Chapter 6

TRAVERSE

Horizontal Control

• Horizontal control is required for initial survey work (detail surveys) and for setting out.

• The simplest form is a TRAVERSE - used to find out the co-ordinates of CONTROL or TRAVERSE STATIONS.
Horizontal Control

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Horizontal Control

• Horizontal control is required for initial survey work (detail surveys) and for setting out.

• The simplest form is a TRAVERSE - used to find out the co-ordinates of CONTROL or TRAVERSE STATIONS.

• There are two types: -  
  a) POLYGON or LOOP TRAVERSE  
  b) LINK TRAVERSE

• Both types are closed.  
  a) is obviously closed  
  b) must start and finish at points whose co-ordinates are known, and must also start and finish with angle observations to other known points.

• Working in the direction A to B to C etc is the FORWARD DIRECTION

• This gives two possible angles at each station.

  LEFT HAND ANGLES  RIGHT HAND ANGLES
Consider the **POLYGON** traverse

The **L.H.** **Angles** are also the **INTERNAL ANGLES**

Using a theodolite we can measure all the internal angles.

\[
\sum \text{(Internal Angles)} = (2N - 4) \times 90^\circ
\]

The difference between \(\sum\) **Measured Angles** and \(\sum\) **Internal Angles** is the **Angular Misclosure**

**Maximum Angular Misclosure** = \(2 \times \text{Accuracy of Theodolite} \times \sqrt{\text{(No. of Angles)}}\)

(Rule of thumb)

Standing at A looking towards F - looking **BACK**

Hence \(\Theta_{AF}\) is known as a **Azimuth**

Standing at A looking towards B - looking **FORWARD**

Hence \(\Theta_{AB}\) is known as a **FORWARD Azimuth**

\[
\text{BACK Azimuth } (\Theta_{AF}) + \text{ L.H. ANGLE } (\angle \text{FAB}) = \text{ NEXT FORWARD Azimuth } (\Theta_{AB})
\]

Reminder: every line has two bearings

**BACK Azimuth** (\(\Theta_{BA}\)) = **FORWARD Azimuth** (\(\Theta_{AB}\) ± 180°)
Traverse Example

Observations, using a Zeiss O15B, 6° Theodolite, were taken in the field for an anti-clockwise polygon traverse, A, B, C, D.

<table>
<thead>
<tr>
<th>Traverse Station</th>
<th>Observed Clockwise Horizontal Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>132 15 30 - 3&quot;</td>
</tr>
<tr>
<td>B</td>
<td>126 12 54 - 3&quot;</td>
</tr>
<tr>
<td>C</td>
<td>69 41 18 - 3&quot;</td>
</tr>
<tr>
<td>D</td>
<td>31 50 30 - 3&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Line</th>
<th>Horizontal Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>638.57</td>
</tr>
<tr>
<td>BC</td>
<td>1576.20</td>
</tr>
<tr>
<td>CD</td>
<td>3824.10</td>
</tr>
<tr>
<td>DA</td>
<td>3133.72</td>
</tr>
</tbody>
</table>

\[ \Sigma \text{(Internal Angles)} = 360 \ 00 \ 12 \]
\[ \Sigma \text{(Internal Angles)} \text{ should be} \ (2N-4)*90 = 360 \ 00 \ 00 \]
\[ \text{Allowable} = 3 \ast 6^\circ \ast \sqrt{N}= 36^\circ \]

OK - Therefore distribute error 12" / 4 = 3"

The bearing of line AB is to be assumed to be 0° and the co-ordinates of station A are (3000.00 mE; 4000.00 mN)

Use Distance and Bearing to go from POLAR to RECTANGULAR to get Delta E and Delta N values.
LATITUDES AND DEPARTURES

FIGURE 6.5:
LOCATION OF A POINT.
A) POLAR TIES
B) RECTANGULAR TIES

LATITUDE = NORTH(+) SOUTH (-)= distance(H) x \cos \alpha

DEPARTURE = EAST(+) WEST (-)= distance(H) x \sin \alpha

CO-ORDINATE DIFFERENCES CALCULATED

<table>
<thead>
<tr>
<th>WHOLE CIRCLE BEARING ( \theta )</th>
<th>HORIZONTAL DISTANCE ( D )</th>
<th>( \Delta E )</th>
<th>( \Delta N )</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 00 00</td>
<td>638.57</td>
<td>0.000</td>
<td>+638.570</td>
</tr>
<tr>
<td>306 12 53</td>
<td>1576.10</td>
<td>-1271.701</td>
<td>+931.227</td>
</tr>
<tr>
<td>195 54 06</td>
<td>3824.10</td>
<td>-1047.754</td>
<td>-3677.764</td>
</tr>
<tr>
<td>47 44 33</td>
<td>3133.72</td>
<td>+2319.361</td>
<td>+2107.313</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.094</td>
<td>-0.654</td>
</tr>
</tbody>
</table>

