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DCC20063 ENGINEERING SURVEY VOL 1

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ENGINEERING SURVEY

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"This book is dedicated to all students and lecturers of Polytechnic Malaysia"

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SYNOPSIS

This book is mainly about engineering survey focusing on chapter related to introduction to engineering survey, area and volume. It also includes tutorial questions to assess the understanding of students in the particular topics.

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TOPIC 1:INTRODUCTION TO SURVEYING

1.0 Introduction

Surveying is one of the oldest arts practiced by man. History reveals that the principles and practices of surveying were used, consciously or unconsciously.

In a more general sense it can be regarded as discipline which include all methods for measuring and collecting information about the physical earth and our environment, processing that information and distributing a variety result to a wide range of clients.

Required prior to and during the planning and construction of buildings, dams, highways, railways, bridges, canals, tunnels, drainage works, water supply and sewerage systems.

Surveying is the starting point for any project or constructional scheme under consideration. Details of the proposed work are plotted from the field notes.

1.1 SURVEYING

It is defined as an art to determine the relative positions of points on, above or beneath the surface of the earth, with respect to each other, by measurements of horizontal and vertical distances, angles and directions.

The purpose of surveying is to determine the dimensions and contours of any part of the earth's surface, to prepare a plan or map, establish boundaries of the land, measure area and volume, and select suitable site for an engineering project.

Both plans and maps are the graphical representations of the features on a horizontal plane. The former is large scale representation whereas the latter is small one.

1.2 CLASSIFICATION OF SURVEY

Surveying classification can be divided based on:

A. **Purpose of survey**

1. Plane Survey

i. The type of survey in which curvature of earth is not taken into account, as the survey is extend over small areas is known as the plane survey.

ii. It's called plane survey because the earth's surface is considered to be plane. The line connecting any two points will be straight line and the angle formed are also plane angles.

iii. The accuracy required for this type of is comparatively low as compare to geodetic surveying. Surveyors put the limit of $250km^2$ for plane survey.

iv. surveys are done for engineering projects on large scale such as factories, bridges, dams, location and construction of canals, highways, railways and also for establishing boundaries.

2. Geodetic Survey

i. Survey in which the curvature of the earth's surface is taken into account and a higher degree of precision is exercised in linear and angular measurements is termed as geodetic surveying.
ii. Such surveys extend over large areas. A line connecting two points is regarded as an arc.
iii. The distance between two points is corrected for the curvature and then is plotted on the plan.
iv. The angles between the intersecting lines are spherical angles. All this necessitates elaborate field work and considerable mathematical computations.
v. The geodetic surveying deals in fixing widely spaced control points, which may afterwards be used as necessary control points for fixing minor control points for plane survey.

B. Instruments used

1. Chain survey

i. When a plan is to be made for a very small open field, the field work may consist of linear measurements only.
ii. All the measurements are done with a chain and tape. However, chain survey is limited in its adaptability because of the obstacles to chain like trees and shrubs.
iii. Also, it cannot be resorted to in densely built up areas. It is recommended for plans involving the development of buildings, roads, water supply and sewerage schemes.

1.1 Chain survey

2. Traverse survey

i. When the linear measurements are done with chain and tape and the directions or angles are measured with compass or transit respectively, the survey is called traversing.
ii. In traversing, speed and accuracy of the field work is enhanced. For example, the boundaries of a field can be measured accurately by a frame work of lines along it forming an open traverse.
iii. On the other hand, in a densely populated area, the survey work can be carried out with a frame of work of lines forming a closed traverse. A traverse survey is very useful for large projects such as reservoirs and dams.

1.2 Traverse survey

3. Levelling

i. This is a method of surveying in which the relative vertical heights of the points are determined by employing a level and a graduated staff.

ii. In planning a constructional project, irrespective of its extent from a small building to a dam, it is essential to know the depth of excavation for the foundations, trenches, fillings.

iii. This can be achieved by collecting complete information regarding the relative heights of the ground by levelling.

1.3 Automatic level

4.. Plane table

i. It is a graphical method of surveying in which field work and plotting are done simultaneously. A clinometer is used in conjunction with plane table to plot the contours of the area and for filling in the details.

ii. This method of surveying is very advantageous as there is no possibility of omitting any necessary measurement, the field being in view while plotting.

iii. The details like boundaries, shore lines can be plotted exactly to their true shapes, being in view. The only disadvantage of plane tabling is that it cannot be recommended in humid climate.

