectangular section of timber placed at centre to centre distance of about 45cm to 60cm.

## B Strap footing or cantilever footing (Fig 8)

A strap footing comprises of two or more footings of individual columns, connected by a beam called a strap. When a column is near or right next to a property limit, its foundation cannot extended beyond the property line, and

if the distance between this columns and the adjoining column is large, in that case strap footing may be provided. The strap beam connecting the spread footings of the two columns do not remain in contact with soil and does not transfer any pressure to the soil. The function of strap beam is to transfer the load of heavily loaded outer column to the inner column. In doing so the strap beam is subjected to bending moment and shear force and it should be suitably designed to withstand these.

Fig 8

STRAP FOOTING
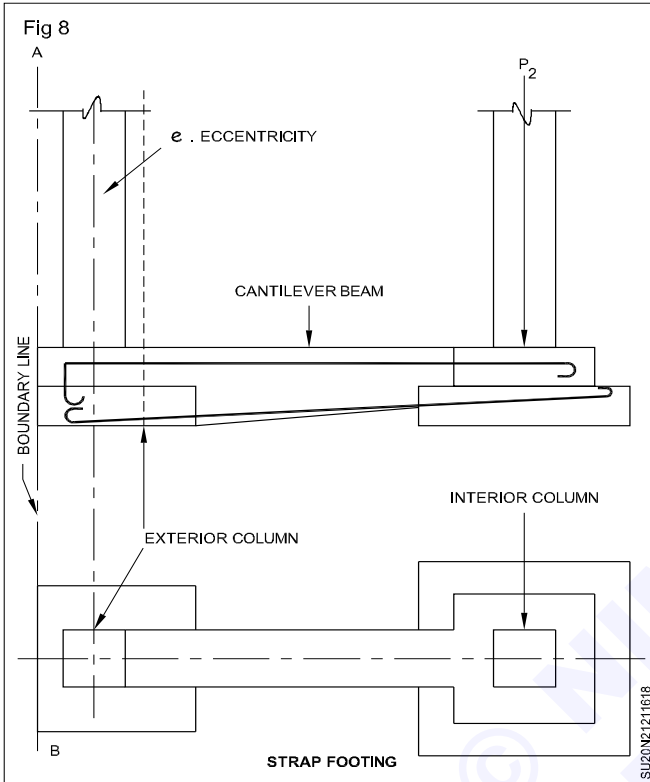
iii Combined footing

Rectangular footing (Fig 9): A spread footing which supports two columns is termed has combined footing. If the footing supports more than two columns it is known as continuous footing.

Fig 9

(a) RECTANGULAR FOOTING
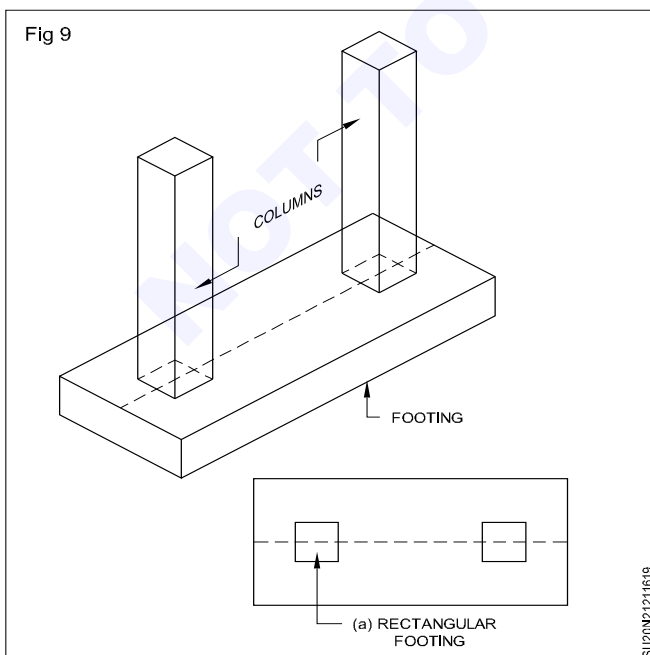
A combined footing is provided under the following circumstances

1   When the columns are very near to each other so that their footings overlap.

2   When the bearing capacity of soil is less requiring more area under individual footing.

3   When the end column is near a property line so that its footing spread in that direction.

A combined footing may be rectangular or trapezoidal in plan. The aim is to get uniform pressure distribution under the footing. For this the centre of gravity of the footing area should coincide with centre of gravity of the combined load of two columns. If the outer column, near the properly line carries heavier load, provision of trapezoidal column becomes essential to bring the c.g of the footing in line with the c.g of the two column loads. In other cases rectangular footing may be preferred. (Fig 10)
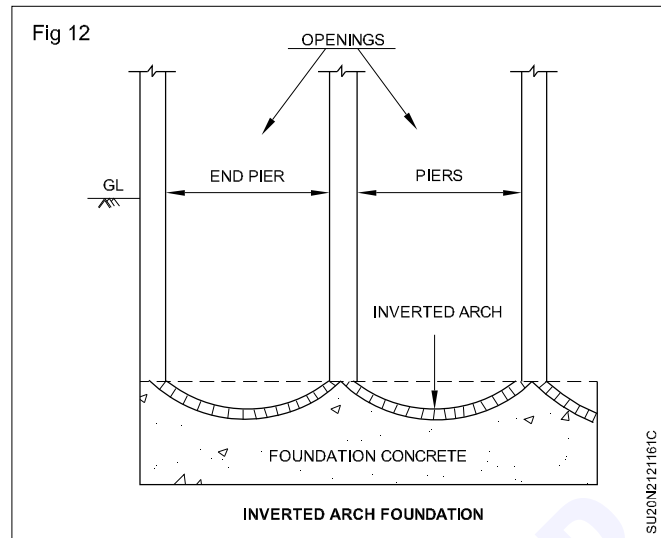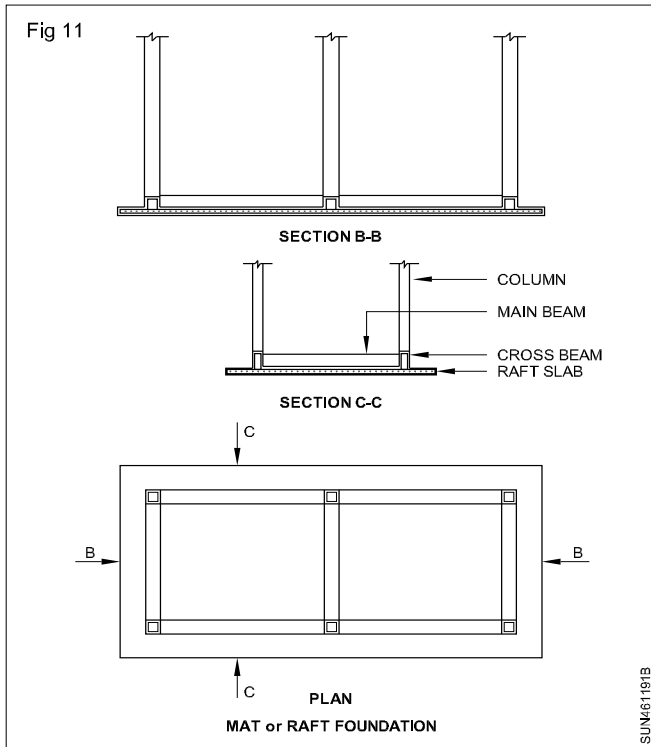

Fig 10

(b) TRAPEZOIDAL FOOTING
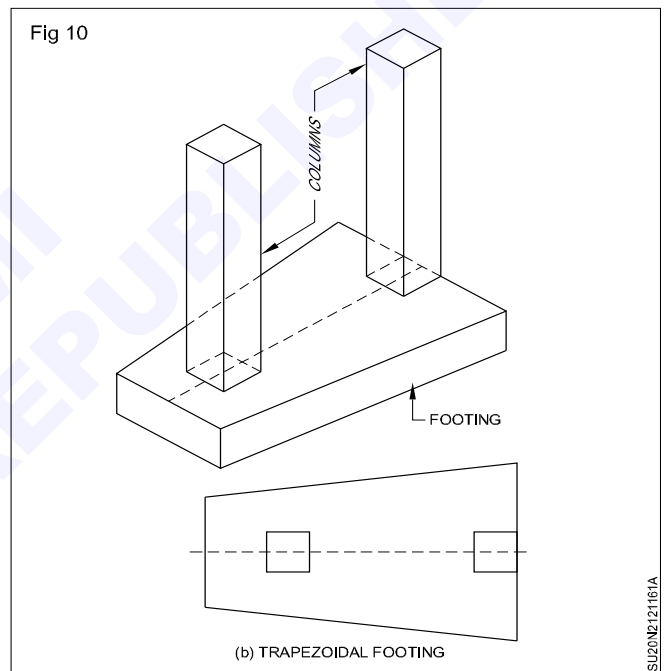
IV Mat or raft foundation (Fig 11)

Generally a raft or mat foundation is used when the bearing capacity of soil is very poor and when it is required to distribute heavy concentrated load over a large area. The raft foundation is useful where there is a possibility of unequal settlement to occur. The raft foundation consist of thick R.C.C slab covering whole area in the form of a mat. If the required area of footing exceeds half the total area of the structures, raft foundation is used. Raft foundation is also used for increasing the area of foundation to neutralise the hydrostatic uplifts.

v Inverted arch foundation (Fig 12)

The foundation which consists of inverted arches between the pier are known as inverted arch foundation. The rise of the arch is about 1/5th -1/10th of the span. The load transmitted to the soil through inverted arch. These are suitable for the construction of bridges, reservoirs, tanks etc. Now a days this type of foundation is rarely used in India.

