Online Surveying FE 208

Lecture 20

Control Surveys

Learning Objectives for this Lecture

1. **Define the term *Control Survey***
2. **Know the two types of control surveys**
3. **Understand the methods for horizontal control surveys**
4. **Know the two major horizontal datums in use**
5. **Understand the methods for vertical control surveys**
6. **Know the two major vertical datums in use**
7. **Be familiar with the FGCS Accuracy Standards for control surveys**
8. **Be familiar with the horizontal and vertical control survey hierarchy**

Control Surveys

The establishment of precise horizontal and vertical positions for reference benchmarks.

There are two types of control surveys.

1. Horizontal

- The establishment of geodetic longitudes and latitudes across large areas
- Establishment of coordinates over smaller areas on planar surfaces

Methods for setting horizontal control:

- GPS
- Triangulation- the use of angles to determine locations
- Trilateration- using horizontal distances from the sides of a shape to determine locations
- Traverse (precise)- EDMs such as total stations would be used
- Photogrammetry

Horizontal Datums

Datums are essentially control networks that have established locations for benchmarks. Horizontal datums establish longitude and latitude benchmarks. There are two primary datums within the US.

NAD27- North American Datum of 1927

- Fits the US well.
- Oriented from the Meades Cattle Ranch in Kansas
- Used for State Plane and UTM projection/coordinate systems
- Approx. 25,000 adjusted measurements used
- Uses Clarke ellipsoid of 1866-> fits US well

NAD83- North American Datum of 1983

- Developed to offset the inconsistencies of NAD27
- Oriented to the center of the earth's mass drawn from satellite and GPS measurements
- Used for State Plane and UTM projection/coordinate systems
- Used 270,000 adjusted measurements
- Uses GRS80 ellipsoid: fits earth better than the US
- Fits the earth better than NAD27-

2. Vertical

- The establishment of elevation benchmarks

Methods for setting vertical control:

- Differential leveling
- Trigonometric leveling
- GPS leveling

Vertical Datums

Vertical datums establish elevations for a set of benchmarks. There are two primary vertical datums in the US.

NGVD29- National Geodetic Vertical Datum of 1929

- Still common on USGS maps
- Taken from an adjusted set of 26 gaging stations along the US and Canadian coastlines
- Sometimes referred to as mean sea level

NAVD88- North American Vertical Datum of 1988

- Between 1929 and 1988, over 625,000 km of additional control leveling lines had been completed (Mexico also)
- Included the original NGVD29 benchmarks
- Shifts in the elevation surface from NGVD29 were over 1.5 m in some places

Accuracy Standards

Factors affecting accuracy:

- Instrument (from cloth tape to total station)
- Experience of personnel
- Purpose of the survey (how accurate should the measurements be?)

The Federal Geodetic Control Subcommittee (FGCS) established sets of standards for the accuracy of control surveys. The purpose of these standards is to:

1. Provide a uniform set of standards specifying minimum acceptable accuracies for control surveys.
2. Establish specifications for instruments, field procedures, and misclosure checks to ensure that intended accuracies are met

FGCS orders of accuracy

Horizontal

GPS Order	Traditional Survey Order	Relative Accuracy Required
AA		1:100,000,000
A		1:10,000,000
B		1:1,000,000
C-1	First Order	1:100,000
	Second Order	
C-2-I	Class I	1:50,000
C-2-II	Class II	1:20,000
	Third Order	
C-3	Class I	1:10,000
	Class II	1:5,000

The horizontal standards are applied to measurements derived from triangulation, trilateration, and traverse procedures.

These are applied to the relative error in distance between any two horizontal control points.

Application:

Two first order stations located 100 km (60 miles) apart should be correctly located to within +/- 1m with respect to each other.

Vertical

Survey Order	Relative Accuracy Required
First Order	
Class I	0.5 mm * $\sqrt{K}$
Class II	0.7 mm * $\sqrt{K}$
Second Order	
Class I	1.0 mm * $\sqrt{K}$
Class II	1.3 mm * $\sqrt{K}$
Third Order	2.0 mm * $\sqrt{K}$

K = distance between benchmarks in km

These are applied to the relative error between any two benchmark elevations.

