

Chapter _5 Traversing

4. Introduction

The word traverse means 'passing across' in surveying it means 'determining the length and direction of consecutive lines' the linear measurements are made with tape and relative directions of the lines are measured with the directions of the lines are measured with the docile the integrated measurements of distance and direction provides the essential two dimensional data for providing horizontal control i.e. the relative location of point an horizontal plane.

The traverse in general consist Reconnaissance, distance measurement, angular measurement, measurement of one reference direction, computation.

5.1. Types of traverse.

General a traverse can be divided in to two

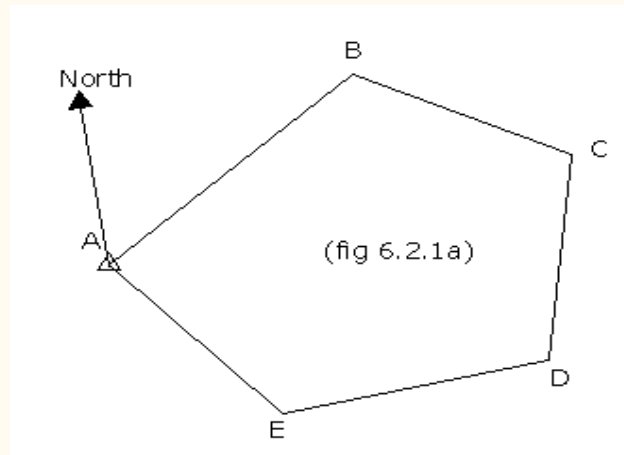
1. Closed traverse
2. Open traverse.

1. **Closed traverse:** - A traverse is said to be closed if it either it ends on starting point. Or if it ends on another known point due to this it can be divided into two.

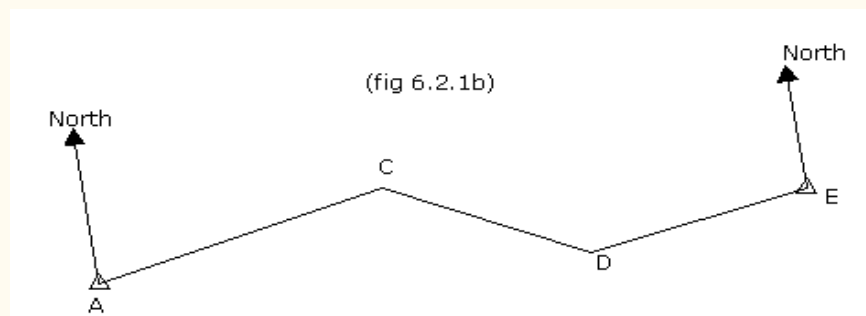
1. Closed traverse

I. Closed loop (ring) traverse (fig 6.2.1a)

Station A is Known

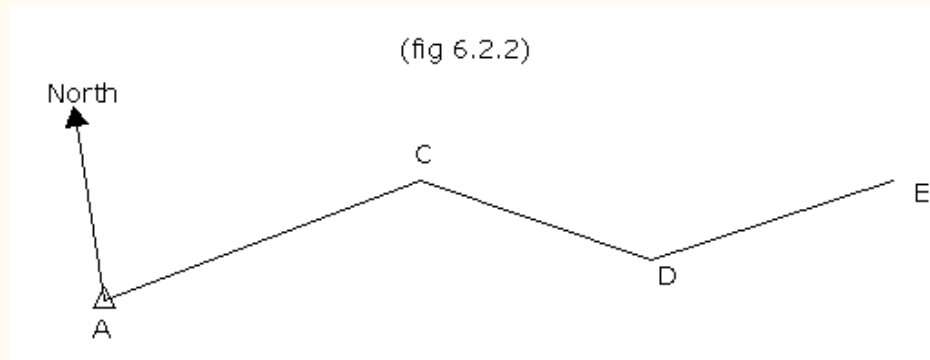


II. Closed route (link) connection) traverse (fig 6.2.1b)



Station A and E are Known

2. **Open traverse:** - It is a kind of traverse that starts from known point and ends on unknown point. (fig 6.2.2)