Fig 11

SECTION B-B

COLUMN
MAIN BEAM
CROSS BEAM
RAFT SLAB

SECTION C-C

PLAN

MAT or RAFT FOUNDATION

Fig 12

OPENINGS

GL

END PIER

PIERS

INVERTED ARCH

FOUNDATION CONCRETE

INVERTED ARCH FOUNDATION

Deep foundation

Objectives: At the end of this lesson, you shall be able to,
• **define deep foundation**
• **state classification of deep foundation**
• **explain pile foundation**
• **identifies various types of piles**
• **describe pier foundation**
• **explain well foundation (caisson)**

Introduction

This construction is adopted when the loose soil extends to a great depth. The load of the structure is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of piles.
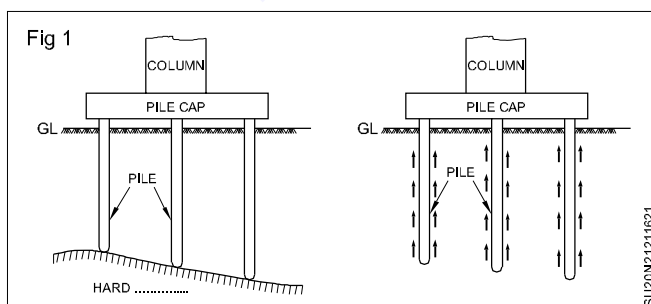
Definition

The depth of foundation is greater than its width is called deep foundation.

Classification of deep Foundation

Pile foundation   Pier Foundation   Well Foundation (Caissons)

A Pile Foundation

Pile is a long vertical load transferring member which may be of timber, steel or concrete. (Fig 1)

Fig 1

COLUMN

PILE CAP

GL

PILE

COLUMN

PILE CAP

GL

PILE

HARD ....

1 The loads are taken to a low level by means of columns in the soil.

2 It may be adopted where no firm bearing strata exists at reasonable depth and the loading is uneven

3 The pumping of subsoil water is too costly for keeping the foundation trench in dry condition.

4 This foundation is to be adopted for the structures in the area where canals ,deep drainage lines, etc. are to be constructed
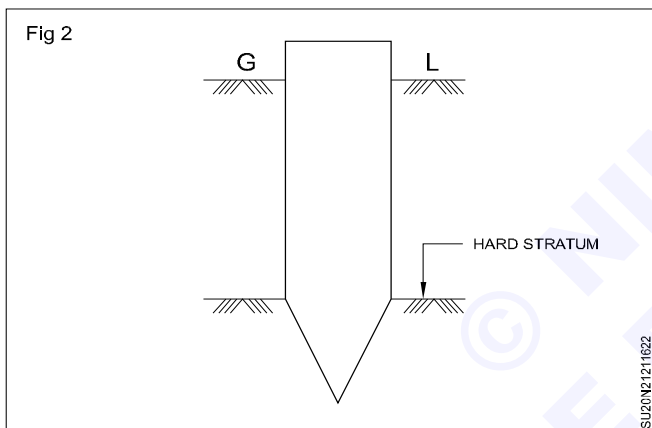
Pile

Following are the situation in which a pile foundation is preferred:-

a When the load coming from the structure is very high and concentrated.

b When the other type of foundation cannot be provided due to heavy cost and site difficulties.

c When the water table is very near to the ground level and may defect the other type of foundation.

d When due to heavy inflow seepage, it is not possible to execute the trenches and keep them dry.

e Where there are availability of construction of irrigation canal in the near by area, which causes seepage of water in the foundation.

f When hard bearing strata is at a greater depth.

Classification of piles

a Classification according to foundation:-

1 End bearing piles (Fig 2)

Fig 2

Piles whose lower end rest on hard rock (hard stratum) is known as end bearing piles. These piles are used to transfer heavy load through water or soft soil to a suitable hard stratum.
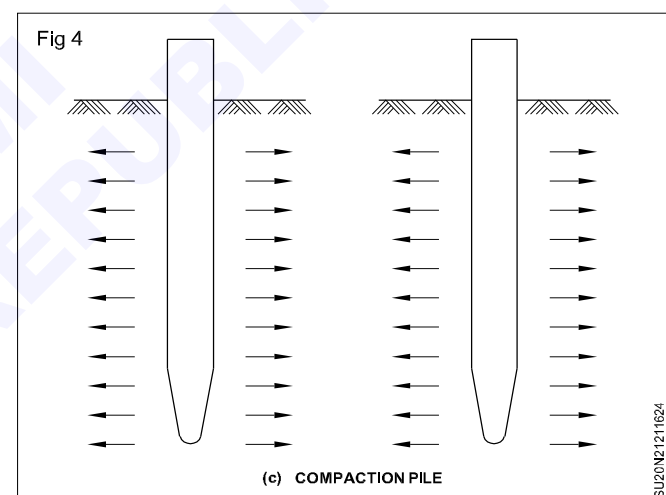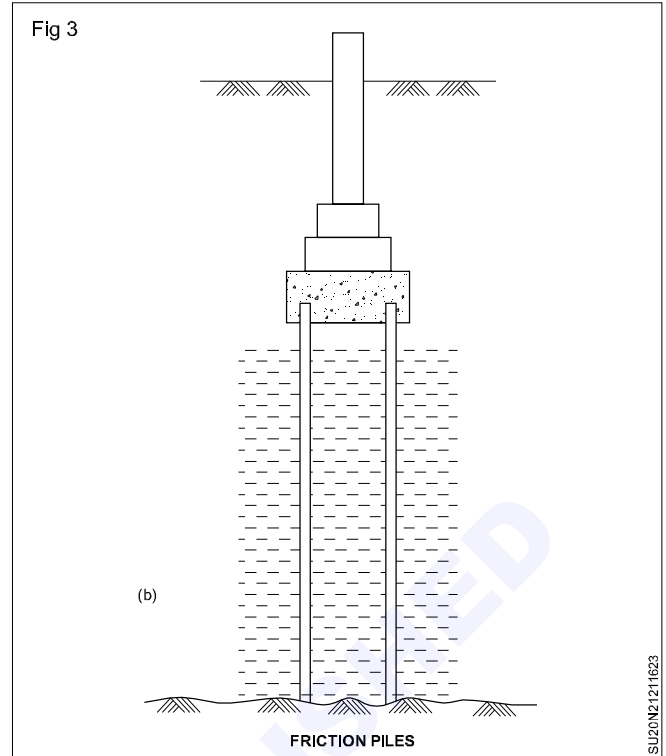
2 Friction piles (Fig 3)

The piles which support the structure load due to friction between the piles and surrounding soil are known as friction piles. Such piles are generally use in granular soil when the depth of hard strata is very high.

3 Compaction piles (Fig 4)

Compaction piles are used to compact loose granular soil thus increasing their bearing capacity. The compaction piles themselves do not carry any load. Hence they may be made of weaker materials like timber, bamboo sticks etc. Sometimes they may be made of sand only. The pile tube driven to compact the soil, is gradually taken out and sand is filled in its place thus forming a sand pile.

4 Tension or uplift pile

The tension piles anchor down the structures subjected to uplifts due to hydrostatic pressure or due to overturning moment.

Fig 3

FRICTION PILES

Fig 4

(c) COMPACTION PILE

5 Anchor piles

These piles provide anchorage against the horizontal uplift from sheet piling or other uplift force.

6 Sheet piles

The piles are differ from bearing pile and friction pile. In that they are rarely used to furnish vertical supports, but are used to retain the soil that is, liable to escape laterally when subjected to pressure or to enclose the area required for some foundation. And protect it from the action of running water or leakage.
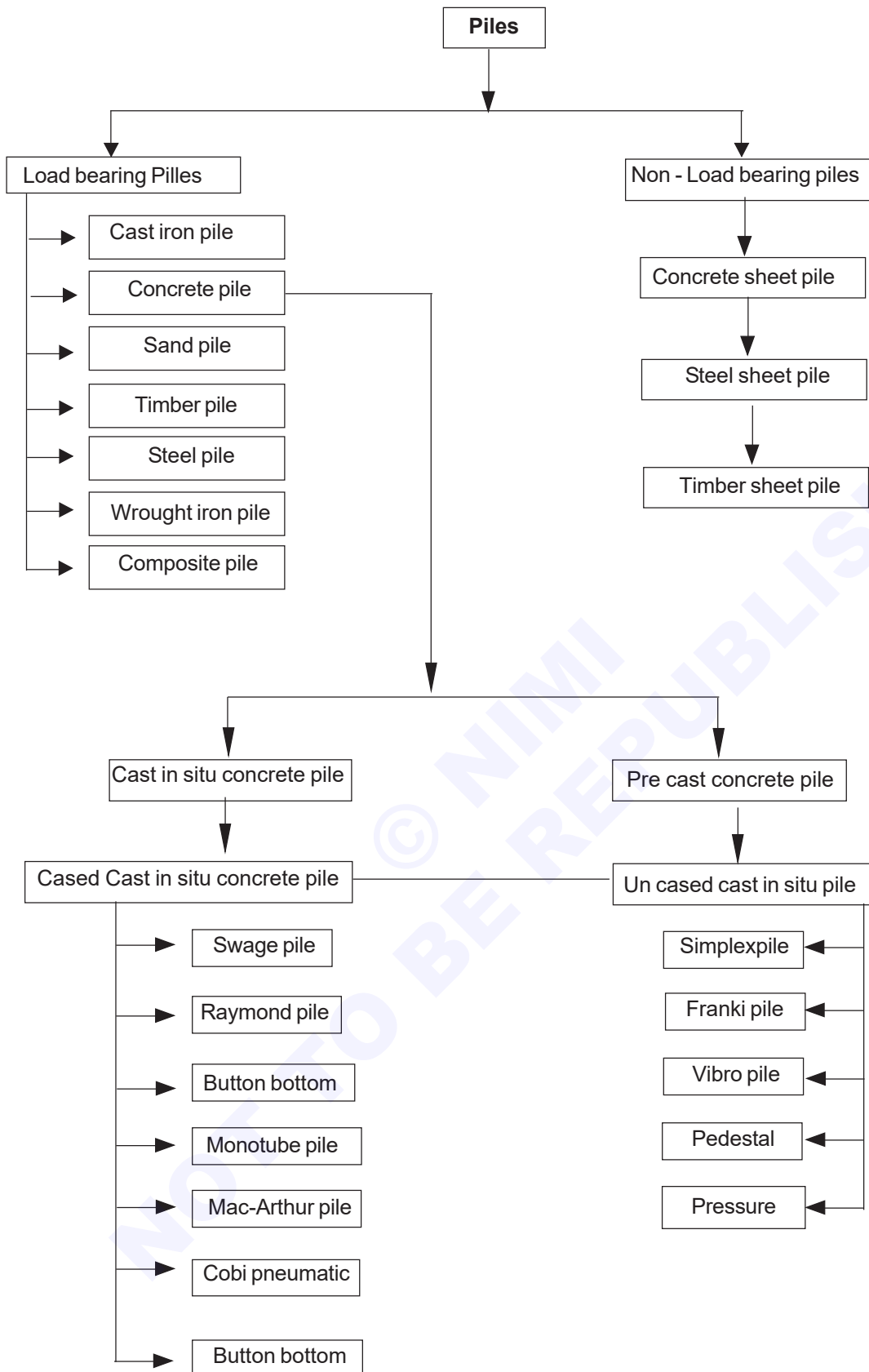
7 Fender piles and dolphins

These piles are used to protect the concrete deck or other water front structures against impact from ship or other floating objects. Ex. Dock yard Areas.