1.3 BRANCHES OF SURVEYING

The work of the land surveyor can be classified into three main areas of responsibility. Firstly, the recording of measurements which allow the size and shape of the earth to be determined.

Secondly, the collection, processing and presentation of the information necessary to produce maps and plans. Thirdly, to locate on the surface of the earth the exact positions to be taken up by new roads, dams or other civil engineering works.

As a consequence of the diverse nature of the land surveyor's duties, several distinct branches of the subject have evolved.

A. Engineering survey

An important basic in all design works in civil engineering. All measurements bond to survey signs legitimately such as boundary mark, control survey mark, benchmark, triangulation monument, GPS monument which have vertical and horizontal control. Engineering survey purpose:-

i. Turnover the earth spatial data for the use of civil engineering works design.
ii. Setting out for civil engineering building structure to the fixed parameter
iii. Produce complete plan for the purposes of engineering works.

There are many types of engineering survey such as:-

i. Control survey level & vertical control survey
ii. Setting out for road, railway, piping, electricity cable
iii. Cross sectioning and profiling and contour
iv. Control deformation for construction such as building, dam, port

B. Cadastral survey

This survey is performed to determine the additional details such as boundaries of fields, houses and other property. The act those involve in land title production are: Peninsular Malaysia- Kanun Tanah Negara 1965, Sabah – Ordinan Tanah (Sabah Bab 68), Sarawak – Akta Tanah (Sarawak Bab 81).

Types of cadastral survey are:-

i. State boundaries determination, district, city
ii. Disposal of land including country land, city and village
iii. Disposal of earth soil
iv Recruitment back land to own

C. Hydrographic survey

It deals with the survey of water bodies like streams, lakes, coastal waters and consists in acquiring data to chart the shore lines of water bodies. It also determines the shape of the area underlying the water surface to assess the factors affecting navigation, water supply, subaqueous construction.

D. Topography survey

This survey is conducted to obtain data to make a map indicating inequalities of land surface by measuring elevations and to locate the natural and artificial features of the earth such as rivers, woods, and hills.

E. Photogrammetry

One of the earliest remote sensing method introduced. The operating system with special camera that assembled on flying aircraft such as airplane and helicopter. The height when visualization is dependent of the photo scale that would be produced.

Usually aerial photograph scale entailment is 1: 40000 for small scale and 1: 5000 for large scale. The usual size is 23cm x 23cm. The visualization is in monochrome or colour according to your requirement.
Measurement and aerial photograph translation carried out by using stereoscope tools and stereo plotter.

The arrangement of air photographs that was rectified with specific tools will produce photomap. Information from aerial photograph used to prepare map.

1.4 WORK METHOD IN SURVEY ENGINEERING

Basic principles of surveying consist of:-

1. To work from whole to the part
2. To fix the positions of new stations of new stations by at least two independent processes
3. To produce plan or map

Basic stages in surveying in general have three main stages:-

1. Reconnaissance survey
   i. Representation of all area
   ii. Planning for the survey work
   iii. Station marking

2. Observation and surveying work
   i. Carry out surveying work that planned
   ii. Observe all data above earth surface

3. Results from surveying work
   i. Information from surveying work
   ii. Field book, booking & calculation
   iii. Map/Plan/Plotting

1.5 SOURCE OF ERRORS

The sources of error in surveying may be classified as natural, instrumental and personal.

A. Natural errors

These results from the temperature, refraction, obstacles to measurements, magnetic declination

B. Instrumental errors

These results from the imperfect construction and adjustment of the instrument. The incorrect graduations of a steel tape and the improper adjustment of the plate levels of a transits are a few examples.

C. Personal errors

These arise from the limitations of human senses such as sight, touch and hearing.

1.6 TYPES OF ERROR

Errors in a measurement may be positive or negative. The former occurs if the measurement is too large and the latter if too small. Errors are classified as systematics error and accidental errors.

A. Systematic errors

i. These are the error which occur from well understood causes and can be reduced by adopting suitable methods

ii. A systematic error follows a definite mathematical or physical law and therefore a correction can always be determined and applied.

iii. Also known as cumulative error.

B. Accidental errors

i. These are the errors due to combination of causes and are beyond the control of surveyor.
ii. It can be plus or minus.
iii. Calibration of a chain is an example of an accidental error.

TOPIC 2 : AREA AND VOLUME

2.0 Introduction

The most construction such as route alignment (road/ highway), reservoirs (dam), railway, drainage ,soil pipe ,sewerage, main hole, tunnels, construction site, etc, will be involved area and volume.

