CVE 212 - Surveying Lab #6
MEASURING DISTANCES USING STADIA METHODS

EQUIPMENT

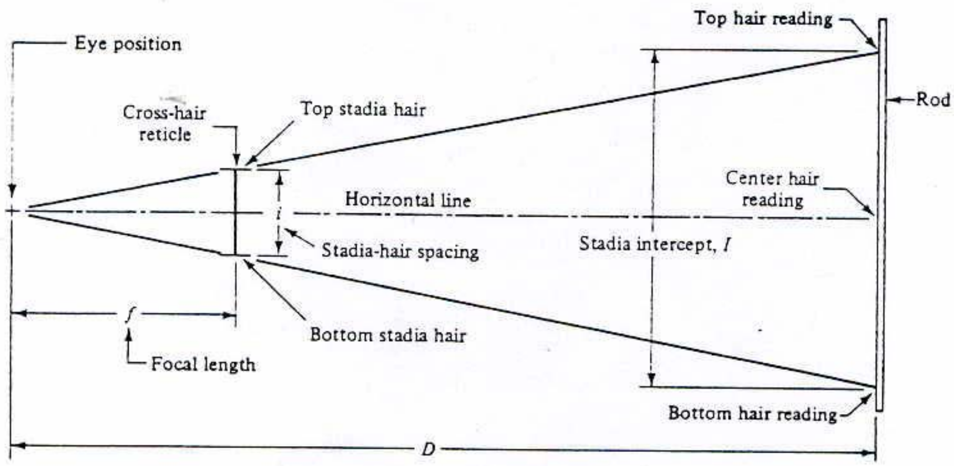
Transit or theodolite with stadia hairs and tripod
Philadelphia leveling rod
Field book
No. 3 drafting pencil

INTRODUCTION

When distances between traverse stations are determined by the stadia method, the resulting survey is called a stadia traverse. The stadia method, referred to as *tacheometry* in Europe, is a rapid and efficient way to measure distances in order to locate topographic details. The term stadia comes from the Greek word for a unit of length originally applied in measuring distances for athletic contests. This is also the origin of the word "stadiums." The distance signified 600 of the Greek equivalent of "feet." This converts to 606 feet 9 inches, which really has no significance in the surveying profession other than its relevance as an historical artifact. The term "stadia" is now applied as an adjective describing the cross hairs or cross wires and the rod used in making measurements. In addition, the term is used to identify the stadia method itself. The stadia method is used in topographic and hydrographic surveys although, in general, its usefulness is declining because of advances in electronic distance measuring. The student is exposed to this method for research purposes. When gathering information in a property search distances may have been determined using stadia techniques in previous surveys. This lab familiarizes the student with the stadia method and the accuracy of measurements relative to taping a distance as well as determining a distance with an EDMI.

Equipment for stadia measurements includes a graduated level rod (for this lab the student will utilize a Philadelphia rod) and a transit/theodolite with a telescope that has two stadia hairs, i.e., a top stadia hair and a bottom stadia. The stadia constant (see the theoretical development below) is imprinted by the instrument manufacturer on a plate attached the transit/theodolite. Level rods are made from wood, metal or fiber glass and are graduated in feet or meters. Unlike a surveyor’s tape a level rod is marked continuously along its full length. On the Philadelphia rods used in this lab large red numerals designate whole feet, while small black numerals designate tenths of feet. Tenth-of-a-foot points and odd five-hundredth-of-a-foot points are indicated by projecting angled cuts on somewhat longer black bars. The exact tenth-of-a-foot point is designated by a projection on top of the adjacent black bar while the exact five-hundredth-of-a-foot point is designated by a projection on the bottom of the corresponding adjacent black bar. Other exact hundredth-of-a-foot marks are designated by either the top or bottom edge of shorter squared-off black bars. At first the gradation on a Philadelphia rod can seem complex to the student. However, the reading method is quickly learned with practice. For short sight distances, i.e., less than 500 ft., the ordinary leveling rod may be used. Beyond this distance the markings of a Philadelphia level rod become indistinct, and a rod with a pattern consisting of larger divisions should be utilized. However, for long sight distances the surveyor is better off determining line lengths using an EDMI.

The stadia method of measurement is rapid and the results are sufficiently accurate for certain types of surveys. Under favorable conditions, the error associated with stadia surveys will not exceed 1/500. In combination with the measurement of vertical angles, height differences can be calculated. The geometry utilized in the theoretical development of stadia measurements for a horizontal sight with an external focusing telescope is depicted in the following figure.