Station A is Known

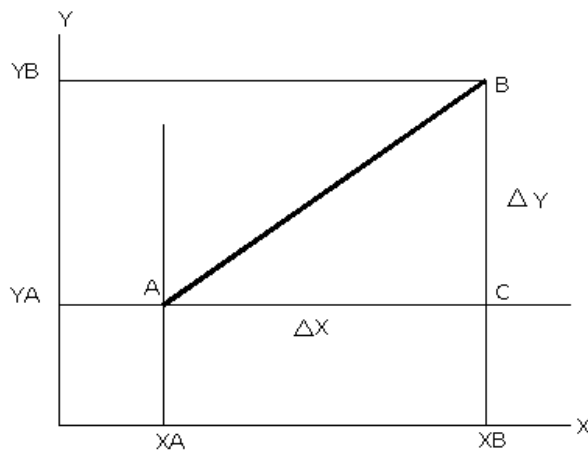
5.2. Departure and latitude

In rectangular coordinate system the can be defined as follows

Departure:- The difference in x- coordinate between two points

Latitude:- The difference in y- coordinate between two points

i- By using coordinates



$$\text{Departure of AB} = \Delta X_{AB} = X_B - X_A$$

$$\text{Latitude of AB} = \Delta Y_{AB} = Y_B - Y_A$$

Illustrative Example

If the coordinates of A= (600.72, 802.93) and

B= (700.00, 891.30)

Calculate departure and latitude of AB and BA

Solution

$$\text{Departure AB} = X_B - X_A = 700.00 - 600.72 = 99.28$$

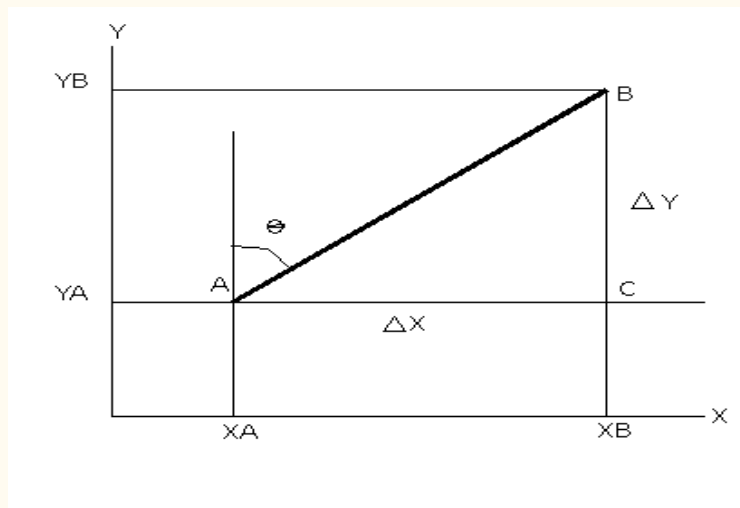
$$\begin{aligned}\text{Latitude AB} &= Y_B - Y_A \\ &= 891.30 - 802.93 \\ &= \underline{88.37}\end{aligned}$$

Again for line BA

$$\begin{aligned}\Delta X_{BA} &= X_A - X_B \\ &= 600.72 - 700.00 \\ &= -\underline{99.28}\end{aligned}$$

$$\begin{aligned}\Delta Y_{BA} &= Y_A - Y_B \\ &= 802.93 - 891.30 \\ &= -\underline{88.37}\end{aligned}$$

ii- **By using distance and azimuth**



Departure: - It is the product of the horizontal distance b/n two points and the sine of the azimuth of a line joining the two points.

$$= \text{distance} * \sin \text{ of Azimuth.}$$

Latitude = it is the product of the horizontal distance between two points and the cosine of the azimuth of a line joining the two points.

$$= \text{distance} * \cos \text{ of Azimuth.}$$

From triangle ACB

AC = departure of AB

CB = latitude of AB

θ = Azimuth of AB

AB = Distance b/n A and B

Therefore $\sin \theta = \frac{\Delta X_{AB}}{\text{dis. AB}}$
 $\Delta X_{AB} = \text{dis. AB} * \sin \theta$

And $\cos \theta = \frac{\Delta Y_{AB}}{\text{Dis. AB}}$
 $\Delta Y_{AB} = \text{dis AB} * \cos \theta$

Illustrative Example

If it is given that azimuth of a line = $60^{\circ} 11' 23''$ and its length is 400.2m. Calculate its departure and latitude.

