Horizontal Control Techniques

A control survey provides a framework of survey points, whose relative positions, in two or three dimensions, are known to prescribe degrees of accuracy. The areas covered by these points may extend over a whole country and form the basis for the national maps of that country. Alternatively the area may be relatively small, encompassing a construction site for which a large-scale plan is required. Although the areas covered in construction are usually quite small, the accuracy may be required to a very high order. The types of engineering project envisaged are the construction of long tunnels and/or bridges, deformation surveys for dams and reservoirs, three-dimensional tectonic ground movement for landslide prediction, to name just a few. Hence control networks provide a reference framework of points for:

(1) Topographic mapping and large-scale plan production.

(2) Dimensional control of construction work.

(3) Deformation surveys for all manner of structures, both new and old.

(4) The extension and densification of existing control networks.

The methods of establishing the vertical control have already been discussed in Chapter 2, so only two-dimensional horizontal control will be dealt with here. Elements of geodetic surveying have been dealt with in Chapter 5 and so plane surveying for engineering control will be concentrated upon.

The methods used for control surveys are:

(1) Traversing.

(2) Triangulation.

(3) Trilateration.

(4) A combination of (2) and (3), sometimes referred to as triangulateration.

(5) Satellite position fixing.

(6) Inertial position fixing.

Whilst the above systems establish a network of points, single points may be fixed by intersection and/or resection.

i- TRAVERSING

Since the advent of EDM equipment, traversing has emerged as the most popular method of establishing control networks not only in engineering surveying but also in geodetic work. In underground mining it is the only method of control applicable whilst in civil engineering it lends itself ideally to surveys and dimensional control of route-type projects such as highway and pipeline construction.

Traverse networks are, to a large extent, free of the limitations imposed on the other systems and, compared with them, have the following advantages:

(1) Much less reconnaissance and organization required in establishing a single line of easily accessible stations compared with the laying out of well-conditioned geometric figures.

(2) In conjunction with (1), the limitations imposed on the other systems by topographic conditions do not apply to traversing.

(3) The extent of observations to only two stations at a time is relatively small and flexible compared with the extensive angular and/or linear observations at stations in the other systems.

It is thus much easier to organize.

(4) Traverse networks are free of the strength of figure considerations so characteristic of triangular systems. Thus once again the organizational requirements are reduced.

(5) Scale error does not accrue as in triangulation, whilst the use of longer sides, easily measured with EDM equipment, reduces azimuth swing errors.

(6) Traverse stations can usually be chosen so as to be easily accessible, as well as convenient for the subsequent densification of lower order control.

(7) Traversing permits the control to closely follow the route of a highway, pipline or tunnel, etc., with the minimum number of stations.

- **Types of traverse**

Using the technique of traversing, the relative position of the control points is fixed by measuring the horizontal angle at each point, subtended by the adjacent stations, and the horizontal distance between consecutive pairs of stations.

The majority of traverses carried out today would most probably capture the field data using a total station. Hence the distance is measured by EDM and the angles by digital processes. Occasionally, steel tapes may be used for distance.

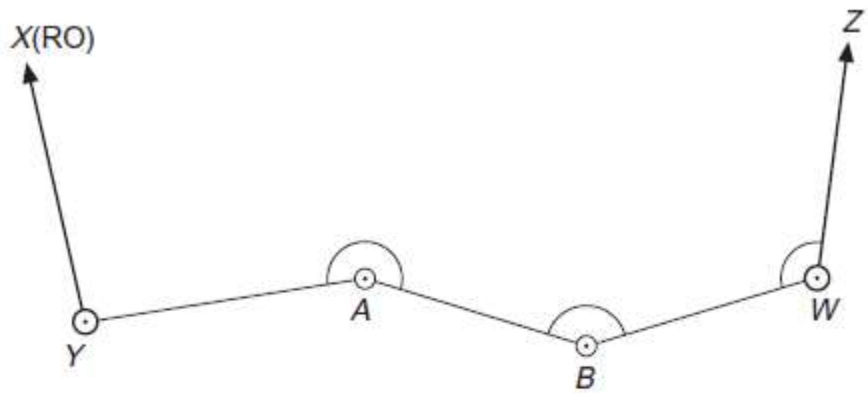
The liability of a traverse to undetected error makes it essential that there should be some external check on its accuracy. To this end the traverse may commence from and connect into known points of greater accuracy than the traverse. In this way the error vector of misclose can be quantified and distributed throughout the network, to produce geometric correctness. Such a traverse is called a‘link’ traverse.