The distance between the top and bottom stadia hair is identified as i (stadia hair spacing). The distance between the top and bottom reading on the rod is identified as I (stadia intercept). The distance from the instrument operator's eye to the stadia reticle (eyepiece) is identified as f (focal length). The distance from the instrument operator's eye to the level rod is identified as D, which is the quantity being determined in a stadia survey. From similar triangles

$$\frac{D}{I} = \frac{f}{i}$$

which leads to

$$D = \left(\frac{f}{i}\right) I$$

The ratio of focal length to stadia hair spacing is a constant for an instrument and is identified as *K*, the stadia interval factor, i.e.,

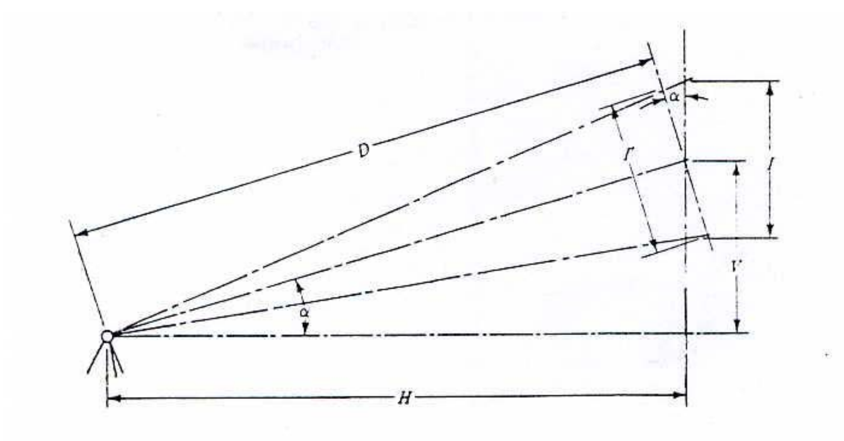
$$K = \frac{f}{i}$$

Thus the distance from the instrument operator's eye to the rod is

$$D = K\,I$$

Thus the student records the top and bottom readings on the rod and calculates the distance using the stadia interval factor for the instrument in use.

The preceding discussion was based on the fact that the telescope of the instrument is level, i.e., horizontal sights were taken. The surveyor may encounter situations where sighting on the level rod with the telescope level leads to an impractical number of instrument setups. This is a function of the terrain. Here the surveyor can conveniently rotate the telescope up or down to take readings on the rod. However, in doing so the instrument operator must record an additional piece of information in order to determine not only the horizontal distance between the instrument and the level rod, but also the vertical distance between the survey point the level rod is resting on and the HI of the instrument. This additional piece of information is the vertical angle α. Utilizing the following figure



the horizontal distance is given by the expression

$$H = K\, I\, cos^2\left(\alpha\right)$$

The vertical distance is given by the expression

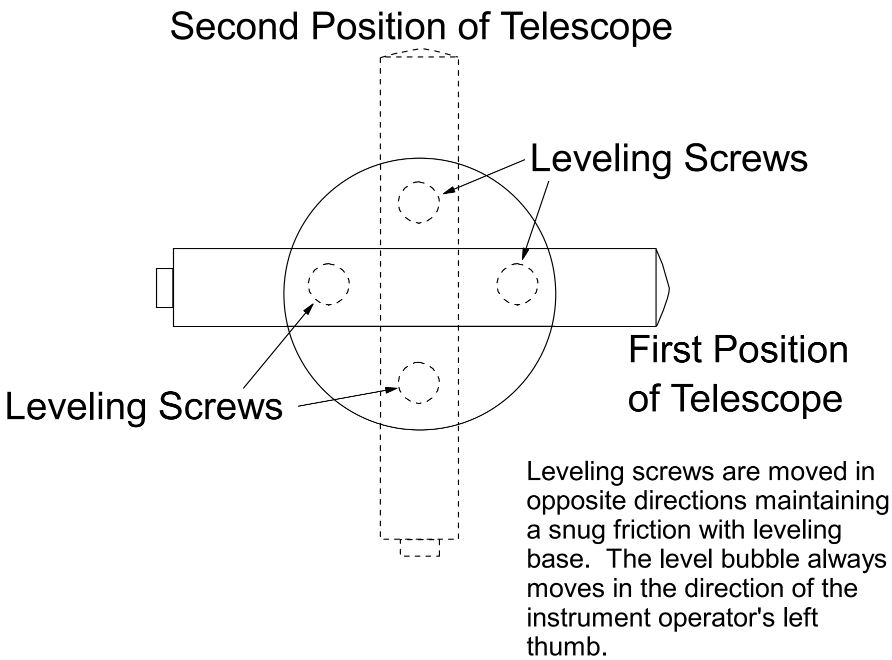
$$V = \frac{K\, I\, sin\left(2\, \alpha\right)}{2}$$

PROCEDURE

A transit/theodolite should be removed from its storage container by lifting the instrument from its base. Do not remove the instrument by grasping the telescope. The instrument base must be screwed snugly on the tripod. If the head is too loose, the instrument is unstable; if too tight, it may freeze on the tripod. The legs of the tripod must be tightened correctly. The tripod legs are tightened to a degree that if the instrument operator lifts a tripod leg up, the tripod leg will lower itself back to the ground under the force of its own weight. Clamping them too tightly strains the plate and screws. If the legs are loose, the instrument wobbles.