8 Batter piles

These piles are driven at an inclination to resist large horizontal or inclined forces.

b Classification according to materials used

Types of pile

```
                            Piles
                              │
        ┌─────────────────────┴─────────────────────┐
        ▼                                             ▼
  Load bearing Pilles                        Non - Load bearing piles
        │                                             │
        ├──►  Cast iron pile                          ▼
        │                                     Concrete sheet pile
        ├──►  Concrete pile ──────────┐               │
        │                             │               ▼
        ├──►  Sand pile               │        Steel sheet pile
        │                             │               │
        ├──►  Timber pile             │               ▼
        │                             │       Timber sheet pile
        ├──►  Steel pile              │
        │                             │
        ├──►  Wrought iron pile       │
        │                             │
        └──►  Composite pile          │
                                      │
                      ┌───────────────┴───────────────┐
                      ▼                                 ▼
            Cast in situ concrete pile        Pre cast concrete pile
                      │                                 │
                      ▼                                 ▼
       Cased Cast in situ concrete pile ──── Un cased cast in situ pile
                      │                                 │
                      ├──► Swage pile                   ├──► Simplexpile
                      │                                 │
                      ├──► Raymond pile                 ├──► Franki pile
                      │                                 │
                      ├──► Button bottom                ├──► Vibro pile
                      │                                 │
                      ├──► Monotube pile                ├──► Pedestal
                      │                                 │
                      ├──► Mac-Arthur pile              └──► Pressure
                      │
                      ├──► Cobi pneumatic
                      │
                      └──► Button bottom
```

1 Concrete piles

2 Timber piles

3 Steel piles

4 Composite piles

1 Cement concrete piles (Fig 5)

Cement concrete possess excellent compressive strength. R.C.C piles are becoming more popular and they are fast replacing piles of other material. R.C.C piles are divided into two groups.

PRECAST CONCRETE PILES
(a) SQUARE PILE (b) OCTAGONAL PILE (c) CIRCULAR PILE
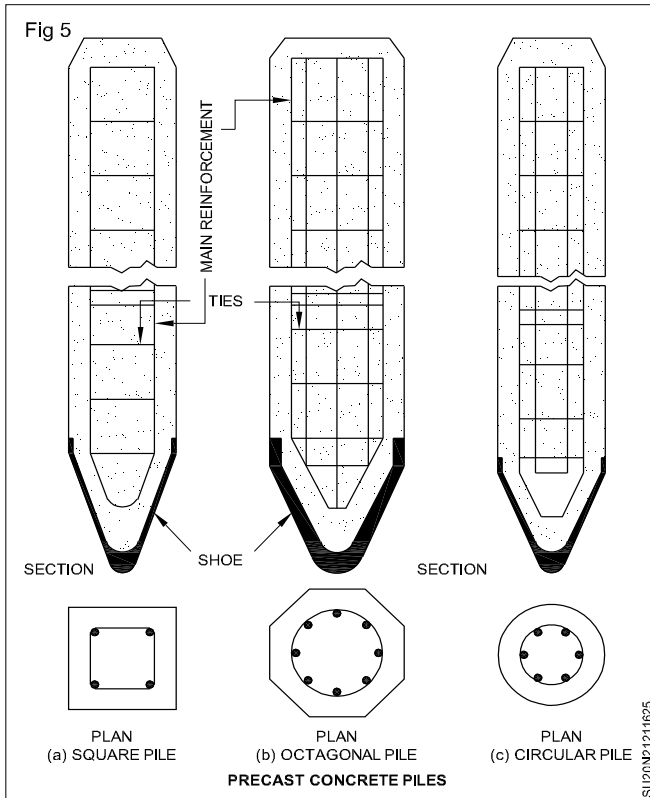
i Pre cast concrete piles (Fig 5)

Pre-cast concrete piles are those which are manufactured in a factory or at a place away from the construction site and then driven into the ground at the place required. They may be square and octagonal piles are cast in horizontal form. The round piles are cast in vertical forms. The size of the piles may be 30cm-50cm and the length may be much as 18m or moré.

The reinforcement may consist of longitudinal steel bars of 20-40 mm in diameter 4-8 No's with lateral ties of 5-10mm binding wires & ties spaced at 10cm-30cm c/c from bottom to middle respectively. A concrete cover of atleast 50mm is provided as shown in figure. At the toe of the piles a steel shoe is generally provided. The steel shoe protect the toe and helps the pile in penetrating into the ground during the driving. Pre-casting piles are useful in carrying fairly heavy loads through soft materials to soft inner strata.

Advantages of pre-cast concrete piles

a The position of reinforcement in pile is not disturbed from its original position.

b These piles can be driven under water. Concrete in the cast-in-site piles may not be set under water.

c It is possible to have a proper control over the composition and design of these piles as they are manufactured in a workshop.

d Any defect of casting such as hollows etc can be found out and repaired before driving the pile.

e Any number of piles can be manufactured at a suitable place and it is may be economical this may prove to be economical.

f These piles process high resistance to biological and chemical action of the ground.

g These piles, when driven are ready to take up the load. There is no wastage of time.

Disadvantages of pre-cast concrete piles

a These piles are heavy in weight and it is therefore difficult to transport, to handle and to drive them.

b Extra reinforcement is provided to resist the stresses during handling and driving operation. This fact makes the pile costly.

c If sufficient care is not taken, piles may break during transport or driving.

d The size and length of pile will depend on the available transport facilities.

ii Cast-in-situ concrete pile

In this type of concrete piles a bore hole is dug into the ground by inserting a casing. This bore is then filled with concrete after placing reinforcement, if any. The casing may be kept in position or it may be withdrawn. The former piles are known as cased-cast-in-situ concrete piles and the latter is known as uncased-cast-in-situ concrete piles.

Advantages of cast-in-situ concrete piles

a Light weight shells are used in cast-in-situ concrete piles and these shells are easy to handle and to drive in the ground.

b No extra reinforcement is necessary to resist stresses developing during handling or driving operation only.

c There is no wastage of materials as the piles of required length is constructed.

d The pile are sound in construction as they are not driven into the ground by a hammer.

Disadvantages

a It is difficult to maintain the reinforcement in correct position during construction of piles.

b These pile cannot be constructed under water.

c The dry ground may absorb, moisture from the wet concrete. The piles are then weakened.
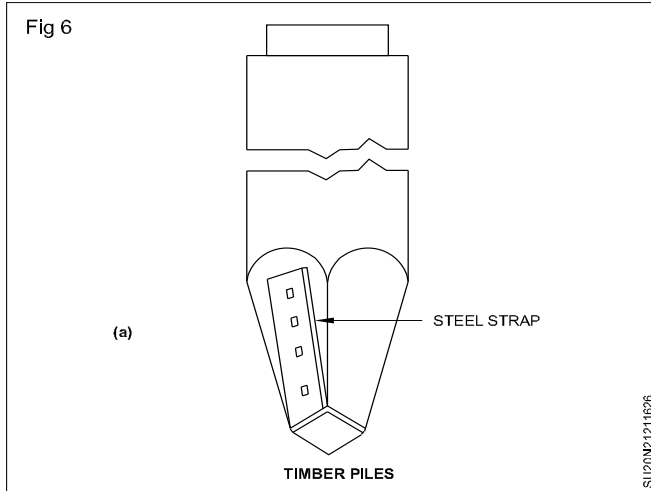
2 Timber piles (Fig 6)

The timber pile may be rectangular, circular, square. The size of timber varies from 50 cm. The length of the timber pile does not exceed 20times its top width otherwise it may fail by buckling. At the bottom a cast-iron shoe is provided and at the top, a steel plate is fixed. The timber pile should be properly treated so as to make them durable.

A timber pile is made of trunk of a tree. The wood to be used for timber pile should be free from knots. flaws and shakes and other defects. The common Indian timber which are used are babool, chir, jarul, poon,. Sal, teak.

Advantages of timber piles

a Where timber is available easily these piles suitable to be economical in cost.

b These piles can be handled easily handle or danger of break.

c   The length of the timber pile can be adjusted either by cutting or lengthening without much extra cost.

d   Skilled supervision is not required in the construction of timber pile.

e   These piles can be removed easily if necessary.

f   These pile donot required heavy equipment for driving them into the ground.

Disadvantages

a   These piles cannot be take heavy loads and are unsuitable for used as end bearing piles.

b   A joint in the lengthened timber pile is a source of weakness.

c   It becomes very difficult to drive these piles in the hard formation.

d   Timber piles are generally used for temporary work.

3   Steel piles

Steel piles are used as load bearing piles in the different form.

i   H-beam piles

ii   Box-piles

iii   Tube-piles

•   H-beam piles

Fig 7 shows the plan of an H-beam steel piles. These piles are usually of wide flange section and they are most common varies of steel piles in general use. They are found very much suitable especially for trested type structure in which the pile extent above ground level and work also as column for the structure. The driving of H-piles is very simple and energy from a piles hammer is effectively transmitted to the lower portion of the pile.