Alternatively, the error vector can be obtained by completing the traverse back to its starting origin. Such a traverse is called a ‘polygonal’ or ‘loop’ traverse. Both the ‘link’ and ‘polygonal’ traverse are generally referred to as ‘closed’ traverses.

The third type of traverse is the ‘free’ or ‘open’ traverse, which does not close back onto any known point and which therefore has no way of detecting or quantifying the errors.

(1) Link traverse

Figure 6.1 illustrates a typical link traverse commencing from higher order point Y and closing onto



point *W*, with terminal orienting bearing to points *X* and *Z*. Generally, points *X*, *Y*, *W* and *Z* would be part of a higher order control network, although this may not always be the case. It may be that when tying surveys into the OSNG, due to the use of very precise EDM equipment the intervening traverse is more precise than the relative positions of the NG stations. This is purely a problem of scale arising from a lack of knowledge, on the behalf of the surveyor, of the positional accuracy of the grid points. In such a case, adjustment of the traverse to the NG could result in distortion of the intervening traverse.

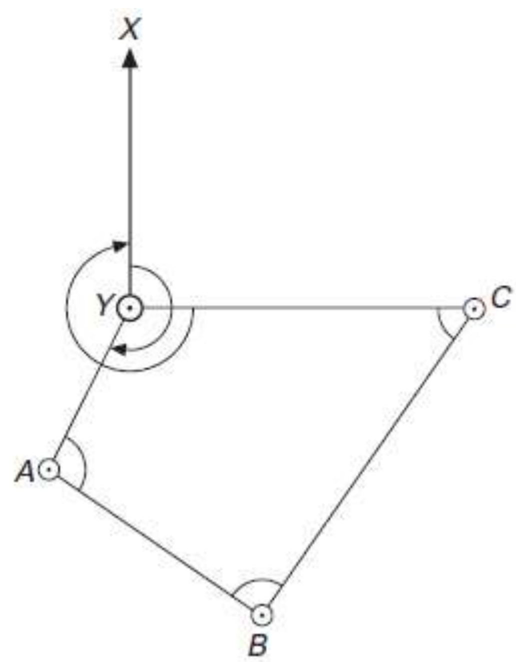
The usual form of an adjustment generally adopted in the case of a link traverse is to hold points

Y and *W* fixed whilst distributing the error throughout the intervening points. This implies that points *Y* and *W* are free from error and is tantamount to allocating a weight of infinity to the length and bearing of line *YW*. It is thus both obvious and important that the control into which the traverse is linked should be of a higher order of precision than the connecting traverse.

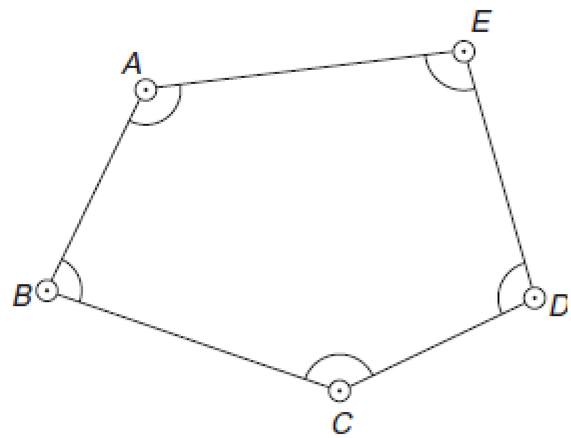
The link traverse has certain advantages over the remaining types, in that systematic error in distance measurement and orientation are clearly revealed by the error vector.

(2) Polygonal traverse

Figures2 and 3 illustrate the concept of a polygonal traverse. This type of network is quite popular and is used extensively for peripheral control on all types of engineering sites. If no orientation facility is available, the control can only be used for independent sites and plans and cannot be connected to other survey systems.