Solution

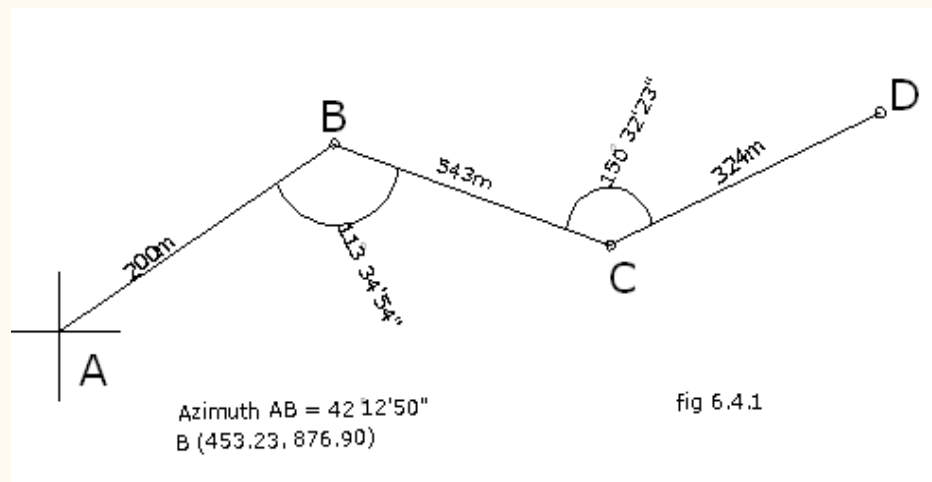
Departure of a line = distance * sin of Azimuth
 $= 400.23 * \sin 60^{\circ} 11' 23''$
 $= \underline{347.244}$

Latitude of a line = distance * cos of Azimuth
 $= 400.2 * \cos 60^{\circ} 11' 23''$
 $= \underline{198.951}$

5.3. Computation of Azimuths consecutive lines

If azimuth of one line and included angle at stations are given we can calculate azimuth of the other lines

Illustrative Example



If it is given that Az AB = $42^{\circ} 12' 50''$ and included angles at stations B and C are given calculate Azimuths of line BC and CD

Solution

Back azimuth of AB = Az BA = azimuth of AB + 180^0 = $222^0 12' 50''$

Therefore

$$\begin{aligned}\text{Az BC} &= \text{Az BA} - \angle B \\ &= 222^0 12' 50'' - 113^0 34' 54'' \\ &= \underline{108^0 37' 56''}\end{aligned}$$

Azimuth of CD = Azimuth of CB + $\angle C$

$$\begin{aligned}&= 108^0 37' 56'' + 180^0 + 150^0 32' 23'' - 360^0 \\ &= \underline{79^0 10' 19''}\end{aligned}$$

5.4. Computation of relative coordinates

If the coordinate of one point and departure and latitude of a line that joining this point to the point we are going to determine its coordinate are known, we can calculate the coordinate of unknown point.

$$\begin{aligned}\text{i.e. } X_2 &= X_1 + \text{dep } 12 \\ Y_2 &= Y_1 + \text{lat. } 12\end{aligned}$$

Illustrative Example 1

Suppose the coordinates of point A are (1000.2, 2341.32) and departure and latitude of line AB are 300.32 and 543.2 respectively, determine the coordinates of point B.