•   Box pile

Fig 8 shows the plan of box pile. Various type of patended box piles are available, the figure shows "Larssen-Box pile". A box is driven either with closed bottom or with open bottom. These piles are used when it is not possible to drive H-beam piles upto the hard strata.
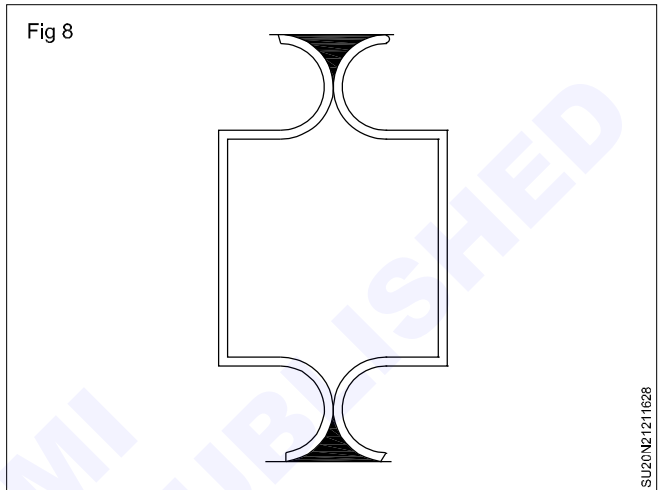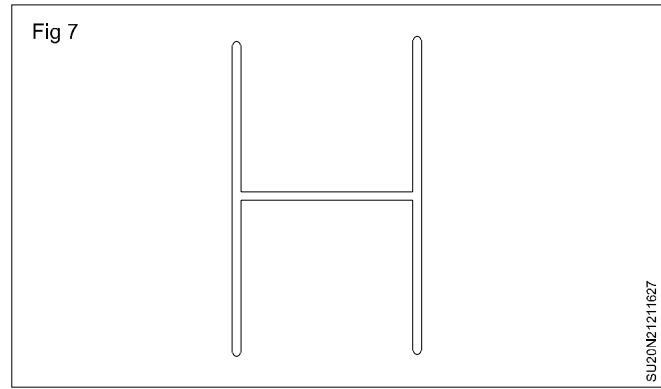
•   Tube piles

Fig 9 shows the plan of tube pile. In this type of steel piles, tubes or pipes of steel are driven into the ground. The pile may be driven either with open end or with closed end. Concrete is filled in side the tube piles. Because of circular cross section these piles are easily to handle and easy to drive.
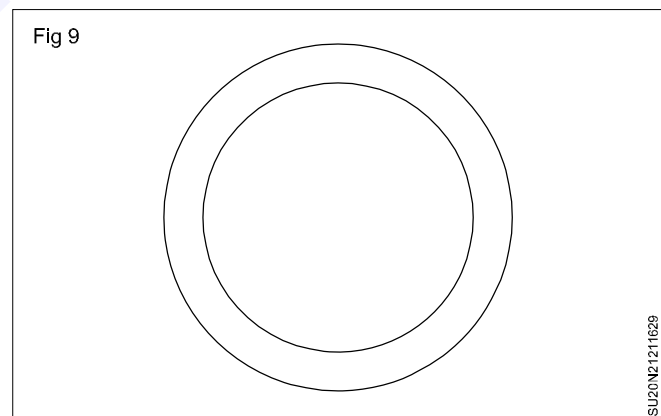
Advantages of steel piles

a   These piles withstand easily the stresses due to driving.

b   These piles can be easily to lengthened by welding without any delay in driving operation.

c   The extra length of these piles can be cut off easily.

d   The bearing capacity of these pile is comparatively high. The allowable compressive stress on steel is taken as about 6-8 kg/mm^2

e   These piles can be handled roughly without any serious damage.

Disadvantages

a   Corrosion is the only drawback of steel pile.

4   Composite piles

Composite piles are those which are made of two portion of two different materials driven one above the other. Two common type of composite piles are:

a   Timber and concrete pile

In the timber and concrete composite pile, timber portion is use below the permanent or lowest water level, while concrete piles, usually cast-in-sites is formed above it. Due to this combination the advantages of both types are combined. Also the total cost of the pile is reduced.

b   Steel and concrete composite pile

This type of composite pile is used where the required length of pile is greater than that available for the cast-in-situ type pile. The pile consists of steel pile attached to the lower end of concrete pile. This type of composit pile is used where satisfactory penetration of the pile into the rock is required for heavy loads.

Foundation for black cotton soil: Black cotton soil is a loose type of soil, and it considerably swells and shrinks by variation in moisture content. The variation in the volume of the soil is to the extent to the extend of 20%-30% of the original volume. During rainy season moisture penetrates into the soil the particles separate out, resulting in increase in the volume.

This increase in volume is known as swelling. During summer season, moisture moves out of the soil and consequently the soil shrinks, shrinkage cracks are formed on the ground surface. These shrinkage cracks are formed on the ground surface. These shrinkage cracks sometimes also known as tension cracks may 10-15cm wide,1/2-2m deep. Hence extreme care should be taken when foundation are to rest on this soil.

Following are the precautions to be taken in designing footings on black cotton soil:-

a   For important structure the raft foundation should be adopted.

b   The black cotton soil should be completely removed if possible and convenient.

c   The black cotton soil should not be allowed to come in direct contact with the foundation masonry.

d   The construction work should be carried out in dry season.

e   The depth of foundation should extend beyond the depth of crack in black cotton soil.

Pile cap and pile shoe: When the column or any other load carrying structural component is supported on more than one pile, the pile should be connected through a rigid pile cap, to distribute the load to individual pile, pile cap maintain the proper alignment of the pile. It is advisable to ensure that a pile projects atleast by about 10cm in the pile cap.

Pile shoes are provided at the tips to facilitate the process of driving through hard strata. Pile shoes are made from cast iron, steel or wrought iron. In case of steel piles it is necessary.

B   Well foundation(caissons) (Fig 10)

CYLINDRICAL OPEN CAISSON (WELL FOUNDATION)
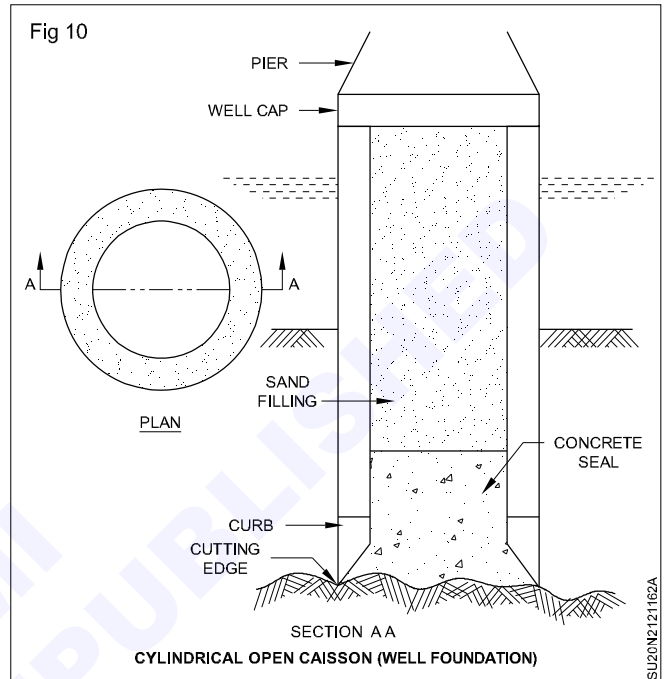
Well foundation is the convenient of securing a trust worthy foundation in deep sand or soft soil. It is also useful in moderate depth of water when foundation is to be taken in soft sandy soil, well are generally made of concrete or masonry. In masonry well vertical holding down bolt and iron plate or loop iron are provided to secure good bond.

In order to prevent cracks during sinking operation. At the bottom of the well curb made of concrete, a steel or cast iron, cutting edge is attached. The position of well to be sank is first correctly marked on the ground and the curb is placed upon it. On the curb masonry ring is built to a height of about 1.2m and allowed to drying.

Type of foundation in black cotton soil

Foundation in black cotton soil may be of the following types.

1   Strip or pad foundation

2   Pier foundation

3   Under-reamed pile foundation

1   Strip or pad foundation

For medium loads strip foundation (for walls) and pad foundation (columns) may be provided. These are two method of strip or pad foundation.

1st method

This method of constructing foundation on black cotton soil is adopted when the depth of black cotton soil is more and there are not chances for surface water to penetrate through the soil for more than 1m-1.5m.

The procedure is as follows

a The foundations trenches are excavated to a depth given by the equation.

d = maximum depth of crack+30cm

b The width of the trenches is kept such that the allowable bearing capacity of the soil does not exceed 15 tonne/m^2.

c Gravel is spread for the face width of the trench and well rammed.

d A layer of concrete of 50cm depth is laid on the gravel.

e The masonry work is started on the top of the foundation soil and it is carried out upto the plinth level.

f The side of the trenches are filled with sand. (Fig 11)

Fig 11
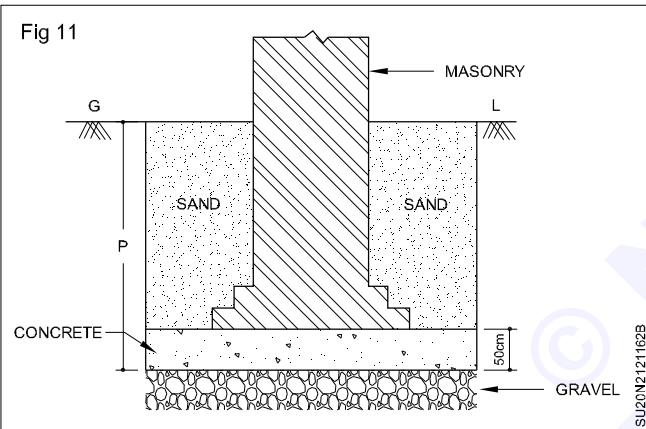
II method

This method of constructing foundation on black cotton soil is adopted at places where there is heavy rain-fall and there are possibility for surface water to reach a greater depth in the soil.

The procedure as follows (Fig 12)

a The foundation trenches are excavated to a depth of 2m.

b The side portion of the trenches are filled with concrete having a section of 25cmx25cm as shown in fig 12 and the hollow space equal to 1st layer of masonry is filled with sand.

c 12cm-15cm thick R.C.C slab covering the face width of the trench is laid.

d The masonry work is started on the top of R.C.C slab and it is carried upto the plinth level.

e 80mm diameter pipes spread at 1.5cm centre to centre are placed through the masonry and R.C.C slab, as shown in figure. The pipes are brought upto plinth level and filled with sand. A plug is provided at the plinth level. These piles are inspected periodically if required.