*
$\Delta N_{AB} = +638.570 \text{m}$

$\Delta N_{BC} = +931.227 \text{m}$

$\Delta N_{CD} = -3677.764 \text{m}$

$\Delta N_{DA} = +2107.313 \text{m}$

$\Delta E_{BC}$

$\Delta N_{CD} = -3677.764 \text{m}$

$\Delta E_{CD}$

$\Delta E_{DA}$

e is the LINEAR MISCLOSURE

$e = \sqrt{e_E^2 + e_N^2}$
**CO-ORDINATE DIFFERENCES**

**CALCULATED**

<table>
<thead>
<tr>
<th>WHOLE CIRCLE BEARING</th>
<th>HORIZONTAL DISTANCE D</th>
<th>ΔE</th>
<th>ΔN</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 00 00</td>
<td>638.57</td>
<td>0.000</td>
<td>+638.570</td>
</tr>
<tr>
<td>306 12 51</td>
<td>1576.10</td>
<td>-1271.701</td>
<td>+931.227</td>
</tr>
<tr>
<td>195 54 00</td>
<td>3824.10</td>
<td>-1047.754</td>
<td>-3677.764</td>
</tr>
<tr>
<td>47 44 33</td>
<td>3133.72</td>
<td>+2319.361</td>
<td>+2107.313</td>
</tr>
<tr>
<td>9172.59</td>
<td></td>
<td>-0.094</td>
<td>-0.654</td>
</tr>
</tbody>
</table>

\[ e = \sqrt{(e_E^2 + e_N^2)} = \sqrt{(0.094^2 + 0.654^2)} = 0.661m \]

Fractional Linear Misclosure (FLM) = \( \frac{1}{D/e} \) = \( \frac{1}{9172.59 / 0.661} \) = 1 in 13500

[To the nearest 500 lower value]

---

**Acceptable FLM values :-**

- **1 in 5000** for most engineering surveys
- **1 in 10000** for control for large projects
- **1 in 20000** for major works and monitoring for structural deformation etc.
## Whole Circle Bearing

<table>
<thead>
<tr>
<th>Bearing</th>
<th>Horizontal Distance (D)</th>
<th>Calculated</th>
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</thead>
<tbody>
<tr>
<td>00</td>
<td>638.57</td>
<td>0.000</td>
</tr>
<tr>
<td>306</td>
<td>1576.10</td>
<td>-1271.701</td>
</tr>
<tr>
<td>195</td>
<td>3824.10</td>
<td>-1047.754</td>
</tr>
<tr>
<td>47</td>
<td>3133.72</td>
<td>+2319.361</td>
</tr>
</tbody>
</table>

**CO-ORDINATE DIFFERENCES**

\[
e = \sqrt{e_E^2 + e_N^2} = \sqrt{(0.094^2 + 0.654^2)} = 0.661m
\]

**Fractional Linear Misclosure (FLM)**

\[
= \frac{1}{\text{D} / e} = \frac{1}{9172.59 / 0.661} = \frac{1}{13500}
\]

If not acceptable ie 1 in 3500 then we have an error in fieldwork.

---

If the misclosure is acceptable then distribute it by:

a) **Bowditch Method** - proportional to line distances

b) **Transit Method** - proportional to \( \Delta E \) and \( \Delta N \) values

c) Numerous other methods including Least Squares Adjustments
a) Bowditch Method - proportional to line distances

The $e_E$ and the $e_N$ have to be distributed

For any line $IJ$ the adjustments are $\delta E_{IJ}$ and $\delta N_{IJ}$

$$\delta E_{IJ} = \left[ \frac{e_E}{\sum D} \right] \times D_{IJ} \quad \text{Applied with the opposite sign to } e_E$$

$$\delta N_{IJ} = \left[ \frac{e_N}{\sum D} \right] \times D_{IJ} \quad \text{Applied with the opposite sign to } e_N$$

<table>
<thead>
<tr>
<th>WHOLE CIRCLE BEARING</th>
<th>CO-ORDINATE DIFFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HORIZONTAL DISTANCE</td>
</tr>
<tr>
<td></td>
<td>$\theta$</td>
</tr>
<tr>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>306</td>
<td>12</td>
</tr>
<tr>
<td>195</td>
<td>54</td>
</tr>
<tr>
<td>47</td>
<td>44</td>
</tr>
<tr>
<td>9172.59</td>
<td>-0.094</td>
</tr>
</tbody>
</table>

$$e = \sqrt{(e_E^2 + e_N^2)} = \sqrt{(0.094^2 + 0.654^2)} = 0.661m$$

Fractional Linear Misclosure (FLM) = $1 \text{ in } \sum D / e$ = $1 \text{ in } 9172.59 / 0.661 = 1 \text{ in } 13500$ $\checkmark$ Check 2
$\delta E_{IJ} = \left( \frac{e_E}{\Sigma D} \right) \times D_{IJ}$  