Application:

Two elevation benchmarks 25 km apart, established by second-order class I standards, should be correct to +/- 1.0 $\sqrt{25}$ or +/- 5mm.

These vertical accuracies are slightly looser than the specifications given for level loops.

Vertical accuracies are applied after adjustments, whereas accuracies for level loops are applied before adjustments.

Horizontal Control Hierarchy

Global-regional

- Used for broad scale surveys. GPS surveyed to AA accuracy.

Primary control

- GPS surveyed to A accuracy. Points are used for regional/local surveys.

Secondary control

- Densifies the network within areas of primary control, especially in high value land areas and for high-precision engineering surveys. GPS surveyed to B accuracy.

Terrestrial-based control

- Applicable to forest surveying.
- Used to meet mapping, land information systems, property surveying and engineering needs.
- Stations are set by traverse and triangulation to first- and second-order standards.
- GPS set by Order C standards.

Local-control

- Applicable to forest surveying.
- Establishes reference points for local construction projects and small-scale topographic mapping.
- Set by third-order standards.

Vertical Control Hierarchy

We talked about these control networks during our level loop survey lecture.

- Level lines are established and benchmarks are placed along the line at intermittent and convenient locations.

Basic framework

- A Network
  - Level lines are spaced about 100-300 km apart using first-order class I standards.
- B Network
  - Level lines are spaced about 50-100 km apart using first-order class II standards.

Secondary network

- Densifies the basic framework, especially in metropolitan areas and for large engineering projects.
- Set to second-order class I standards.

General area control

- Vertical control for local engineering, surveying, and mapping projects
- Set to second-order class II standards.

Local control

- Vertical references for minor engineering projects and small-scale topographic mapping.
- Set to third-order standards.

Triangulation

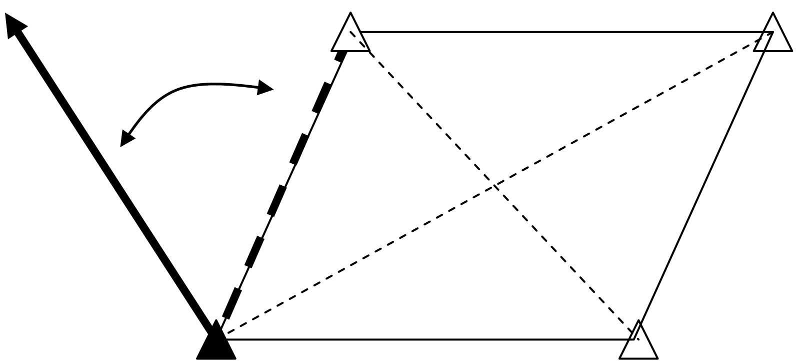
Triangulation originated as the preferred method for horizontal control prior to EDM’s since angles were more precise over long distances than horizontal distance measurement.

Triangulation possesses a large number of inherent checks for blunders and increases the possibility of meeting high standards of accuracy.

Triangulation utilizes figures composed of triangles. Horizontal angles and a limited number of sides called baselines are used to solve for coordinates of stations by trigonometry.

Customary form for triangulation is a chain of quadrilaterals.

Arcs of triangulation originate from one or more stations of known or fixed position and requires the azimuth of at least one line