Fig 12

2 Pier foundation (Fig 13)


Fig 13

SEC. X - X
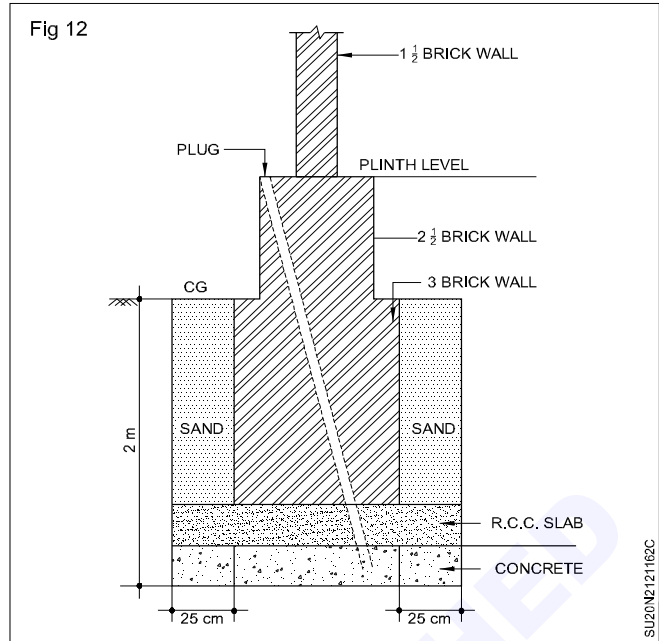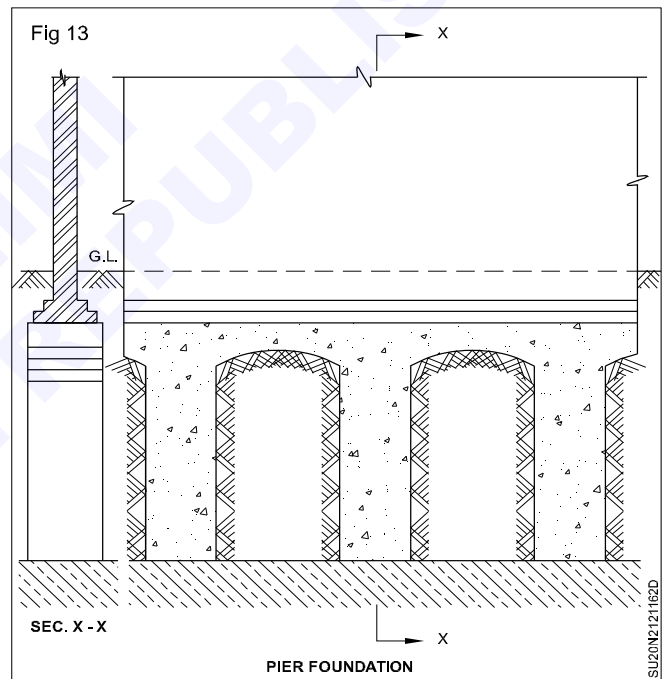
PIER FOUNDATION

When a heavy loaded building is situated in a sandy soil, black cotton soil or soft soil, over lying hard bed at reasonable depth pier foundation are sometimes used to transfer the load the building to the hard bed below. This method consist in sinking vertical shaft upto hard bed and filling them with concrete.

The diameter of the shaft and the centre to centre spacing depend upon the loading condition, the nature of soil and depth at which hard bed is situated. The diameter or horizontal dimension should be less than 1/12th its height. To prevent the side earth from falling in the side, the shaft is sometimes lined with timber. The timber lining is removed during the filling up the shaft with concrete. The shaft are connected to each other by an arch or reinforced cement concrete or steel grillage cap.

3 Under reamed pile foundation

These piles are developed for serving as foundation for black cotton soil. An under reamed pile is a bored concrete pile having one or more bulbs in its lower portion. The bulbs or under-reams are formed by under reaming tools. The foundation will be anchored to the ground, and it would not move with the movement of the soil. The diameter of a under-reamed pile is about 3m-8m. The spacing of pile may vary from 2m-4m. The safe load for an under reamed pile varies from 20 to 40 tonne (Fig 14).

Fig 14

BULB OR UNDER REAMES
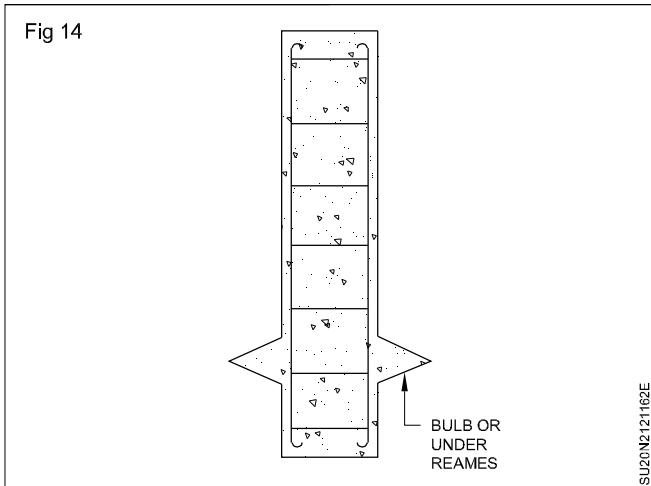
The load carrying capacity of under reamed pile can be increased by adopting pile of large diameter or by extending the length of pile, or by making more bulb at the base. A single under-reamed pile has only one bulb at the bottom. When the no.of bulbs at the base (2 or more) it is known as multi under-reamed piles. The vertical distance of bulbs varies from 1.25 to 1.50 times the diameter of the bulb. The under-reamed pile is selected by the consideration of pile length, stem diameter, bulb diameter, a no of bulbs. In black cotton soil the bulb of under-reamed piles, not only increase the load bearing capacity, but also provide anchorage against uplifts.

Foundation on slopping ground or stepped foundation (Fig 15)

1   When the ground is sloping it becomes an-economical to provides foundation at same level along the length of the wall, in such cases stepped or benching foundation may be provided. The foundation trench is excavated in the form of steps, if possible all the steps should be of equal depth and length. Overlap between two layer of foundation concrete should be atleast equal to the depth of foundation concrete. A minimum depth of 1m for soil and 60cm for rock should be provided between sloping surface and the lower edge of the footing.

Coffer dam and caisson

Coffer dam

Is defined as a temporary structure which is constructed so as to remove water and soil from an area and make it possible to carry out the construction work under reasonably dry condition.

Fig 15

G.F. LEVEL

G.L

OVER LAP

PILE

STEPPED FOUNDATION
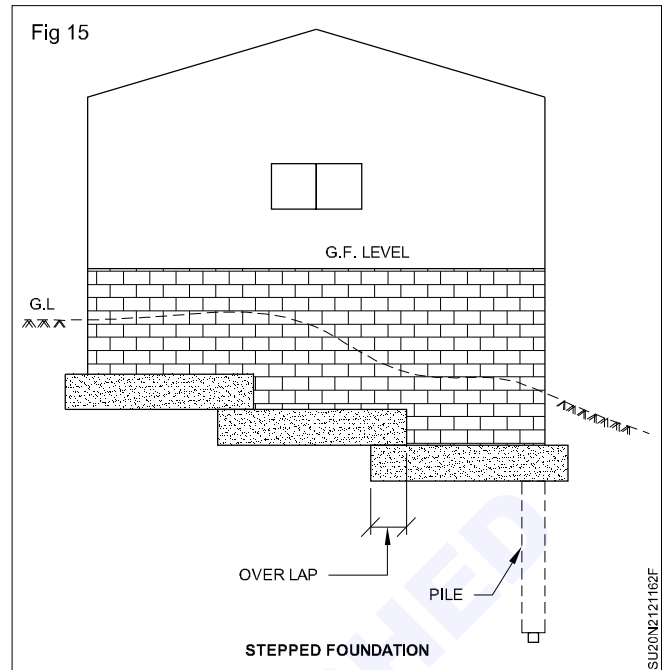
Following are the uses of coffer dam

1   To facilitate the pile driving operation

2   To place grillage and raft foundation.

3   To construct foundation for pier and abutment of bridge, dams etc.

4   To provide working platform for the foundation of buildings when water is met with in it.

5   To provide space for carrying out the foundation work without disturbing or damaging the adjoining structure such as building, pipe line etc.

Caisson: It is defined as a structure which is sunk through ground or water to exclude the water and semifluid material during the process of excavation of foundation and which subsequently becomes an integral part of the sub-structure.

Following are the use of the caisson

1   To reach the hard bearing stratum for transferring the load coming on supports for bridge pier

2   To serve as an impervious core wall of earth dams. when place adjacent to it.

3   To provide on access to a deep shaft or tunnel.

4   To provide an encloser below water level for installing machinery, pump etc.

The main difference between coffer dam and caisson is that the coffer dam is a temporary structure, while caisson forms the part of the permanent work.

Procedure of prepare a detailed estimate

Objectives: At the end of this lesson you shall be able to
• state the method of building estimate
• state the separate or individual wall method
• state the centre line method.

Methods of building estimate

The dimensions, length, breadth and height or depth are to be taken out from the drawing – Plan, Elevation and Section. From the study of the drawings, the building is to be imagined and pictured in the mind and the dimensions are to be taken out correctly. There is no hard and fast rule for finding out dimensions from the drawing but the dimensions are to be taken out accurately. Junctions of wall at the corners and at the meeting points of the walls require special attention.

For symmetrical foundation which is the usual case, earth work in excavation in foundation, foundation concrete, brickwork in foundation and plinth, and brickwork in superstructure may be estimated by either of the following two methods.

Method I

Separate or individual wall method – In this method, measure of find out the external length of walls running in the longitudinal direction generally the long walls out-to-out, and the internal lengths of walls running in the transverse direction in-to-in i.e. of cross or short walls, in-to-in, and calculate quantities multiplying the length by the breadth and the height of wall. The same rule applies to the excavation in foundation, to concrete in foundation and to masonry. Care should be taken to not the difference in dimensions at different height due to offset, or footings. It is convenient to imagine plans at different level of heights as foundation trench plan, foundation concrete plans of each footing, etc. and dealing each plan or part separately.

The simple method to take the long walls and short or cross walls separately and to find out the centre to centre lengths to long walls and short walls from the plan. For symmetrical footing on either sides, the centre line remains same for super structure and for foundation and plinth.