Earthworks such as excavation, hauling, dumping, loading, moving, cutting (excavate) and filling (embankment) will involve area and volume. All this will computing the area and volume which various of shapes (irregular) and these require special attention.

2.1 Use In Civil Engineering

a) Areas and Volumes are often required in the context of **design**, eg. we might need the surface area of a lake, the area of crops, of a car park or a roof, the volume of a dam embankment or of a road cutting.

b) **Estimation** of area and volume is basic to most engineering schemes is the most significant and costly aspect of the work on which **profit** or loss may depend.

c) to enable contract **estimates** of time and **cost** to be made for proposed work.

d) to form the basis of **payment** for work carried out.

e) Area and volume may be required in connection with the **purchase or sale of land**, with the division of land or with the grading of land.

2.2. Measurement Of Areas

Areas of ground may be obtained from the plotted plan but results are only as accurate as it is possible to scale off the drawings. Accuracy is greatly increased by using the measurements taken in the field. In most surveys the area is divisible into two parts :

a) ***The rectilinear*** areas enclosed by the survey lines

b) ***The irregular areas*** of the strips between these lines and the boundary In order to calculate the area of the whole, each of these areas must be evaluated separately because each is defined by a different form of geometrical figure.

2.2.1 Rectilinear Areas

The method of evaluating the rectilinear area enclosed by survey lines depends on the method of survey.

a) Mathematical Formulae

Some important mathematical formulae shown on figure 2.1.

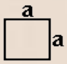
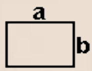
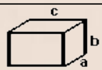
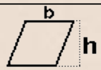
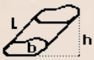
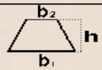
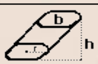
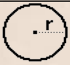
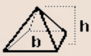
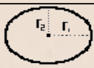
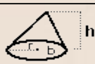
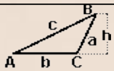
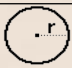
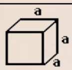
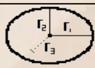
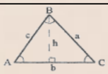
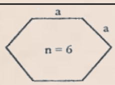
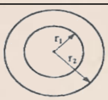
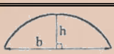
AREAS		VOLUMES	
	square = a^2		cube = a^3
	rectangle = ab		rectangular prism = a b c
	parallelogram = bh		irregular prism = b h
	trapezoid = $h/2\ (b_1 + b_2)$		cylinder = b h = πr^2 h
	circle = *pi* r^2		pyramid = (1/3) b h
	ellipse = *pi* $r_1\ r_2$		cone = (1/3) b h = 1/3 πr^2 h
	triangle = (1/2) b h		sphere = (4/3) πr^3
	SURFACE AREA cube = 6 a^2		ellipsoid = (4/3) *pi* $r_1\ r_2\ r_3$
	Triangle $\frac{1}{2}bh$ or $\frac{1}{2}a \cdot b \cdot \sin(C)$		
	Regular Poligon $\frac{1}{4} n \cdot a^2 \cdot \cot\left(\frac{180°}{n}\right)$		
	Circular ring $\pi\left(r_2^2 - r_1^2\right)$		
	Circular Sector $\frac{1}{360}\pi \cdot \Delta \cdot r^2$		
	Circular Segment $\frac{1}{2} r^2 \left(\frac{\pi\Delta}{180} - \sin\Delta\right)$		
	Parabola $\frac{2}{3}bh$		

Figure 2.1 : Mathematical Formulae

b) **Geometric Figures**

Calculating the area of each triangle by using the usual geometrical and trigonometric formulae shown on figure 2.1 bellow.

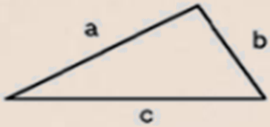
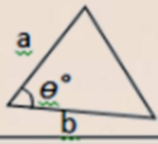
Area triangle	
	**Triangles** if s = (a + b + c) / 2 then area $Area = \sqrt{s(s-a)(s-b)(s-c)}$
	$C^2 = a^2+b^2 - 2\ ab\ Kos\ \theta°$ $Area = ½\ (a \times b)\ \sin \theta$

Figure 2.2 : Geometrical And Trigonometric Formulae

2.2.2 Irregular Areas

There are many methods whereby the area of an irregular plane surface may be found and these include:

(a) Trapezoidal rule,

(b) Mid-ordinate rule

(b) Simpson’s rule.