Applied with the opposite sign to $e_E$

$e_E = -0.094 \text{m}$  

$\Sigma D = 9172.59 \text{ m}$

$\delta E_{IJ} = \left[ \frac{+0.094}{9172.59} \right] \times D_{IJ} = +0.0000102479 \ldots \times D_{IJ}$

For line AB  

$\delta E_{AB} = +0.0000102479 \ldots \times D_{AB} = +0.0000102479 \ldots \times 638.57$

\[ \delta E_{AB} = +0.007 \text{m} \]

For line BC  

$\delta E_{BC} = +0.0000102479 \ldots \times D_{BC} = +0.0000102479 \ldots \times 1576.20$

\[ \delta E_{BC} = +0.016 \text{m} \]

For line CD  

$\delta E_{CD} = +0.039 \text{m}$  

For line DA  

$\delta E_{DA} = +0.032 \text{m}$

---

**CO-ORDINATE DIFFERENCES**

<table>
<thead>
<tr>
<th>STATION</th>
<th>CALCULATED</th>
<th>ADJUSTMENTS</th>
<th>ADJUSTED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Delta E$</td>
<td>$\Delta N$</td>
<td>$\delta E$</td>
</tr>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>+638.570</td>
<td>+0.007</td>
</tr>
<tr>
<td>-1271.701</td>
<td>-1271.701</td>
<td>+931.227</td>
<td>+0.016</td>
</tr>
<tr>
<td>-1047.754</td>
<td>-1047.754</td>
<td>-3677.764</td>
<td>+0.039</td>
</tr>
<tr>
<td>+2319.361</td>
<td>+2319.361</td>
<td>+2107.313</td>
<td>+0.032</td>
</tr>
<tr>
<td>-0.094</td>
<td>-0.094</td>
<td>-0.654</td>
<td></td>
</tr>
</tbody>
</table>

$e_E = -0.094 \text{m}$  

$e_N = -0.654 \text{m}$
\[ \delta N_{IJ} = \frac{e_N}{\Sigma D} \times D_{IJ} \quad \text{Applied with the opposite sign to } e_N \]

\[ e_N = -0.654\text{m} \]

\[ \delta N_{IJ} = \left[ +0.654 / 9172.59 \right] \times D_{IJ} = +0.000071299 \ldots \times D_{IJ} \]

Store this in the memory

\[ \delta N_{AB} = +0.000071299 \ldots \times D_{AB} = +0.000071299 \ldots \times 638.57 \]

\[ \delta N_{AB} = +0.046\text{m} \]

\[ \delta N_{BC} = +0.112\text{m} \]

\[ \delta N_{CD} = +0.273\text{m} \]

\[ \delta N_{DA} = +0.223\text{m} \]

<table>
<thead>
<tr>
<th>STATION</th>
<th>CO-ORDINATES</th>
<th>CO-ORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3000.00</td>
<td>4000.00</td>
</tr>
<tr>
<td>B</td>
<td>-1271.701</td>
<td>+931.227</td>
</tr>
<tr>
<td></td>
<td>-0.007 +0.067</td>
<td>+0.007 +1838.616</td>
</tr>
<tr>
<td>C</td>
<td>+1729.32</td>
<td>+5569.96</td>
</tr>
<tr>
<td></td>
<td>+1271.685</td>
<td>+931.395</td>
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<tr>
<td>D</td>
<td>-1047.754</td>
<td>-3677.764</td>
</tr>
<tr>
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<td>+1271.685</td>
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<tr>
<td>A</td>
<td>+2107.536</td>
<td>+2107.536</td>
</tr>
<tr>
<td></td>
<td>+3677.491</td>
<td>+3677.491</td>
</tr>
</tbody>
</table>

\[ e_E = -0.094 \]

\[ e_N = -0.654 \]

\[ \sum = 0 \]

\[ \sum = 0 \]

Check 3
6.13 SUMMARY OF TRAVERSE COMPUTATIONS

1. Balance the field angles (1st step)
2. Correct (if necessary) the field distances (2nd step)
3. Compute the bearings and/or azimuths (3rd step)
4. Compute the linear error of closure and the precision ratio of the traverse (4th step)
5. Compute the balances latitudes ($\Delta y$) and balanced departures ($\Delta x$) (5th step)
6. Compute coordinates (6th step)
7. Compute the area (7th step)

6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE METHOD

The double area of a closed traverse is the algebraic sum of each X coordinate by the difference between the Y values of the adjacent stations.