Solution

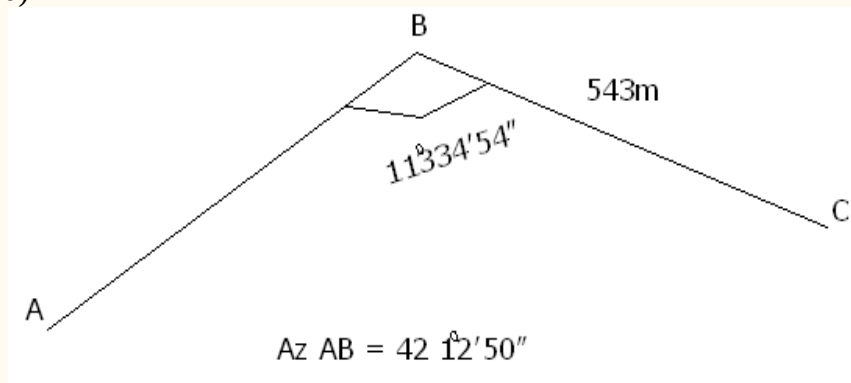
$$\begin{aligned}X_B &= X_A + \text{dep AB} \\ &= 1000.2 + 300.32 \\ &= \underline{1300.52}\end{aligned}$$

$$\begin{aligned}Y_B &= Y_A + \text{lat. AB} \\ &= 2341.32 + 543.2 \\ &= \underline{2884.52}\end{aligned}$$

Therefore B (1300.52, 2884.52)

Illustrative example 2

Referring fig below, determine the coordinate of station C if coordinates of station B is (453.23, 876.90)



Solution

$$\begin{aligned}\text{Azimuth of BA} &= \text{back azimuth of AB} \\ &= 42^{\circ}12'50'' + 180^{\circ} \\ &= \underline{222^{\circ}12'50''} \\ \text{Azimuth of BC} &= \text{AZ}_B^A - \angle B \\ &= 222^{\circ}12'50'' - 113^{\circ}34'54'' \\ &= \underline{108^{\circ}37'56''} \\ \text{Departure BC} &= \text{dis} * \sin \text{azimuth} \\ &= 543 * \sin 108^{\circ}37'56'' \\ &= \underline{514.541} \\ \text{Latitude BC} &= \text{dis} * \cos \text{Azimuth} \\ &= 543 * \cos 108^{\circ}37'56'' \\ &= -173.484 \\ X_C &= X_B + \text{dep. BC} \\ &= 453.23 + 514.541 \\ &= \underline{967.771} \\ Y_C &= Y_B + \text{lat. BC} \\ &= 876.90 + -173.484 \\ &= \underline{703.416}\end{aligned}$$

Therefore, coordinates of C are **(967.771, 703.416)**

5.5. Balancing the traverse

Balancing the traverse means making adjustment to remove any apparent error. For balancing the traverse the underlying objective is to adjust the traverse in such away that the sum the latitude and departure should each equal to zero in closed loop traverse. The closing error, however it is distributed throughout the traverse such that the above mentioned objective is achieved this operation is called **Balancing the traverse**.

There are different methods of balancing the traverse, however two of them are recommended at this stage.

1. Bowditch rule
2. Transit rule.

According to the Bowditch rule error is proportional to the length of the side

$\text{Correction lat./dep.} = \frac{\text{Closure error in lat/dep}}{\text{Perimeter of the traverse}} * \text{length of the side}$
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According to Transit rule

$\text{Correction lat./dep.} = \frac{\text{Closure error in lat/dep}}{\text{Total sum of lat/dep}} * \text{lat/dep of the side}$
--

Procedures for adjusting closed loop traverse can be summarized in the following five (5) steps

1. Sum up all observed angle and check the sum with the **(n-2) 180°**
 Where $(n-2)*180^\circ$ = Nominal sum or theoretical sum
 n = Number of station
 Sum (observed) = Actual (practical)

$$\text{Then} \quad \text{Error} = \text{Nominal} - \text{Actual}$$

$$\text{Correction} = \frac{\text{Error}}{n}$$

2. By using the given azimuth of the first line find the azimuth of all lines.
 If it is right hand traverse
 $\text{Az of } (i+1) = \text{Az of } i + 180^\circ - \beta$
 If it is left hand traverse
 $\text{Az of } (i+1) = \text{Az of } i + \beta - 180^\circ$
 Where β is adjusted angle
3. Find the latitude and departure of all lines and sum up to get closure error of departure & latitude.
4. Adjust the latitudes and departures by Bowditch rule.
5. Find the coordinates of all points.

Illustrative example 1

The following data is observed for a closed loop traverse ABCDEF. Using given data calculate the coordinates of stations B, C, D, E, F.