A) **Trapezoidal Rule**

To find the area ABCD in **Figure 2.3**, the base AD is divided into a number of equal intervals of width **d**. This can be any number, the greater the number the more accurate the result. The ordinates y_1, y_2, y_3, etc. are accurately measured. The approximation used in this rule is to assume that each strip is equal to the area of a trapezium.

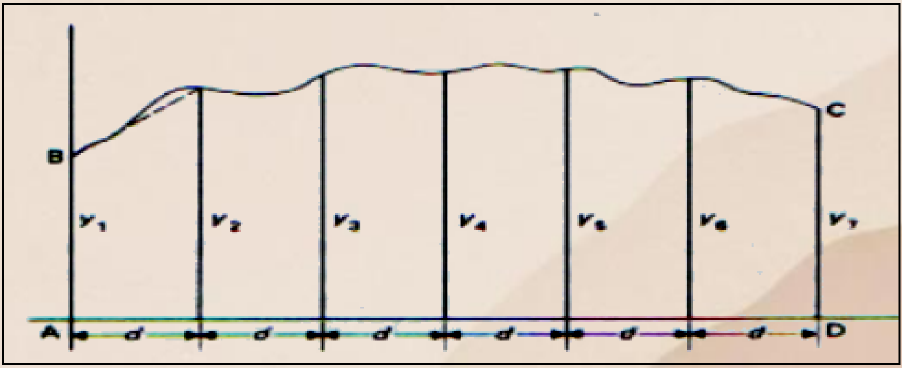


Figure 2.3 : Derive Trapezoidal Rule

Generally, the trapezoidal rule states that the area of an irregular figure is given by:

Area = (width of internal) [½ (first + last ordinate) + sum of remaining ordinates]

$$ABCD = d\left[\frac{(y_1 + y_n)}{2} + y_2 + y_3 + y_4 + y_5 + y_6 + \ldots\ldots y_{n-1}\right]$$

$$ABCD = d\left[\frac{(y_1 + y_n)}{2} + \sum y_{others}\right] or \frac{y}{2}\left[(y_1 + y_n) + 2\sum y_{others}\right]$$

B) Mid-Ordinate Rule

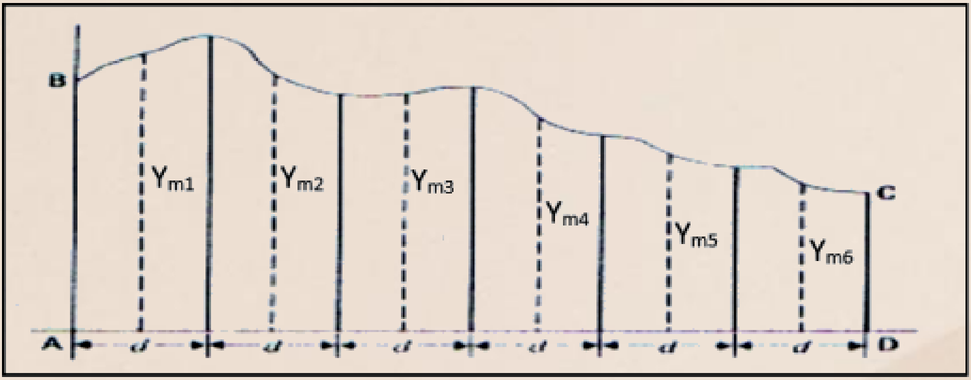


Figure 2.4 : Derive Mid-Ordinate Rule

To find the area of ABCD in **Figure 2.4** the base AD is divided into any number of equal strips of width *d*. (As with the trapezoidal rule, the greater the number of intervals used the more accurate the result.) If each strip is assumed to be a trapezium, then the average length of the two parallel sides will be given by the length of a mid-ordinate, i.e. an ordinate erected in the middle of each trapezium. This is the approximation used in the mid-ordinate rule.

The mid-ordinates are labelled Y_{m1}, $Y_{m2,}$ $Y_{m3,}$ $Y_{m4,}$ $Y_{m4,}$ $Y_{m6,}$ etc. as in **Figure.** 2.4 and each is then accurately measured. Hence the approximate area of ABCD