The final area can result in a positive or negative number, reflecting only the direction of computation (either clockwise or anti-clockwise). However there area is POSITIVE...THERE ARE NO NEGATIVE AREAS.
6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE METHOD

Area 2 - Area 1 = Area of Traverse

(a)

The area of the traverse is, in effect, area 2 minus area 1.

\[
\text{Area 2} = \frac{1}{2}(X_4 + X_3)(Y_4 - Y_3) + \frac{1}{2}(X_3 + X_2)(Y_3 - Y_2)
\]

\[
\text{Area} = \frac{1}{2}(X_4 + X_1)(Y_4 - Y_1) + \frac{1}{2}(X_1 + X_2)(Y_1 - Y_2)
\]

\[
2A = [(X_4 + X_3)(Y_4 - Y_3) + (X_3 + X_2)(Y_3 - Y_2)] - [(X_4 + X_1)(Y_4 - Y_1)] + (X_1 + X_2)(Y_1 - Y_2)
\]

Stated simply, the double area of a closed traverse is the algebraic sum of each X coordinate multiplied by the difference between the Y values of the adjacent stations.
6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE

EXAMPLE 6.4
Area Computation by Coordinates
Refer to the traverse example in Section 6.6 and to Figures 6.15 and 6.22. The coordinates are summarized next:

<table>
<thead>
<tr>
<th>STATION</th>
<th>NORTH</th>
<th>EAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,089.981</td>
<td>935.049</td>
</tr>
<tr>
<td>B</td>
<td>1,000.000</td>
<td>1,000.000</td>
</tr>
<tr>
<td>C</td>
<td>1,078.754</td>
<td>1,068.139</td>
</tr>
<tr>
<td>D</td>
<td>1,046.635</td>
<td>1,205.498</td>
</tr>
<tr>
<td>E</td>
<td>1,154.366</td>
<td>1,030.252</td>
</tr>
</tbody>
</table>

\[ 2A = X_1(Y_2 - Y_1) + X_2(Y_3 - Y_2) + X_3(Y_4 - Y_3) + X_4(Y_1 - Y_4) \]

Solution
The double area computation (to the closest m²) is:

\[ XA(\bar{Y}B - \bar{Y}E) = 935.049(1,000.000 - 1,154.366) = -144,340 \]
\[ XB(YC - YA) = 1,000.000(1,078.754 - 1,089.981) = -11,227 \]
\[ XC(YD - YB) = 1,068.139(1,046.635 - 1,000.000) = 49,813 \]
\[ XD(\bar{Y}E - YC) = 1,205.498(1,154.366 - 1,078.754) = 91,150 \]
\[ XE(YA - YD) = 1,030.252(1,089.981 - 1,046.635) = 44,657 \]

\[ 2A = +30,053 \text{ m}^2 \]

Area = 15,027 m²

= 1.503 hectares

---

6.14 AREA OF A CLOSED TRAVERSE BY THE COORDINATE

EXAMPLE 6.5
Area Computation by Coordinates
Refer to the traverse example in Example 6.3, and the computed coordinates shown in Figure 6.18, which are summarized next:

<table>
<thead>
<tr>
<th>STATION</th>
<th>NORTH</th>
<th>EAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,000.000</td>
<td>1,000.000</td>
</tr>
<tr>
<td>B</td>
<td>1,250.73</td>
<td>1,313.81</td>
</tr>
<tr>
<td>C</td>
<td>1,302.56</td>
<td>1,692.14</td>
</tr>
<tr>
<td>D</td>
<td>934.77</td>
<td>1,683.54</td>
</tr>
<tr>
<td>E</td>
<td>688.69</td>
<td>1,160.27</td>
</tr>
</tbody>
</table>

Solution
The double area computation (to the closest ft²), using the relationships shown in Equation 6.7, is:

\[ 2A = X_1(Y_2 - Y_1) + X_2(Y_3 - Y_2) + X_3(Y_4 - Y_3) + X_4(Y_1 - Y_4) \]

\[ XA(\bar{Y}B - \bar{Y}E) = 1,000.000(1,250.73 - 688.69) = +562,040 \]
\[ XB(YC - YA) = 1,313.81(1,302.56 - 1,000.00) = +397,971 \]
\[ XC(YD - YB) = 1,692.14(1,250.73 - 1,205.498) = -534,649 \]
\[ XD(\bar{Y}E - YC) = 1,683.54(1,000.000 - 934.77) = +25,984 \]
\[ XE(YA - YD) = 1,160.27(1,000.000 - 688.69) = -533,716 \text{ ft}^2 \]

Area = 266,858 ft²

2A = -533,716 ft²

Also:

Area = 246,858

43.560 = 6.126 acres

(1 acre = 43,560 ft²)
END OF CHAPTER 6
THANK YOU FOR YOUR ATTENTION