<u>Included clockwise angle</u>	<u>Line</u>	<u>Distance (m)</u>
<FAB = 115°11'20"	AB =	429.37
<ABC = 95°00'20"	BC =	656.54
<BCD = 129°49'20"	CD =	301.83
<CDE = 130°36'20"	DE =	287.40
<DEF = 110°30'00"	EF =	526.72
<EFA = 138°54'40"	FA =	372.47

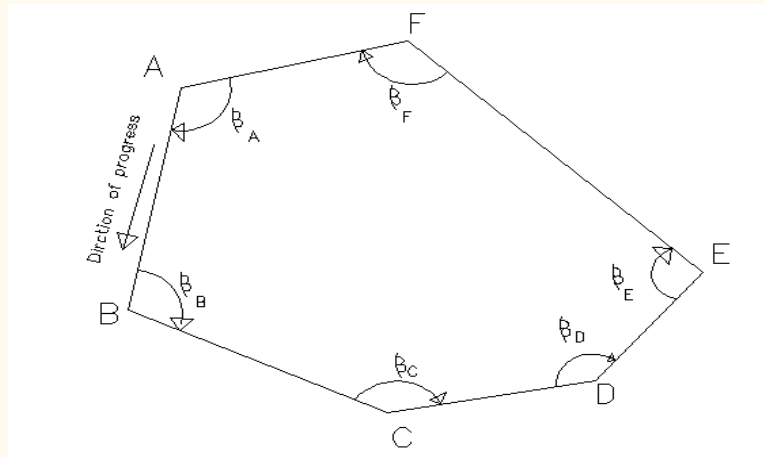
Coordinates

XA = 500.00

YA = 1000.00

Azimuth

AB = 191°11'00"



Solution

$$\begin{aligned}
 1. \quad \sum \beta_{\text{practical}} &= \beta_A + \beta_B + \beta_C + \beta_D + \beta_E + \beta_F \\
 &= 720^\circ 02'00'' \\
 \sum \beta_{\text{Nominal}} &= (n-2) * 180^\circ \\
 &= (6-2)*180^\circ \\
 &= 720^\circ 00'00'' \\
 \text{Error} &= \sum \beta_{\text{Nominal}} - \sum \beta_{\text{practical}} \\
 &= -2'00''
 \end{aligned}$$

$$\begin{aligned}
 \text{Correction} &= \text{Error} / n \\
 &= -20''
 \end{aligned}$$

$$\begin{aligned}
 \text{Allowable error} &= 1' (n)^{1/2} \\
 &= 2'27'' \quad \text{since error is less than allowable error the measurement is } \mathbf{ok!}
 \end{aligned}$$

Therefore the adjusted angles are

$$\begin{array}{rclcl}
 \angle FAB & = & 115^\circ 11'20 & -20'' & = & 115^\circ 11'00'' \\
 \angle ABC & = & 95^\circ 00'20'' & -20'' & = & 95^\circ 00'00'' \\
 \angle BCD & = & 129^\circ 49'20'' & -20'' & = & 129^\circ 49'00'' \\
 \angle CDE & = & 130^\circ 36'20 & -20'' & = & 130^\circ 36'00 \\
 \angle DEF & = & 110^\circ 30'00'' & -20'' & = & 110^\circ 29'40'' \\
 \angle EFA & = & 138^\circ 54'40 & -20'' & = & 138^\circ 54'20'' \\
 & & & & & \underline{\sum 720^\circ 00'00''}
 \end{array}$$

Computation of azimuths

$$\begin{aligned}
 \text{Az AB} &= 191^\circ 11'00'' \\
 \text{Az BC} &= \text{Az AB} + \beta_B - 180^\circ \\
 &= 106^\circ 11'00'' \\
 \text{Az CD} &= \text{Az BC} + \beta_C - 180^\circ \\
 &= 56^\circ 00'00'' \\
 \text{Az DE} &= \text{Az CD} + \beta_D - 180^\circ \\
 &= 6^\circ 36'00'' \\
 \text{Az EF} &= \text{Az DE} + \beta_E - 180^\circ \\
 &= 297^\circ 05'40'' \\
 \text{Az FA} &= \text{Az EF} + \beta_F - 180^\circ \\
 &= 256^\circ 00'00''
 \end{aligned}$$