$V = Y_{m1}d + Y_{m2}d + Y_{m3}d + Y_{m4} + Y_{m5}d + Y_{m6}d$

$V = d\,(Y_{m1} + Y_{m2} + Y_{m3} + Y_{m4} + Y_{m4} + Y_{m6})$

$$V = d\left[\sum Y_m\right]$$

where d = (length of AD / number of mid-ordinates)

c) **Simpson's Rule**

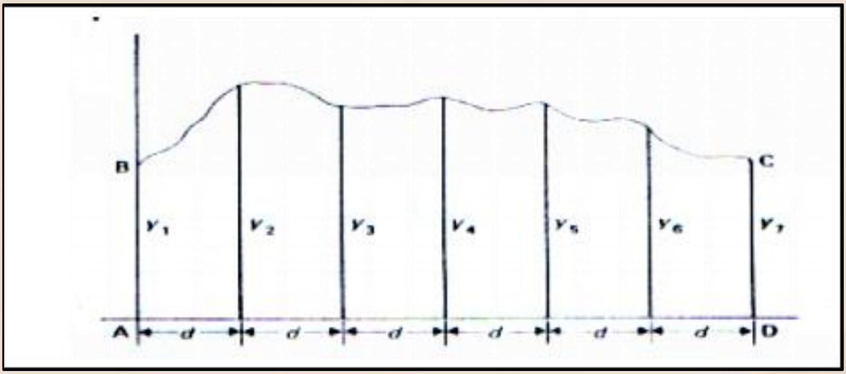


Figure 2.5 : Derive Simpson's Rule

To find the area A BCD in **Figure 2.5** the base AD must be divided into an even number of strips of equal width *d*. Thus producing an odd number of ordinates. The length of each ordinate, y_1, y_2, y_3, etc., is accurately measured. Simpson's rule states that (the area of the irregular area ABCD is given by;

$$\text{Area ABCD} = d/3\ [(y_1 + y_n) + 4(\sum y_{even}) + 2\ (\sum y_{odd})]$$

$$\text{ABCD} = d/3\ [(y_1 + y_7) + 4(y_2 + y_4 + y_6) + 2(y_3 + y_5)]$$

For Example 1

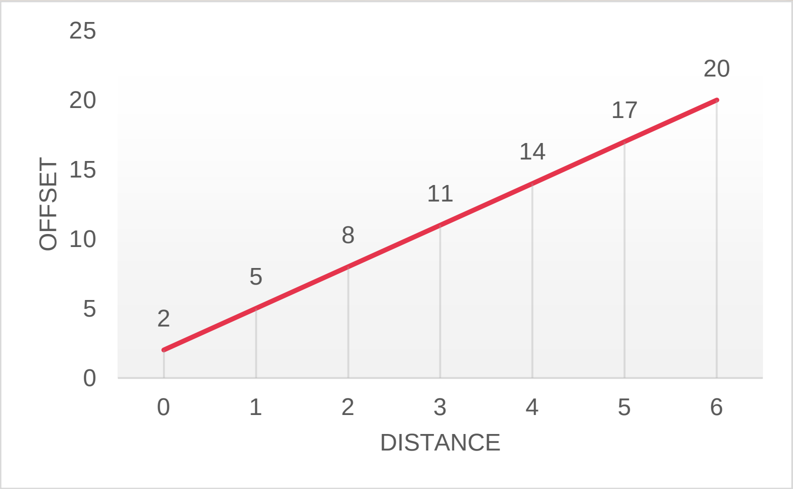
The values of the *y* ordinates of a curve and their distance *x* from the origin are given in the table below. Plot the graph and find the area under the curve by :

Distance (x)	0	1	2	3	4	5	6
Offset (y)	2	5	8	11	14	17	20

a) The trapezoidal rule
b) The mid-ordinate rule
c) Simpson's rule

Solution:

Plot graph area under curve



a) The trapezoidal rule

$$A = d\left[\frac{(y_1 + y_n)}{2} + \sum y_{others}\right]$$

$$A = 1\left[\frac{(2 + 20)}{2} + \sum (5 + 8 + 11 + 14 + 17)\right]$$

$$A = \left(\frac{22}{2}\right) + 55$$

$$A = 66$$

or

$$A = \frac{d}{2}\left[(y_1 + y_n) + 2\sum \underset{A}{y_{others}}\right]$$

$$A = \frac{d}{2}\left[(y_1 + y_n) + 2\sum \underset{A}{y_{others}}\right]$$

$$A = \frac{1}{2}\left[(2 + 20) + 2\sum (5 + 8 + 11 + 14 + 17)\right]$$

$$A = \frac{1}{2}[22 + 110]$$

$$A = 66$$

b) The mid-ordinate rule

Find y midle y_m

Y_{m1}= (2+5)/2=3.5

Y_{m2}= (5+8)/2 =6.5

Y_{m3} = (8+11)/2 =9.5

Y_{m4} = (11+14)/2 = 12.5

Y_{m5} = (14+17)/2 = 15.5

Y_{m6} = (17+20)/2 = 18.5

$$A = d[\sum y_{midle}]$$

$$A = 1\left[\sum 3.5 + 6.5 + 9.5 + 12.5 + 15.5 + 18.5\right]$$

$$A = 66$$

c) Simpson's rule

$$A = \frac{d}{3}\left[(y_1 + y_n) + 4(\sum y_{even}) + 2(\sum y_{odd})\right]$$

$$A = \frac{1}{3}[(2 + 20] + 4\sum(5 + 11 + 17) + 2\sum(8 + 14)$$

$$A = \frac{1}{3}[(22 + 132 + 44]$$

$$A = 66$$

2.3 Measurement Of Volume

Volume is a solid figure is one that occupies three dimensional space, the three dimensions beaing length, width and height.

Typical, earthwork is done in the following project such as road work, railway, irrigation project (canal and dam) and other common earthwork applications are land grading to reconfigure the topography og site or to establize slope.

In construction works, the excavation, loading, hauling and dumping of earth frequently forms a substantial part of the project.

These volumes must be calculated and depending on the shape of the site, this may be done in two w ays :

a) by **cross-sections**, generally used for long, narrow works such as roads, railways, pipelines, etc.

b) by **spot height**, generally used for small areas such as underground tanks, basements, building sites, etc

2.3.1 Cross Section

Cross-sections are established at some convenient intervals along a centre line of the works for calculating volumes of roads, pipelines, channels, dam, embankments, etc.

Volumes are calculated by relating the cross-sectional areas to the between them. In order to compute the volume of earthwork it is first necessary to evaluate the cross-sectional areas, which may be calculate either by:

a) End Area Method

b) Prismoidal Method

The graphic measure of the cross-sectional area is most often used and provides a sufficiently accurate estimate of volume, Cross section of earthwork of road in embankment or in cutting is usually in the from trapezium **(Figure 2.6)** and **Figure 2.7** show formulae are given below for the most common cross-section cases

a) Prismoidal Method

The graphic measure of the cross-sectional area is most often used and provides a sufficiently accurate estimate of volume, Cross section of earthwork of road in embankment or in cutting is usually in the from trapezium **(Figure 2.6)** and F**igure 2.7** show formulae are given below for the most common cross-section cases

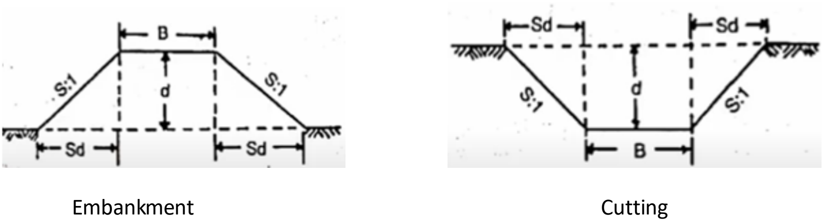


Figure 2.6 : Embankment and Cutting of Road

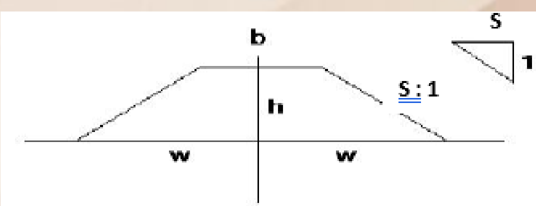
<u>Horizontal ground</u> Man-made structures usually have constant side slopes : eg (simple case) <u>One Level Section</u> 	w = b/2 + s.h Area = h . [2.w + b] / 2 = h.(b + s.h) or A= (b +sh)h

Figure 2.7 : cross-sectional area

Generally for long narrow work such as roads, railways, pipelines, etc. Cross sections are established at some convenient intervals along a centre lineof the works.
Volume are calculated by relating the cross-sectional areas to the distance between them.