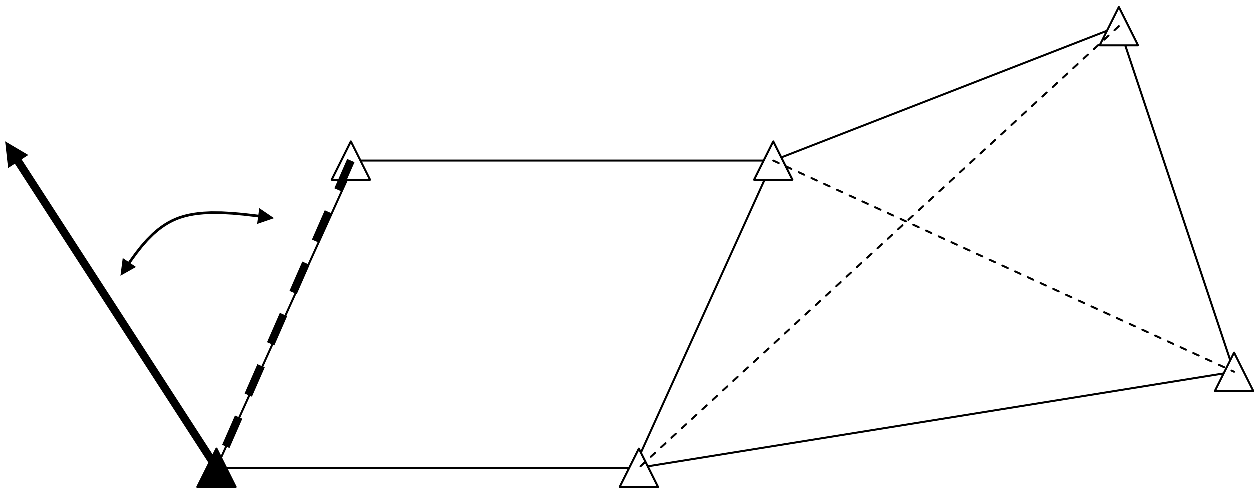
▲ Fixed Station

△ Triangulation Station

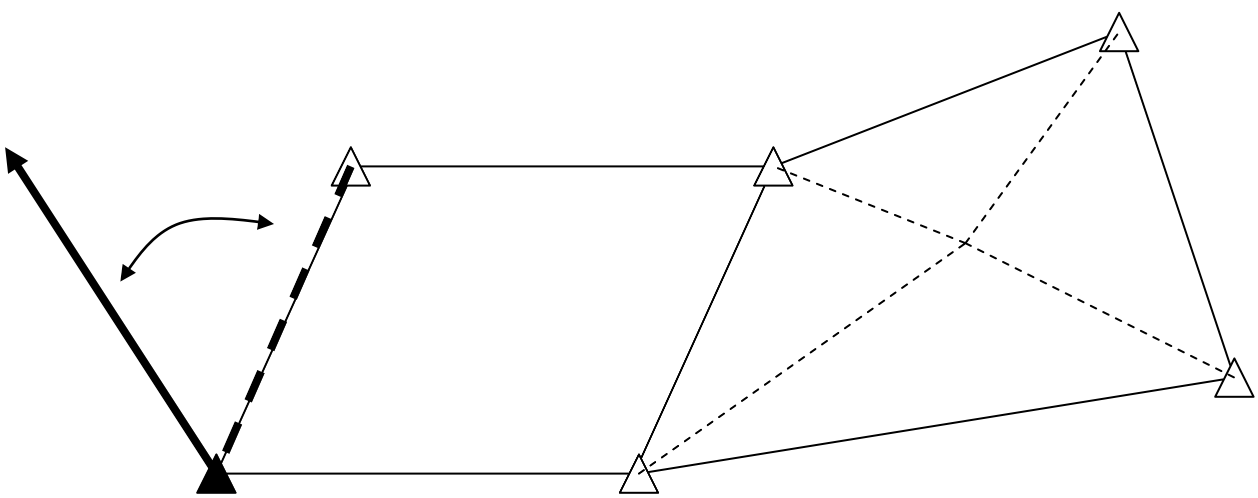
If two or more stations are known, the azimuth orientation is automatic.

Fixed starting stations are generally from higher order surveys.

The network is expanded by adding to the chain of quadrilaterals.



Intersection stations are used for additional control but are not occupied stations to be used for local control.



Selection of control stations

Factors to be considered:

1. Strength of figure
2. Station intervisibility
3. Station accessibility
4. Project efficiency

Strength of figure

- Triangulation is based on the Law of Sines
- Sine function changes rapidly near 0 degrees and 180 degrees
- Therefore good strength exists when angles are > 30 degrees and < 150 degrees within the network

Station intervisibilty

- Line of sight to all stations must exist for angle measurements

On control networks with very large triangles, the triangles can not be assumed to be plane but are spherical and thus the sum of internal triangles is no longer 180 degrees.
This is called spherical excess

This is approximated by:

$$\in'' = \frac{ab \sin C}{2R_e^2 \sin 1''}$$

Where:

$\in''$ = Spherical excess in seconds
a,b = the lengths of two sides of the triangle in meters
C = the included angle
R_e = The Earth's mean radius (6,371,000 meters)

Excess is generally about 1" for every 75.5 square miles of area