For long walls add to the centre length one breadth of wall, which gives the length of the wall out-to-out, multiply this length by the breadth and the height and get the quantities. Thus for finding the quantities of earthwork in excavation, for length of the trench out-to-out add to the centre length one breadth of foundation. Adopt the same process for foundation concrete, and for each footing. It should be noted that each footing is to be taken separately and the breadth of the particular footing is to be added to the centre length.

$$\begin{pmatrix} \text{Long wall length} \\ \text{ou-to-out} \end{pmatrix} = (\text{Centre to centre length})$$

+ (half breadth on one side)

+ (half breadth on the other side)

= (Centre to centre length) + (One breadth)

For short or cross walls subtract (instead of adding) from the centre length one breadth of walls, which gives the length in-to-in, and repeat the same process as for the long walls, subtracting one breadth instead of adding.

$$\begin{pmatrix} \text{Short wall length} \\ \text{in} - \text{to} - \text{in} \end{pmatrix} = (\text{Centre to centre length}) \\ - (\text{one breadth})$$

That is, in case of long wall add one breadth and incase of short wall subtract one breadth from the centre length to get the corresponding lengths.

This method is simple and accurate and there is no chance of any mistake. This method may be named as LONG WALL and SHORT WALL method or general method.

Method II

Centre line method: In this method known as centre line method sum-total length of centre lines of walls, long and short, has to be found out. Find the total length of centre lines of walls, of same type, long and short having same type of foundations and footings and then find the quantities by multiplying the total centre length by the respective breadth and the height. In this method, the length will remain same for excavation in foundation, for concrete in foundation, for all footings and for superstructure (with slight difference when there are cross walls or number of junctions). This method is quick but requires special attention and consideration at the junctions, meeting points of partition or cross walls, etc.

Centre line length of each items = c/c length - no. of junctions x half width of each item.

This centre line then multiplied by the width and height gives the quantity of each items.

For rectangular, circular polygonal (hexagonal, octogonal, etc.) buildings having no inter or cross walls, this method is quite simple. For buildings having cross or partition walls, for every junction or partition or cross walls with main wall, special consideration shall have to be made to find the correct quantity. For each junction half breadth of respective item or footing is to be deducted from the total centre length. Thus in the case of a building with one partition wall or cross wall having two junctions, for earthwork in foundation trench and foundation concrete deduct one breadth of trench or concrete from the total centre length (half breadth for one junction and one breadth (2 x ½ = one for two junctions). For footings, similarly

deduct one breadth of footing for two junctions from the total centre length, and so on. If two walls come from opposite directions and meet a wall at the same point, then there will be two junctions.

For building having different types of walls, each set of walls shall have to be dealt separately. Find the total centre length of all walls of one type and proceed in the same manner as described above. Similarly find the total centre length of walls of second type and deal this separately, and so on.

Knowledge of R.C.C works and building material

Objectives: At the end of this lesson you shall be able to
• **define R.C.C**
• **state advantages of R.C.C**
• **list out materials used in R.C.C**
• **explain grade of cement**
• **explain reinforcement materials**
• **explain bending of bars**
• **state the testing of steel reinforcement**
• **calculate bending moment and shear force.**

Introduction: Concrete may be defined as a building material obtained by mixing cement, aggregates and water in a suitable proportion which when allowed to cure, becomes hard like a stone. The proportion of ingredients varies with the nature of work for which the concrete is to be used. It can be readily moulded into durable structural items of various size and shapes. This mixed concrete is strong in compression but weak in tension.

Reinforced cement concrete (R.C.C) is the above said mixture of cement concrete with addition of reinforcement in it. The plain concrete is weak in tension, so steel reinforcement is added to make it strong both in compression and tension. The resulting product of cement, aggregates, water and steel reinforcement is called reinforced cement concrete.

Definition: Concrete is a brittle material and is strong in compression. It is weak in tension, so steel is used inside concrete for strengthening and reinforcing the tensile strength of concrete. The steel must have appropriate deformations to provide strong bonds and interlocking of both materials. When completely surrounded by the hardened concrete mass in forms an integral part of the two materials, known as "reinforced concrete".

Reinforced concrete is a structural material widely used in many types of structures. It is competitive with steel if economically designed and executed.

Advantages of reinforced concrete

• Reinforced concrete also has greater compressive strength as compared to most other materials used for construction besides good in tension.

• It has better resistance to fire than steel and capable of resisting fire for a longer time.

• It has long service life with low maintenance cost.

• In some types of structures, such as dams, piers and footings, it is the most economical structural material.

• It can be cast to take the shape required, making it widely used in pre - cast structural components.

• It yields rigid members with in minimum apparent deflection.

• Yield strength of steel is about 15 times the compressive strength of structural concrete and well over 100 times its tensile strength.

• By using steel, cross sectional dimensions of structural members can be reduced e.g in lower floor columns.

• Less skilled labour is required for erection of structures as compared to other materials such as structural steel.

Disadvantages of reinforced concrete

• It needs mixing, casting and curing, all of which affect the final strength of concrete.

• The cost of the forms used to cast concrete is relatively high.

• It has low compressive strength as compared to steel (the ratio is about 1:10 depending on material) which leads to large sections in columns/beams of multistory buildings cracks develop in concrete due to shrinkage and the application of live loads.

Materials used in R.C.C

1 Cement

Generally any of the following cements is used for R.C.C

a Ordinary or low heat portland cement conforming to IS: 269.

b Rapid hardening portland cements conforming to IS: 8041.

c Portland slag cement conforming to IS: 455.

d Portland pozzolona cement conforming to IS: 1489.

e High strength ordinary portland cement conforming to IS: 8112.

f Hydrophobic cements conforming to IS: 8043.

g High alumina cements conforming to IS: 6452.

h Super sulphated cement conforming to IS: 6909.

2 Fine aggregate (SAND)

The aggregate which passes through IS sieve no.480 is called fine aggregate. The particle size of this aggregate does not exceed 4.75 mm. Fine particles passing though the sieve no. IS: 15 should not exceed 8%. Sand and sieved quarry dust are usually using as fine aggregate. It should be free from silt clay, salts and other organic matter and it should be conforming to IS: 383.

3 Coarse aggregate (KANKAR) - (METAL)

The aggregate, which is retained over, sieve no. IS: 480 are called coarse aggregate. The size of this aggregate depends upon the type and nature of work. It should be free from clay, clods and other organic matter. It should not have glossy surface. It should not be soft, porous or flaky. It should not absorb more than 5% of water by weight when immersed in 24 hours and in all aspects it should be conforming to IS: 383.

4 Water

Water used for making concrete should be free from dirt, organic impurities, sulphur contamination and chlorides which cause efflorescence. The clear water used for drinking purpose (IS: 14543) should be used. The pH value of water should be between 6 and 8. Mixing or using of concrete with seawater is not recommended because of presence of harmful salts in seawater.

5 Reinforcement (STEEL)

Reinforcement shall be any of the following

- Mild steel and medium tensile steel bars conforming to IS: 432.

- Hot rolled deformed bars conforming to IS: 1139.

- Cold twisted bars conforming to IS: 1786.

- Hard - drawn steel wire fabric conforming to IS: 1566.

- Rolled steel made from structural steel conforming to IS: 226.

- All reinforcement shall be free from mill scales, loose rust and coats of paints, oil, mud or other coatings, which destroy or reduce bond.

Grades of concrete: The concrete shall be in grades M5, M7.5, M10, M15, M20,M25,M30,M35 and M40. In the designation of concrete grade, letter M refers to the mix and the number to the specified characteristic compressive strength of 15 cm cube after 28 days, expressed in N/mm^2. Grades of concrete lower than M15 shall not be used in R.C.C.

Grade of cement: For engineering purposes, there are many types of cement but in general, 'ordinary portland cement' (OPC) which is available in three grades should be used for house construction.

33 grade ordinary portland cement: This ordinary 'portland' cement is used widely in the country. It is more suitable cement for masonry and general concrete works where the members are not taken to very high stresses. It is not suitable where 'sulphate' is in the soil or in the ground water.

Nominal Proportion for different Grades

| Grade | Proportion | | | Quantity of water in litres per 50 kg of cement | Mix proportion cement: FA: CA |
	Cement	Fine aggregate	Coarse aggregate		
M5	1	5	10	60	1:5:10
M7.5	1	4	8	45	1:4:8
M10	1	3	6	34	1:3:6
M15	1	2	4	32	1:3:4
M20	1	1.5	3	30	1:1:5:3
M25	1	1	2	28	1:1:2

43 Grade ordinary portland cement: 43 grades of cement are used where highly reached strength in 1 to 28 days range is required. These days the 'structural engineers' propose this cements mainly for RCC works where each structural member takes high tensile stress.

53 grade ordinary portland cement: 53 grades of cement are used where high early strength in 1 to 28 days between is required. These days 'structural engineers' propose these cements mainly for RCC works where a member takes high tensile stress.

Caution in the use of 53 grade cement in construction: The strength of 53 grade cement does not increase much after 28th day because of early gain while 33 grade cement continues to gain strength after 28th day.

In addition, due to faster hydration process, the concrete releases heat of hydration at much faster rate initially and release of heat is the highest in case of 53 grade. The heat of hydration being higher, the availability of micro - cracking of concrete is much greater. Thus during initial setting period of concrete, the higher heat of hydration can lead to the damage of micro - cracking within the concrete which may not be visible at surface.

This cracking is different from shrinkage or cracks which occur due to faster dryness of concrete in windy conditions. The situation can be worse when we tend to increase the quantity of the cement in concrete with a belief that such increments are better for both strength and durability of concrete.

Thus it is very essential to be very careful in advance that higher grade cement specially grade 53 should be used only where such use is warranted for making the concrete of higher strength and also where precautions are taken to relieve the higher heat of hydration through chilling of aggregates. (Grade refers to the strength of cement at 28 days, when tested as per IS: 4031 - 1988). If the 28 days strength is less than $33N/mm^2$, it is called 33 grade cement. If the 28 days strength lies between 33 to 43 N/mm^2, it is called 43 grade cement. If the 28 days strength is lies between 43 to 53 N/mm^2, it is called 53 grade cement.