Term: i - Earthworks is the movement of soil or rock from one location to anather for contruction purpose

ii - Excavated or Cuting is a volume of earth, that is remove from its natural location.

iii - Fill or embankment is excavated material that is placed and compacted in a different location **(Figure 2.8)**

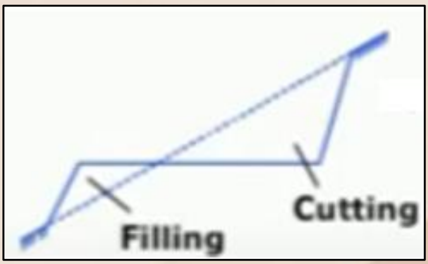


Figure 2.8: Cut and Fill

b) End Area Method

This is comparable to the trapezoidal rule for area

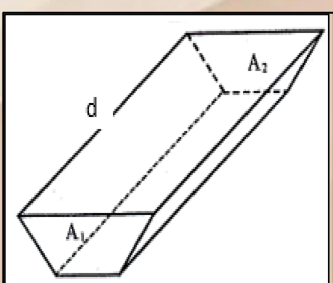


Figure 2.9

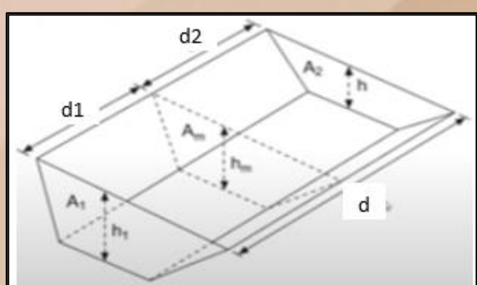


Figure 2.10

$$V = \left(\frac{A_1 + A_n}{2}\right) d$$

, d = distance between section .... (Figure 2.9)
But if many section like a trapezoidal rule

$$V = \frac{d}{2}[(A_1 + A_n) + 2(\sum A_{others})]$$

or ....(Figure 2.10)

$$V = d\left[(\frac{(A_1 + A_n)}{2}) + (\sum A_{others})\right]$$

....(Figure 2.10)

For Example 2

Compute the volume of fill between station CH1 0 + 500, whre the area $A_{1\ is}$ $100m^2$ and station CH2 0+ 600, where area $A_2 = 150m^2$

Solution :

Use End Area Method formula

$A= d[(A_{1\ +}A_2)/2]$

A = 100 [(100+200)/2]

A = 100 [150]

$A = 15000\ m^3$

A) Prismoidal Method

This is comparable to Simpson's Rule for area and is more accurate than the and area Method. Necessary to have odd number anf even of cross sections.

$$V = \frac{d}{3}\left[(A_1 + A_n) + 4(\sum A_{even}) + 2(\sum A_{odd})\right]$$

Importance , to use prismoidal method the number of section must be odd

For Example 3

Calculate, using the prismoidal formula, the cubic contents of an embankment of which the cross-sectional areas at 15m intervals are as follows :

Distance (m)	0	15	30	45	60	75	90
Area (m^2)	11	42	64	72	160	180	220

Solution,

V = 15 / 3 (11 + 220 + 4 (42 + 72 + 180) + (64 + 160))

V = 5 (231 + 1176 + 448)

V = **9275 m^3**

For Example 4

Calculate, using the end areas method, the cubic contents of the embankment of which the cross-sectional areas at 15m intervals are as follows :

Distance (m)	0	15	30	45	60	75	90
Area (m^2)	11	42	64	72	160	180	220

Solution

V = 15{[(11 + 220) / 2] + 42 + 64 + 72 + 160 + 180 }

V = **9502.5 m^3**

For Example 65

Calculate the volume of earth work in an embankment for which the Cross-Section areas at 20m interval are follow:

Diatance (m)	0	20	40	60	80	100	120
Areas (m^2)	88	62	74	18	22	28	18

Solution:

Simpson rule

$$V = \frac{d}{3}\left[(A_1 + A_n) + 4\left(\sum A_{even}\right) + 2\left(\sum A_{odd}\right)\right]$$

$$V = \frac{20}{3}[38 + 13 + 4(62 + 18 + 28) + 2(74 + 22)]$$

$$V = \frac{20}{3}[(51 + 432 + 192)]$$

$$V = \frac{20}{3} \times 675 \qquad V = \underline{4500 m^3}$$

For Example 6

An embankment of width 10m and side slope $1\ ^1/_2 : 1$ is required to be made on a ground which is level in a direction traverse to centre line. The central height at 20m intervals are as follows:

0.8, 1.2, 2.25, 2.6, 1.9, 1.4 and 0.9

Than calculate the volume of earth work according to :

a) The End Area Mathod

b) The Prismoidal Mathod

Solution :