For this particular lab it will be necessary to set the level up over a specific point. Since the objective of the lab is to measure distances along the traverse previously measured with the surveyor's tape, the instrument must be positioned over each bench mark in the traverse. The student surveyor is reminded that the most convenient height for the telescope is one which enables the instrument operator to sight through the telescope without stooping or stretching.

Typical instruments have bases with four adjusting screws, or three adjusting screws. For an instrument with four adjusting screws the telescope is rotated until the line of sight along the telescope intersects two opposing adjusting screws (see the figure below). The bubble is approximately centered by using the thumb and first finger of each hand to adjust the opposing screws. The procedure is repeated with the telescope over the remaining two opposing leveling screws. Time can wasted by centering the bubble exactly on the first position since this effort in leveling the instrument will be thrown off during the cross leveling of the telescope in the second position. Continue to adjust the instrument over each pair of adjusting screws until the level bubble remains centered no matter what direction the telescope is pointed. This usually requires about three pairs of adjustments.



The leveling screws are turned in opposite directions at the same speed by both hands, unless this intention is to tighten or loosen the leveling head. A simple rule is the bubble follows the left thumb. If one hand turns faster than the other the screws bind, or the screws loosen (and the head rocks on two screws). Final precise adjustment may be made with one hand only. Leveling screws should be snug, not wrench-tight, to save time and to avoid damage to the threads and the base plate. The instrument operator must develop a feel for the proper setting of the leveling screws in order to allow ready movement of the instrument without binding the threads. The student should take care to insure that the instrument is level on the base plate before it is returned to the box.

The rodman is responsible for maintaining the rod plumb. *Waving* the rod is a procedure used to ensure that the rod is plumb when a reading is taken. The method consists of slowly tilting the top of the rod, first toward the instrument and then away from it until the instrument operator determines minimum value. The instrument operator makes certain the rod is plumbed in the lateral direction by checking its alignment with the vertical cress hair and signaling for adjustments. The rodman can aid in keeping the rod level by using buildings, telephone poles or even a plumb bob as a guide to keep the rod plumb.

When performing a stadia traverse, the student surveyor will observe the stadia interval in both directions for a given distance. Thus a backsight and a foresight will be read and recorded for each setup of the instrument. In this way, two independent observations are made for each distance in the traverse. If the two values for each line are close then one is provided with a check against blunders. The mean value of the two calculations is used as the best estimate for the distance. For topographic surveys, the elevation and horizontal position of each survey point is required. The procedure consists of observing directions by the azimuth method, and distances by stadia.

In this lab the student surveyor is required to conduct a stadia traverse of the same traverse measured by means of the transit and tape method. Record *vertical angles* if necessary. Vertical angles require the use of a transit or theodolite. Calculate horizontal distances and elevations of all points along the traverse. Determine the elevation of your starting point by sighting on OM 1618. For this particular lab the student survey crew is required to do the following:

1. Set the instrument over one of the bench marks in the traverse.

2. Sight on the forward bench mark in the traverse and record the rod readings at the top stadia hair and the bottom stadia hair.

3. Without moving the instrument, take a backsight on the previous bench mark in the traverse and record the rod readings at the top stadia hair and the bottom stadia hair.

4. Move the instrument to the next bench mark in the traverse and repeat steps 1 through 3. If the calculated distance from a second observation is not close in value to the calculated distance from the first observation, stop and determine if you have made a procedural error. If the student is unable to reconcile the second observation with the first observation, the first observation must be made again. If the discrepancy persists the student surveyor should check with the lab assistant.

HINTS AND PRECAUTIONS

1. Sight in the direction of the rod and focus the telescope before centering the bubble exactly.

2. In general, depending on the accuracy of the level, sight distances should not exceed 200 feet.

3. Keep the foot of the level rod free from dirt.

4. Be sure that the level rod is held vertical while an observation is made.

5. Use standardized hand signals when necessary.

6. Describe all bench marks and O.M.s in the field notes.

FIELD NOTES

The following figure contains typical field notes for a stadia survey.

STADIA SURVEY

Rod Locat.	Rod top	Rod bottom	Δ(T-B)	Dist.	Σ(Dist)
Instrument @ BM A					
B1	2.889	2.055	0.834	83.40	
B2	2.495	1.360	1.135	113.50	
B3	3.840	2.750	1.090	109.00	
B4	5.488	4.255	1.233	123.30	
BM B					429.20
Instrument @ BM B					
B1	4.981	3.625	1.356	135.60	
B2	2.695	2.390	0.305	30.50	
B3	2.120	1.775	0.345	34.50	
BM C					200.60
Instrument @ BM C					
C1	4.280	3.041	1.239	123.90	
C2	6.349	4.715	1.634	163.40	
BM D					287.30

Instrument K = 100 78°
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