3. Computation of latitude and departure.

Side	Azimuth	Distance(m)	Departure	Latitude
AB	191 ⁰ 11'00"	429.37	-83.276	-421.217
BC	106 ⁰ 11'00"	656.54	630.524	-182.985
CD	56 ⁰ 00'00"	301.83	250.228	168.781
DE	6 ⁰ 36'00"	287.40	33.033	285.495
EF	297 ⁰ 05'40"	526.72	-468.916	239.899
FA	256 ⁰ 00'00"	372.47	-361.406	-90.109
Σ		2574.33	+0.187	-0.136

$$\text{Closure error of a traverse} = [\text{cl}_{\text{dep}}^2 + \text{cl}_{\text{lat}}^2]^{1/2} \\ = 0.231$$

$$\text{Relative accuracy of a traverse} = [\text{Cl}_{\text{traverse}} / \text{perimeter}] \\ = 0.231/2574.33 \\ = 1: 11,144$$

4. Adjustment of latitude and departure by using Bowditch rule.

$$\text{Let } A = \frac{[\text{closure error of latitude}]}{\text{Total length of a traverse}}$$

$$\text{And } B = \frac{[\text{closure error of departure}]}{\text{Total length of a traverse}}$$

Since the summation of latitude is negative, the correction should be positive.

And the summation of departure is positive, the correction should be negative.

Therefore

Line	Adjusted departure	Adjusted latitude
AB	-83.276 – [B*429.37] = -83.307	-421.217 – [A*427.37] = -421.194
BC	630.524 – [B*656.54] = 630.476	-182.985 – [A*656.54] = -182.950
CD	250.228 – [B* 301.83] = 250.206	168.781 – [A* 301.83] = 168.797
DE	33.033 – [B*287.40] = 33.012	285.495 – [A*287.40] = 285.510
EF	-468.916 – [B*526.72] = -468.954	239.899 – [A*526.72] = 239.927
FA	-361.406 – [B* 372.47] = -361.433	-90.109 – [A* 372.47] = -90.090

5. Computation of relative coordinates

$$X_B = X_A + \text{dep AB}$$

$$= 500 + -83.307$$

$$= 416.693$$

$$X_C = X_B + \text{dep BC}$$

$$= 416.693 + 630.476$$

$$= 1047.169$$

$$X_D = X_C + \text{dep CD}$$

$$= 1047.169 + 250.206$$

$$= 1297.375$$

$$X_E = X_D + \text{dep DE} = 1297.375 + 33.012 = 1330.387$$

$$\begin{aligned}
X_F &= X_E + \text{dep EF} \\
&= 1330.387 + - 468.954 \\
&= 861.433 \\
Y_B &= Y_A + \text{lat AB} \\
&= 1000 + - 421.194 \\
&= 578.806 \\
Y_C &= Y_B + \text{lat BC} \\
&= 578.806 + - 182.950 \\
&= 395.856 \\
Y_D &= Y_C + \text{lat CD} \\
&= 395.856 + 168.797 \\
&= 564.653 \\
Y_E &= Y_D + \text{lat DE} \\
&= 564.653 + 285.510 \\
&= 850.165 \\
Y_F &= Y_E + \text{lat EF} \\
&= 850.165 + 239.927 \\
&= 1090.09
\end{aligned}$$

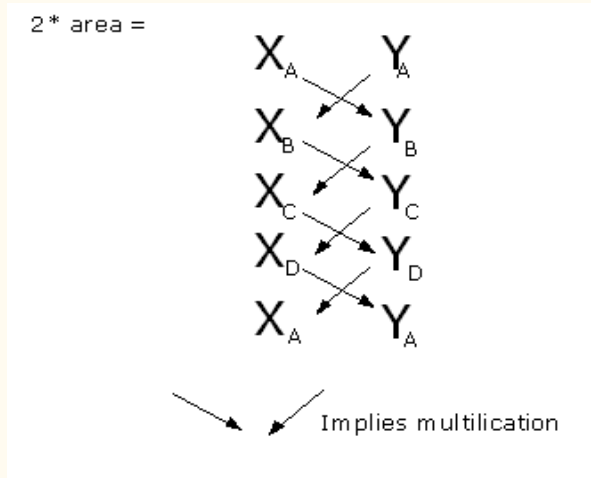
All the above computations and values are summarized in the following traverse table.