Area = (b = sh)h

H = 0.8, 1.2, 2.25, 2.6, 1.9, 1.4 , 0.9

A1=	(10+1.5x0.8)x0.8 $\underline{8.96\ m^2}$	A5=	(10+1.5x1.9)x1.9$\underline{24.42m^2}$
A2=	(10+1.5x1.2)x1.2$\underline{14.16m^2}$	A6=	(10+1.5x1.4)x1.4$\underline{16.94m^2}$
A3=	10+1.5x2.25)x2.6$\underline{30.09m^2}$	A7=	(10+1.5x0.9)x0.9$\underline{10.22m^2}$
A4=	(10+1.5x2.6)x2.6$\underline{36.14m^2}$		

a) The End Area Method

$$V = \frac{d}{2}[(A_1 + A_n) + 2(\sum A_{others})]$$

$$V = \frac{20}{2}\left[(8.96 + 10.22) + 2\sum 14.16 + 30.09 + 36.14 + 24.42 + 16.94\right]$$

$$V = 10[19.18 + 242.10$$

$$V = \underline{261.80m^3}$$

b) The Prismoidal rule

$$V = \frac{d}{3}[(A_1 + A_n) + 4(\sum A_{even}) + 2(\sum A_{odd})]$$

$$V = \frac{20}{3}[8.96 + 10.22 + 4(14.16 + 36.14 + 16.94) + 2(30.09 + 24.42]$$

$$V = \underline{2647.73m^3}$$

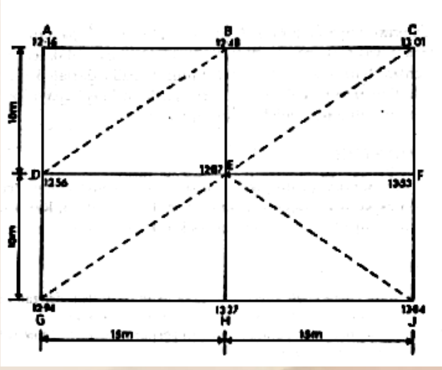
2.3.1 Spot Height

This is a method of volume calculation frequently used on excavations where there are vertical sides covering a fairly large area, although it can be used for excavation with sloping sides.

The site is divided into squares or rectangles, and if they are of equal size the calculations are simplified. The volumes are calculated from the product of the mean length of the sides of each vertical truncated prism (a prism in which the base planes are not parallel) and the cross-sectional area.

The sizes of the rectangles is dependent on the degree of accuracy required. The aim is to produce areas such that the ground surface within each can be assumed to be plane.

For Example 7



Picture 1 shows the reduced levels of a rectangular plot which is to be excavated to a uniform depth of 8m above datum. Calculate the mean level of the ground and the volume of earth to be excavated.

Picture 1 : Calculating volume from spot height

Solution

Two type calculation of spot heights :

(a) Calculation from **rectangles** :

Point	Reduced levelOf Old Elevation (m)	Reduced Level of New Elevation(m)	Depth of excavation(X)	No of Ractangl(N)	N . X
A	12.16	8.0	4.16	1	4.16
B	12.48	8.0	4.48	2	8.96
C	13.01	8.0	5.01	1	5.01
D	12.56	8.0	4.56	2	9.12
E	12.87	8.0	4.87	4	19.48
F	13.53	8.0	5.53	2	11.06
G	12.94	8.0	4.94	1	4.94
H	13.27	8.0	5.27	2	10.54
J	13.84	8.0	5.84	1	5.84
TOTAL				16	79.11

Average of depth excavation = 79.11 /16 = **4.944**

Volume = Total area x Depth

= 30 x 20 x 4.944

= 2966.4 m^3

(b) Calculation from **triangles**

It is usually more accurate to calculate from triangles as the upper base of the triangular prism is more likely to correspond with the ground plane than the larger rectangle. The mean level of each prism is then the mean of the three height enclosing the triangle instead of four as before.

Point	Reduced levelOf Old Elevation (m)	Reduced Level of New Elevation(m)	Depth of excavation(X)	No of Ractangle(N)	N . X
A	12.16	8.0	4.16	1	4.16
B	12.48	8.0	4.48	3	13.44
C	13.01	8.0	5.01	2	10.02
D	12.56	8.0	4.56	3	13.68
E	12.87	8.0	4.87	7	34.09
F	13.53	8.0	5.53	2	11.06
G	12.94	8.0	4.94	2	9.88
H	13.27	8.0	5.27	2	10.54
J	13.84	8.0	5.84	2	11.68
total				24	118.55

Average of depth excavation = 118.55 /24 = **4.94**

Volume = Total area x Depth

= 30 x 20 x 4.94

= 2963.75 m^3

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