Reinforcement: The material which can be used as reinforcement in R.C.C. work should have the following characteristics:

1 It should be able to develop perfect bond with concrete.

2 Its co - efficient of thermal expansion should be nearly same as that of concrete.

3 It should have high tensile strength.

4 Concrete should not produce any harmful effect on the embedded material.

5 It should be easy to cut, bend, bind or weld.

6 It should be easily available.

It is seen that steel meets all the above requirements and as such it is the only material which is used on large scale in R.C.C works.

The various types of steel that are commonly used for making different forms of reinforcement are mild steel, medium tensile steel, high tensile steel and hard drawn steel. These differ from each other in their chemical composition and other properties like, ultimate tensile strength, yield points etc. (Fig 1)

Fig 1
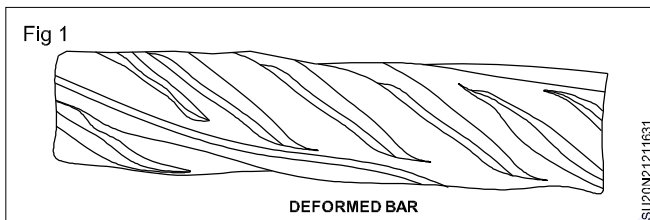
DEFORMED BAR

The various forms in which steel is used as reinforcement in R.C.C work are: round bars, deformed bars (pipe), twisted bars, square bars and flats. Sometimes expanded metal fabric or fabric made by welding or weaving steel wire in the form of oblong or square mesh are also used as reinforcement in slabs, shells and concrete roads. For works of large dimensions like massive foundations, etc., sections like rolled steel beams, channels or angle iron are also used as reinforcement.

Mild and medium tensile steel bars of round section are most commonly used in R.C.C work. The diameter of round bars (in mm.) used in normal building work are:

6,8,10,12,16,18,20,22,25,28,32,36 and 40

Bars of greater diameter, i.e., 45 mm. and 50 mm., are only used in exceptionally heavy foundations, large girders, or counterforts etc.

With the introduction of deformed bars and twisted bars, the use of plain round bars is gradually declining. Deformed bars or high yield strength deformed bars (HYSD) are furnished with lugs, ribs or other form of surface deformations for the purpose of increasing their bond strength with concrete.

It is seen that the process of twisting a plain or a deformed bar results in the following improvements in its properties:

• Considerable increase in yield stress.

• Increase in tensile strength.

• Increase in bond strength.

Twisted plain or deformed bars not only have high yield stress but also have bond strength which is 40% more than that of plain round bars. On account of increased bond strength such bars do not need end hooks, and require reduced length for overlaps etc. thereby effecting reduction in the cost of reinforcement and labour.

Permissible stresses in reinforcement: The permissible stresses in steel reinforcement as per IS: 456 - 2000 are given in table 1.

HYSD bars having yield stress (0.2% proof stress) equal to 415 N/mm² and permissible tensile stress equal to 230 N/mm² are exceedingly being used in R.C.C. work. These bars are also commonly known as Fe 415 HYSD bars.

In case of structures requiring use of still higher tensile strength of reinforcing bars, another form of HYSD bars known as Fe 500 HYSD are used. These bars have a yield stress equal to 500 N/mm² and have permissible tensile stress equal to 275 N/mm².

It is observed that HYSD bars when used in combination with high strength concrete i.e. M20 and above prove to be more economical.

Characteristic strength of steel reinforcement: The term characteristic strength of steel reinforcement means that value of the strength of steel below which not more than 5% of the test results are expected to fall. The characteristic strength of different type of steel reinforcement or (f_y) is taken as the value of the minimum yield stress (or 0.2% proof stress) for the type or grade of steel used in the manufacture of the reinforcement. The value of (f_y) or the characteristic strength for three commonly used type of reinforcing bars are given in table 2.

Note 1: For high yield strength deformed bars of grade Fe 500, the permissible stress in direct tension and flexural tension shall be 0.55 f_y. The permissible stresses for shear and compression reinforcement shall be as for grade Fe 415.

Note 2: For welded wire fabric conforming to IS: 1566 - 1967 the permissible value in tension σ_{st} is 230 N/mm².

Note 3: The yield stress of steels for which there is no clearly defined yield point should be taken to be 0.2 percent proof stress.

Note 4: When mild steel conforming to grade II of IS: 432 (part I) - 1966 is used, the permissible stresses shall be 90 percent of the permissible stresses in column 2 above or if the design details have already been worked out on the basis of mild steel conforming to grade I of IS 432 (part I) - 1966, the area of reinforcement shall be increased by 10 percent of that required for grade I steel.

Table 1 - Permissible stresses in steel reinforcement

Types of stress in steel reinforcement	Permissible stresses		
	Mild steel bars conformating to grade I of IS:432 (Part I) - 1966 or deformed mild steel bars conforming to IS:1139 - 1966	Medium tensile steel conforming to IS: 432 (part I) 1966 or deformed medium tensile steel bars conforming to IS: 1139 - 1966	High yield strength deformed bars conforming to IS: 1139 - 1966 or IS: 1786 - 1979 (Grade Fe 415)
1	2	3	4
1 Tension (σ_{st} or σ_{sc}) a Upto and including 20 mm b Over 20 mm	140 N/mm^2 130 N/mm^2	Half the guaranteed yield stress subject to a maximum of 190 N/mm^2	230 N/mm^2 230 N/mm^2
2 Compression in column bars (σ_{sc})	130 N/mm^2	130 N/mm^2	
3 Compression in bars in a beam or slab when compressive resistance of concrete is taken into account.	The calculated compressive stress on the surrounding concrete multiplied by 1.5 times the modular ratio or σ_{sc} which ever is lower.		
4 Compression in bars in a beam or slab where the compressive resistance of concrete is not taken into account. a Upto and including 20 mm. b Over 20 mm.	140N/mm^2 130N/mm^2	Half the guaranteed yield stress subject to a maximum of 190 N/mm^2	190 N/mm^2 190 N/mm^2 190 N/mm^2

Table 2 - Characteristic strength of steel reinforcement

S.No.	Types of reinforcement	Yield stress or 0.2% proof stress	Characteristic strength (F_y)	Permissible tensile strength σ_{st}
1	Mild steel bars conforming to grade 1 of IS:432 (Part 1) or de-formed m.s. bars conforming to IS: 1139.	250 N/mm^2 (average)	250 N/mm^2	140 N/mm^2 (for bars upto 20 mm ϕ) 130 N/mm^2 (for bars over 20 mm ϕ)
2	High yield strength deformed bars (HYSD bars) conforming to IS: 1109 or grade Fe 415 of IS: 1786.	415 N/mm^2	415 N/mm^2	230 N/mm^2
3	High yield strength deformed bars conforming to grade Fe 500 of IS:1786.	500 N/mm^2	500 N/mm^2	275 N/mm^2

Handling of reinforcement at site

Whatever be the magnitude of R.C.C. work, it is necessary to prepare a bar bending schedule based on the structural drawing prior to start of handling reinforcement at site. Bar bending schedule is a descriptive list containing details regarding the exact bending shape, dimension and diameter of each and every bar together with the number of bars of each shape.

Bars are cut to the desired lengths and then bent cold in accordance with the details given in bar bending schedule. Before placing the bars in position in the formwork it is necessary to ensure that the reinforcement is clean and free from, loose mill scale, loose rust, oil or other coating. This precaution is necessary to meet the requirement of good bond between concrete and steel for monolithic behaviour.

The reinforcement should be placed accurately in position and maintained in position by tieing bars at junction with binding wire or by welding. To ensure proper cover to reinforcement, small precast cover blocks made out of cement mortar are used. The cover blocks are inserted below the reinforcement mesh and tied to it with the help of binding wire, prior to concreting. In addition, precaution should be taken to prevent the displacement or distortion of reinforcement during concreting.

Reinforcement shall be any of the following:

a   Mild steel and medium tensile steel bars conforming to IS: 432.

b   Hot rolled deformed bars conforming to IS: 1139.

c   Cold twisted bars conforming to IS:1786.

d   Hard - drawn steel wire fabric conforming to IS: 1566.

e   Rolled steel made from structural steel conforming to IS: 226.

f   All reinforcement shall be free from mill scales, loose rust and coats of paints, oil, mud or other coatings, which destroy or reduce bond.
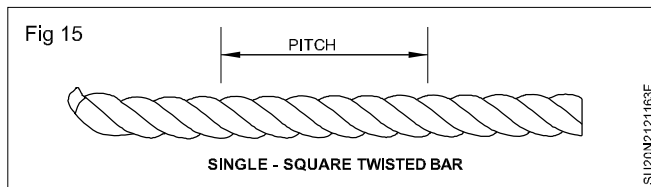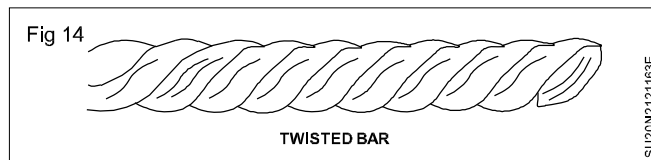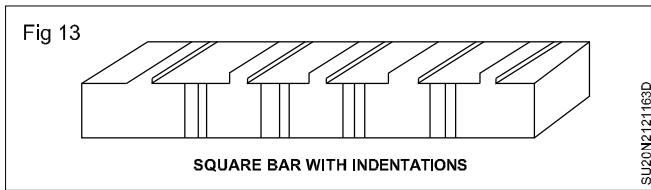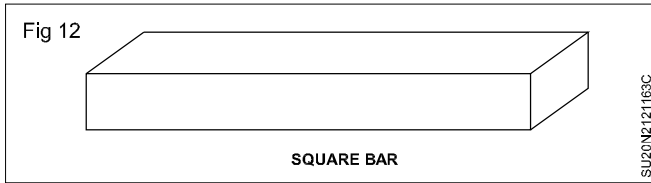
Types of reinforcement steel (Figs 2 to 16)

In R.C.C works steel reinforcement may be used in the form of plain round bars deformed bars, twisted bars, and square bars or flats. According to chemical composition and other properties like yield point, ultimate strength etc. steel is divided into.