4.7. Area calculation by Coordinate method

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

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

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



Two sums of products should be taken

1. product of all adjacent terms taken down to the right
i.e. $X_A Y_B$, $X_B Y_C$, $X_C Y_D$, $X_D Y_A$

2. Product of all adjacent terms taken up to the right

i.e. $Y_A X_B$, $Y_B X_C$, $Y_C X_D$, $Y_D X_A$

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

Illustrative Example

Calculate the area enclosed by a traverse given example 6.1

Solution

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

$$\begin{aligned}
 X_A Y_B &= 500.00 * 578.866 &= 289433 \\
 X_B Y_C &= 416.693 * 395.856 &= 164950.4242 \\
 X_C Y_D &= 1047.169 * 564.653 &= 591287.1174 \\
 X_D Y_E &= 1297.375 * 650.165 &= 843507.8169 \\
 X_E Y_F &= 1330.387 * 1090.090 &= 1450241.565 \\
 X_F Y_A &= 861.433 * 1000.000 &= 861433.0
 \end{aligned}$$

$$\sum 1 = 4200852.923\text{m}^2$$

$$\begin{aligned}
 Y_A X_B &= 1000.000 * 416.693 &= 416693 \\
 Y_B X_C &= 578.866 * 1047.169 &= 606170.5304 \\
 Y_C X_D &= 395.856 * 1297.375 &= 513573.678 \\
 Y_D X_E &= 564.653 * 1330.387 &= 751207.0107 \\
 Y_E X_F &= 650.165 * 861.433 &= 560073.5864 \\
 Y_F X_A &= 1090.090 * 500.00 &= 545045.0 \\
 \sum 2 &= 3392762.806
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= \frac{\sum 1 - \sum 2}{2} \\
 &= \frac{808090.1175}{2} \\
 &= \underline{404045.059\text{sq.m}}
 \end{aligned}$$

5.4 Sources of errors and precision of traversing

When traversing, errors may arise in the following measurements.

- a.** Linear measurements: Errors in linear measurement are those as systematic, and random errors. These errors in linear measurements should be corrected considering its type.
- b.** Angular measurements: There are two main sources of errors in the measurement of the traverse angle.

i) **Observational errors:**

- Due to lateral refraction, haze and wind the line of sight may not be truly straight. It is therefore important to keep the line of sight 1m above ground on hot sunny days. In wind and haze no need to attempt at accurate readings.
- If the signal is too large it is not possible to bisect accurately, and if the signal is not plumbed vertically above the station mark, wrong direction will be observed. Therefore try and always observe directly on the station mark. If this is not possible, sight to a plumb-bob or accurately plumbed target or signal; never sight to a hand held ranging rod.
- Errors can arise in misreading and misbooking observations of the vernier or micrometer, so always check that the reading booked appears on the instrument.

ii) **Instrumental errors.**

- Error in the adjustment of the theodolite. Always observe on both faces of the theodolite when measuring horizontal and vertical angles.
- The theodolite must be properly leveled before observations are made. So that ensure the plate bubble remains in the same position in its tube when the theodolite is rotated through 360° .
- Ensure that the theodolite is stable with the legs firmly planted in solid ground and that the tripod adjusting screws are properly tightened.

- The theodolite must be properly centered over the station mark with an optical plummet or plumbing rod.
- If the horizontal circle is moved between observations the reduced angles will be in error. This can occur for any of the following reasons.
 - i) Screwing the theodolite too loosely to the tripod head.
 - ii) Omitting to secure the movable head.
 - iii) Omitting to clamp the lower plate.
 - iv) Using the lower tangent screw instead of the upper tangent screw.
 - v) Moving the orientation screw on single-axis theodolites.