Loop traverse (oriented)

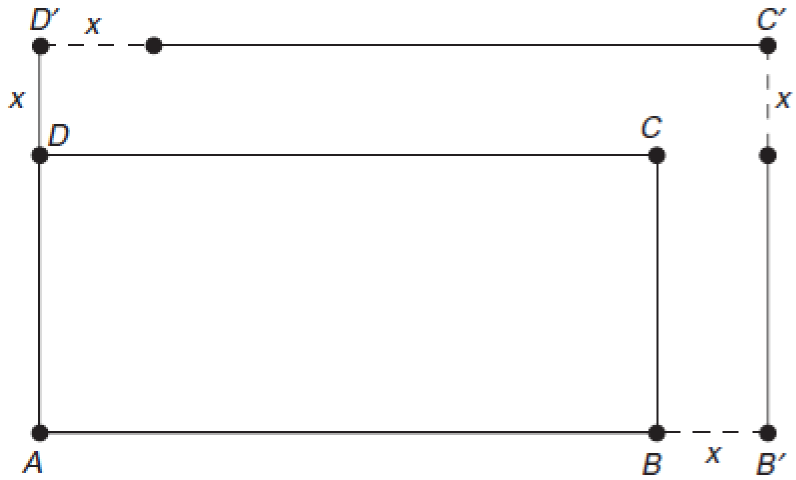


Loop traverse (independent)

In this type of traverse the systematic errors of distance measurement are not eliminated and enter into the result with their full weight. Similarly, orientation error would simply cause the whole network to swing through the amount of error involved and would not be revealed in the angular misclosure.

(3) Open (or free) traverse

Figure4 illustrates the open traverse which does not close into any known point and therefore cannot provide any indication of the magnitude of measuring errors. In all surveying literature, this form of traversing is not recommended due to the lack of checks. Nevertheless, it is frequently utilized in mining and tunnelling work because of the physical restriction on closure.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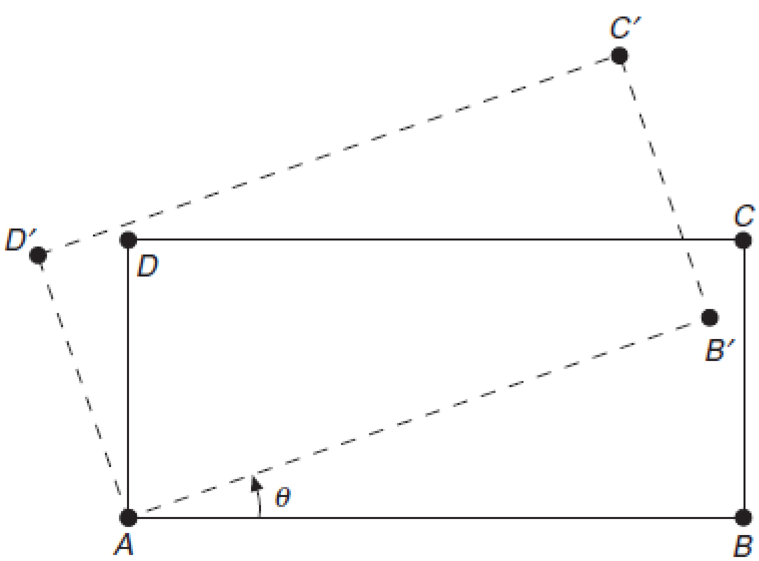
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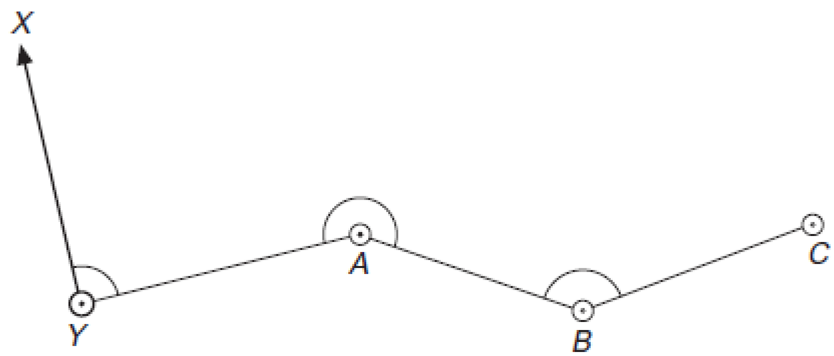

Open (or free) traverse

Sources of error

The sources of error in traversing are:

(1) Errors in the observation of horizontal and vertical angles (angular error).

(2) Errors in the measurement of distance (linear error).

(3) Errors in the accurate centring of the instrument and targets, directly over the survey point

(centring error).