Section 2: Differential Leveling

Overview

Differential leveling is the process of measuring vertical distances from a known elevation point to determine elevations of unknown points. The most common methods to determine elevation are through the use of 1) a compensator type, automati (engineering level) and level rod(s), and 2) an electronic digital barcode leveling instrument with barcode rod. A thorough knowledge of leveling principles and proper application of methods and equipment will prevent costly delays and generate the needed results and accuracy.

Preferred methods of obtaining elevations (in order of preference/accuracy) are:

- Differential Leveling - control bench marks, cross-sections, point elevations
- Trigonometric Leveling - for Digital Terrain Model (DTM), 3D Model
- Indirect leveling (and location) by measuring horizontal distances and vertical angles
- Three-dimensional coordinates - both horizontal position and elevation are computed by processing the measurements
- GPS survey - given the appropriate equipment, procedure and data collection.

Other forms of leveling are available but are not discussed in this manual as they are not preferred or their use may be limited.

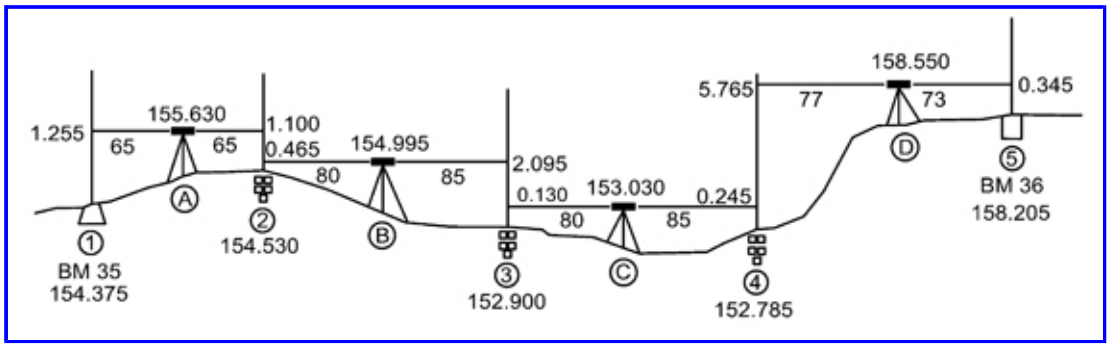

Figure 4-3. Illustration of Differential Leveling.

The method in Figure 4-3 uses the difference in elevation between a known elevation and the height of the instrument, and then the difference in elevation from the height of instrument to an unknown elevation point.

Equipment

- The Rod
  - Rods are, in essence, a tape supported vertically, and used to measure the vertical distance (difference of elevation) between a horizontal line of sight and a required point above or below it. The most common types are the Philadelphia rod- a 2 piece rod usually 13' in length, the Frisco rod- a 3 piece rod 12'-15' in length, the Lenker rod- a moveable face, direct reading rod, and the fiberglass-rod- a multi-section, extension rod from 8' - 45' in length. Electronic digital levels use a barcode marked rod. Precision leveling, known as First Order leveling, to extend or establish vertical control over long distances, requires use of invar scale rods.
  - All rods should be checked and maintained to ensure consistent readings. Cleaning and adjustment or repair should be done as needed.

- The Level
    - The compensator type, automatic (engineer) level is made by various manufacturers, and is a precision, self-leveling instrument, equipped with a built-in compensator that automatically maintains a horizontal line of sight and has a telescope with approximately 30-power magnification. The level mounts on a standard surveying tripod, or a fixed-leg tripod for more precise leveling.
    - The electronic digital level is also a precision, self-leveling instrument with additional advantages. Advanced capabilities include automatic measurement of height and distance by reading a barcode rod, high precision by employing image processing technology, data display and data recording either internally or to a data collector, installed software for elevation stake-out or other leveling procedures. The digital level offers greater productivity and simplicity in all applications of leveling work.
    - All leveling equipment must be checked regularly and properly maintained to ensure that it remains in proper working condition and that systematic errors are eliminated to produce the expected results. This includes daily checks, periodic routine maintenance and yearly cleaning and adjustment by a qualified repair shop.
    - Daily - keep the instrument clean by wiping occasionally, especially when used in dusty or wet environment. Operate and adjust the motions. With a compensator type, automatic level, observe the compensator while adjusting level screws to make sure that motion is smooth. If erratic compensator movement is detected, have a qualified repair shop service the instrument.

Instrument Check

On a regular basis and before beginning a leveling project, perform a peg test for collimation error to make sure that readings are consistent. If not, have the instrument serviced.