1   Mild steel (Fe 250)

Grade -I (IS:432)

Grade -II (IS:432)

2   Medium tensile steel (IS:432)

3   High yield strength deformed bars (Fe 415) (IS: 1139).

Twisted bars are nothing but mild steel bars whose quality has been improved by various processes of cold working and have improved its yield stress is about 50% more than that for ordinary mild steel bars. The ribs, legs and deformations on their surface increase the bond strength.
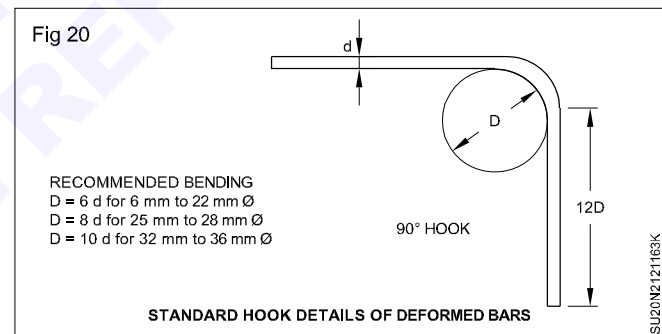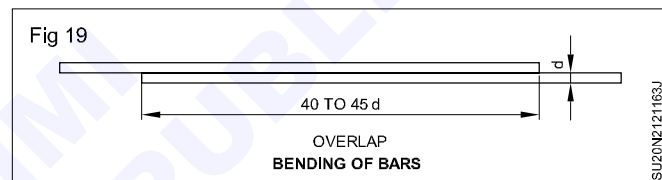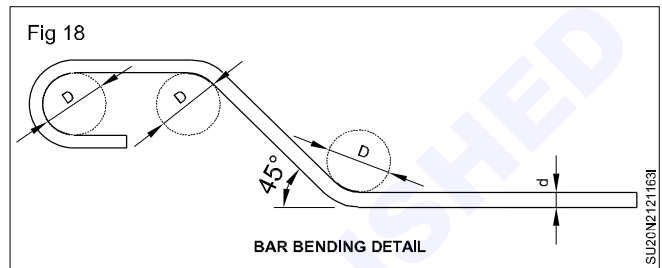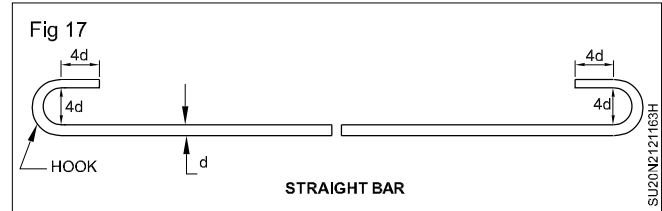

Fig 2 — TWIN TWISTED BARS

Fig 3 — RIBBED TORSTEEL

Fig 4 — GRIP BAR

Fig 5 — TRSTRONG BAR 1 & 2

Fig 6 — TISCON 42 , 12 MM , 2 RIBS

Fig 7 — TISCON 42 , 12 MM , 4 RIBS

Fig 8 — TISCON 42 , 20 MM , 4 RIBS

Fig 9 — STAR MARKS — TISCON 50 , 12 MM , 2 RIBS

Fig 10 — STAR MARKS — TISCON 50 , 20 MM , 4 RIBS

Fig 11 — CIRCULAR BAR

Fig 12 — SQUARE BAR

Fig 13 — SQUARE BAR WITH INDENTATIONS

Fig 14 — TWISTED BAR

Fig 15 — SINGLE - SQUARE TWISTED BAR

Fig 16 — TWIN TWISTED BAR
TWISTED BARS

Reinforced materials

1 **Deformed bars:** There are bars whose surface is roughened to increase the resistance to slipping between the bar and the concrete. These have same types of corrugation or projections on their surface which check the slipping. (Fig 1)

2 **Twisted bars:** The quality of steel bars can be improved by the use of various processes or working. One of these methods is if twisting of bars. Twisting of bars may be singly or doubly is shown in figure. During the double as twin twisting the length of combined bar will be shortened. The effects of twisting are as follows"

   i   A considerable increase in the yield strength of bar.

   ii A slight increase in ultimate tensile stress.

   iii Considerable decrease in the ultimate elongation.

Do the yield stress is increased by 50% or more and thus the working stresses are also increased proportionality and it results by 33% or so. The steel used as reinforcement shall conform with IS:456.

I.S. Codes

Indian standard codes have been prepared to be used for the construction of various structures. On such code IS: 456 which deals with construction of reinforced cement concrete structures. Various specification to be adopted for steel and concrete are laid down in the code for guidance. While designing the R.C.C structures these codes are followed.

Bending of bars

In case round bars are used as reinforcement in concrete, hooks at the ends are provided. Provision of hooks, bends and laps etc. are shown in figures. (Figs 17 to 20)

Fig 17 — STRAIGHT BAR

Fig 18 — BAR BENDING DETAIL

Fig 19 — OVERLAP
BENDING OF BARS

Fig 20

RECOMMENDED BENDING
D = 6 d for 6 mm to 22 mm Ø
D = 8 d for 25 mm to 28 mm Ø
D = 10 d for 32 mm to 36 mm Ø

90° HOOK

STANDARD HOOK DETAILS OF DEFORMED BARS

Cover in reinforcement

The reinforcement in shape of bars is embedded in concrete so that it is fully covered. Minimum cover required for various structures as per IS: 456 - 1962 is as given below:

Clear cover at the ends of bars = Not less than twice the dia of bars but minimum 25 mm.

Clear cover of slabs = 15 mm or dia of bar whichever is more

Clear cover of beams = 25 mm or dia of bar whichever is more

Clear cover for columns = 40 mm or dia of longitudinal bar whichever is more

Clear cover for foundation slabs and beams = 50 mm.

When surfaces of concrete members are exposed to the action of harmful chemicals, acids, vapours, sulphurous smoke etc. the cover thickness may be increased.

Symbols and conventions

a Abbreviations relating to shape of bars: These are to indicate the general shape of reinforcing bars.

Alt	Alternate bar
Bt	Bent bar
B	Bottom bar
T	Top bar
St	Straight bar
Stp	Stirrup
Sp	Spiral
Ct	Column tie
Min	Minimum
Max	Maximum

b Abbreviations relating to structural members: These are used in the key plan for easy identification of members.

Bm or B	Beam (S)
Col	Column (S)
Fg	Footing (S)
GR	Girder (S)
JT	Joint (S)
LL	Lintel (S)
LB	Lintel beam (S)
Sb or S	Slab (S)
WL	Longitudinal wall
Wx	Cross wall
£	Centre line

c Symbols for type and size of reinforcement: These are used distinguishing between plain, square or deformed bars used in a structure.

φ Plain round bar or diameter of plain round bar

☐ Plain square bar or side of plain square bar

Deformed bar, or square twisted bar or its nominal size

d Symbols relating to position and direction of reinforcement:

These indicate the limits and direction of particular bars used in structural elements.

EW	Each way
@	Spacing centre to centre
	Limit of area covered by bars
	Direction in witch bars extend

e Examples denoting reinforcement: These form the most important symbols used against each type of reinforcement indicated in a drawing.

16 @ 150

(16 mm DIA PLAIN BARS SPACED AT 150mm CENTRE TO CENTRE)

20@ 250

(20mm DIA DEFORMED BARS SPACED AT

250mm C.C)

f Some drawing conventions in R.C.C detailing

Each symbol is to be pointed by an arrow and the details of bars denoted as given in (e).

Testing of steel reinforcement

Steel reinforcement shall be produced under a permanent system of routine inspection and testing.
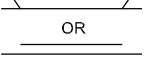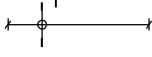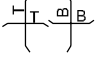
The testing is done to determine the yield point, ultimate strength, percent elongation, bend and weight per meter.

The universal tensile test is to determine the strength of materials. During the test, the specimen, elongation reduction and applied load are measured, tensile stresses and strain are calculated from the result. After the material break, the final length and cross sectional area of specimen is used to calculate the percentage of elongation and percentage of reduction.

The rate of testing shall be as follows:

- For chemical composition, one analysis per test unit. The chemical composition (cast analysis) of the steel reinforcing bar shall have been determined by the QA manufacturer. (Quality assessment manufactures) (Fig 21)

Fig 21

THIN	CONCRETE LINE
— — THIN — —	UNEXPOSED CONCRETE OR MASONRY WALL LINE
THICK	REINFORCEMENT
— — THICK — —	REINFORCEMENT IN DIFFERENT LAYER
	BAR BENT AT RIGHT ANGLE TO THE PAPER
	BAR WITH HOOKS
	BAR WITH 90 BEND
OR	BARS SHOWN SEPARATED
	WELDED FABRIC OR WIRE MESH ON PLAN
	BUILDING BAR ENDMARKING INDICATES THE NUMBER OF BARS
	TYPICAL BAR IN A SET WITHIN A LENGTH
	TOP & BOTTOM LAYER OF REINF BARS OF A SLAB IN PLAN
	REINFORCEMENT ON NEAR FACE & FACE OF A WALL IN ELEVATION

CONCRETE DETAILING

To create contour lines

1 In Display Manager, right-click a surface layer and select Create Contour Layer.

2 In the Generate Contour dialog box, enter a name for the new Display Manager layer that will contain the contour lines.

3 In the Contour Elevation interval list, select the differences in elevation between contour lines for example 10, 20 or 50.

4 Select the units (meters or feet) used to measure the elevation in your surface.

5 In the Major Contour Every list, select the interval between major (bold) contour lines. For example, if you choose 5, every fifth contour line will be bolded.

6 To label the major contour lines with the elevation they represent, select the Label. The Elevation check box.

7 For Create Contour As, select the type of feature to use when creating contour lines. (polyline or polygon)

8 For Save Contours into Filename, enter a name for the new SDF file that will store your contour line features.

9 Click OK.

The new contour line features are added to your map. They are placed on a new Display Manager layer with the layer name you specified and stored in an SDF file.

To edit the line styles and labels used for the contour lines

1 In Display Manager, click the contour layer and click Style in the tool strip.

2 In the Style Editor, modify the line styles and labels, as you would for other features.

To delete a layer of contour lines

1 In Display Manager, select the contour layer.

2 Click Remove

Contours are graphical illustrations of surface elevation changes. You can create a surface from contours drawn as 2D or 9D polylines where each unique polyline contails points that are all at the same elevation.

The following illustrations show polyline data (Fig 12) that has been added to a surface (Fig 13) whose style is set to display contours, traingles and the surface boundary.