Anytime an instrument is dropped or severely bumped, or suspected of the same, it should be checked immediately. If questionable, have the instrument serviced before continuing use.

Leveling Methods

- 2nd Order for primary elevation control, extending or establishing bench marks on a project.
- 3rd Order intermediate or temporary bench marks, turning points on a project; aerial photo mapping control; major structures.
- General data collected for a DTM, topographic mapping, cross sections, or other purpose.

Leveling Tolerance

See Table 4.4 TSPS Manual of Practice Chart for Tolerances for Conditions, for specifications and survey conditions.

Datum

The NAVD 88 vertical datum shall be used on all TxDOT projects unless specified by TxDOT prior to the beginning of the survey.

Three-Wire Leveling

Three-wire leveling is the process of reading and recording a rod reading for each of the three horizontal cross-hairs on each shot, then averaging the readings for agreement with the center reading. This method is most accurate as it gives immediate results and a check/confirmation of rod reading. If a difference is detected a check can be done on the spot, before moving on.

An electronic digital level can perform and record this process automatically, after sight of the rod is made. Automated data collection eliminates transposition errors and data is downloaded into a computer for complete analysis.

This is the preferred method for setting or checking control bench marks. Three-wire leveling will be used for all orders of leveling except *general*.

Bench Marks (BM) and Temporary Bench Marks (TBM)

The primary purpose of running a level loop is to establish points of known elevation or bench marks. They are solid, well protected points that can be relied upon to remain undisturbed and unchanged. They should be positioned so as to be usable from a wide area and away from the construction as much a possible so as to remain undisturbed. Consideration should be given to construction activities such as utility re-location proposed within the ROW. It is preferred that bench marks are located in a public ROW, to allow for continued accessibility.

The exact location of the bench mark should be carefully selected, then sketched and recorded in notes, a field book or a data collector.

The numbering or identification system should be consistent with district numbering convention, if any and should be identified with enough detail for another crew to locate the bench mark easily. Bench marks set should always be turned through as part of a closed level loop.

Examples of good bench marks are an iron rod driven to refusal or a TxDOT cap set vertically in a concrete monument (similar to a Type II ROW Monument), a ROW monument, a point or corner of a stable concrete structure, or occasionally spike set in a large tree or utility pole. It is usually advisable to use a variety of types of bench mark monuments as utility relocation or construction activity may remove objects from a ROW.

The bench marks should not include objects subject to tampering or removal.

Two or more bench marks should be used from the specified reference datum (NAVD 88 unless directed by TxDOT). Thes bench marks should be identified, confirmed undisturbed, and elevations proved by running a complete level loop between the two, returning to the starting bench mark.

Distance between bench marks should be confirmed with the TxDOT project manager or the district survey coordinator before beginning a project.

Turning Points/Temporary Bench Marks (TP/TBM)

Turning points may be points set either before or during the course of the survey, or natural or man-made points in the area. They must be solid, well defined (or marked) and permanent enough to remain intact until the level loop is finished. Points with a small, sharply defined top are preferred to large flat surfaces.

Turning points should be marked when used so as to insure that the rod is in the exact same place when the backsight and foresight are taken. They are also marked because turning points that are part of a closed level loop are points of known elevation that may have value during future surveys in the area.

Temporary bench marks can be *turning points* that remain or additional intermediate bench marks placed for added convenience.

Temporary bench marks set in trees or power poles should consist of a spike (railroad spike, boat spike, or large nail spike) set horizontally approximately 1 to 2 ft. above ground elevation, also free of above obstructions to the level rod.

General Considerations / Objectives

During the course of running a level loop, choose/set turning points and bench marks to accomplish the required objective and accuracy.

Balance shot distances – The rodman and instrument man must work as a team to balance the backsight and foresight distances. This can be accomplished by use of a digital level, estimating distance by pacing, three-wire stadia difference or, when available, by observing stationing marked on the project. Balanced backsights and foresights, essential in precise leveling, will help eliminate errors caused by refraction, the curvature of the earth and an instrument that is out of adjustment and are an especially necessary procedure when establishing control bench marks.

Maximum sight distance – care should always be given to observe recommended or required distance of sight, depending on the purpose of leveling. See the NGS specifications and Table 4.3 TSPS Manual of Practice Chart for Tolerances for Conditions found in this chapter, or the manufacturer's recommendations.

Control points and bench marks should always be set to the highest level of accuracy suitable for the project or a higher level if it can be justified.