Construction of Levels

Types of Levels

The instrument most extensively used in leveling is the engineers' level. Until about 1950, engineers' levels were of two general types: the wye level, or Y level, and the dumpy level. A level of either type consists essentially of a telescope having a very accurate spirit level attached to it longitudinally. In a wye level the telescope rests in Y-shaped supports, from which it can be removed. In a dumpy level the telescope is rigidly attached to the bar supporting it.

Setting Up the Level

Leveling of the Telescope

The first step in making a level ready for use is to screw the instrument securely onto the tripod head and to plant the tripod legs firmly in the ground. For a wye level or a dumpy level, the legs of the tripod should be placed so that the plate or the similar plate of the dumpy level is nearly horizontal.

If the instrument has four leveling screws, the telescope is rotated until it is over one pair of opposite screws and the bubble is brought to the center of the glass vial by turning only these two screws. The screws should be held between the thumb and forefinger of each hand, and they should be turned in opposite directions; that is, the thumbs should move either toward each other or away from each other. Both screws should be turned at the same time and at about the same rate. After the bubble has been brought to the center of the glass vial for this position of the telescope, the telescope is turned on the vertical axis through an angle

of 90 degrees so that it is over the other pair of leveling screws. The bubble is then brought to the center of the vial by means of these two screws. The telescope is turned back to its first position, care being taken not to have it reversed end for end, to see whether the bubble remains in the center. If it does, the instrument is leveled. If it does not, it is brought to the center over each pair of leveling screws alternately, until it stays in the center for both positions of the telescope.

If there are three leveling screws, the telescope is first placed parallel to the line through any two of them, and the bubble is brought to the center of the vial by means of these two screws. Then the telescope is revolved until it is over the third screw, and the bubble is brought to the center by means of this screw alone. If the bubble remains in the center when the telescope is brought back to its first position, the instrument is leveled. Otherwise, the operations must be repeated until the bubble remains in the center for both positions of the telescope.

The expression "setting up the level" will be considered to include making the line of sight horizontal as well as merely placing the tripod legs in position, since the instrument must always be leveled before it can be used for determining elevations.

When a self-leveling level is used, the legs of the tripod should be placed so that the head is nearly horizontal. Then the bubble in the circular level should be brought nearly to the center of the vial. With the tele-

scope in any convenient position, the bubble is centered in one direction by operating two screws. It is then centered in the other direction by operating the third leveling screw.

Placing the Tripod Legs

As already stated, the tripod legs of a wye or dumpy level should be so located that the plate of the level is nearly horizontal. If the instrument has four leveling screws, the following procedure is recommended to get the plate in a suitable position most efficiently. Although the description may seem lengthy, the operations can be performed rapidly after a little practice.

After the level has been screwed onto the tripod at the first setup, two adjacent leveling screws should be loosened just enough to permit the entire assembly to be moved on the plate. Then the assembly should be turned so as to bring any leveling screw over the center of any tripod leg, and the screws should be tightened again so that the leveling assembly is held firmly in this position on the plate. This preliminary step is required only when the position of the leveling screws with respect to the tripod legs is changed. For convenience in the following explanation, we will call the leveling screw over the tripod leg "screw 1," and we will call that leg "leg A."

When the instrumentman carries the level on his shoulder from point to point, with the telescope behind him and the tripod legs pointed ahead, he should always

have leg A toward the right if he is right-handed and toward the left if he is left-handed. Also, of the other two legs, the same one should always rest on his shoulder, and the other should always be on top. If one leg is slightly longer than the other two, as it usually is, the long leg should be on top. We will call the leg that is on top "leg B" and the third leg "leg C." We will assume that the instrumentman is right-handed. If he is left-handed the word "right" should be changed to "left" and word "left" should be changed to "right" in the following instructions.

When the instrumentman gets to the place at which the level is to be set up, he should face toward the point to which the telescope will be directed. Then, holding leg A in his right hand and leg C in his left hand, he should set the tripod down and rest it on the ground on the point of Leg B. Almost in the same motion he should spread the tripod legs and set the point of Leg C in the ground at any convenient distance from the point of leg B and in such a position that a line through the leveling screw 1 and the opposite leveling screw (which we will call 3) would be nearly in the direction of the proposed line of sight.

With the points of legs B and C resting on the ground and leg A still held in his right hand with its point just off the ground, the instrumentman should let go of leg C and use his left hand to turn the telescope so that it is over leveling screws 2 and 4. He should then swing leg A to the right

or left until the bubble in the glass vial is nearly in the center of the vial. This leveling with leg A is possible because the hinged joints at the tops of tripod legs B and C allow some freedom of movement of the plate. Now the instrumentman should turn the telescope so that it is over screws 1 and 3 and should move the point of leg A toward or away from the telescope until the bubble is nearly in the center of the vial. He should then set the point of Leg A on the ground. The plate should now be nearly horizontal.

The final steps in setting up are to push the point of each tripod leg firmly into the ground and to level the instrument accurately by using the leveling screws in the manner described in previous paragraphs.

In the preceding article it was assumed that the ground on which the tripod is set is fairly firm. If the ground is quite soft the procedure just described should be modified slightly. It will probably be described for the instrumentman to embed the points of legs B and C a few inches in the ground before he moves the leg A to the right or left. Also, he should select the final position of leg A so that the end of the telescope nearer this leg will be a little too high when the point of the leg just touches the ground. The telescope will then be nearly horizontal when the leg is embedded in the ground.

The procedure for setting up a wye or dumpy level that has three leveling screws is essentially similar to the procedure described for an instrument

with four leveling screws. All three leveling screws will be over the centers of tripod legs at the same time, and any leg can be chosen as the adjusting leg. In its first position the telescope should be parallel to a line through the leveling screws over the other two legs. In its second position, the telescope should be over the adjusting leg.

When a self-leveling level is to be set up, the telescope may be in any convenient position and any leg of the tripod may be chosen as the adjusting leg. The instrumentman should center the bubble of the circular level roughly in one direction by moving the adjusting leg to the left or right and should then center the bubble roughly in the perpendicular direction by moving that leg toward or away from the telescope.

Care of Level

The level should not be exposed to the sun, to rapid changes of temperature, to unequal temperatures on its different parts, to dust, or to rain when such exposure can be avoided. Changes of temperature disturb the adjustments, dust may damage the bearings and the lenses, while moisture obscures the lenses and may otherwise damage the instrument. When it is impossible to avoid working in the rain, wipe the lenses frequently and carefully with a soft linen cloth. Also, when the instrument is not in use, cover the eyepiece and put the cap

on the objective. After returning to the office or camp, wipe the entire instrument very carefully and thoroughly, finishing with a piece of dry chamois skin. Then leave it in a moderately warm, dry place so that every particle of moisture will be removed.

When a wye or dump level is carried on its tripod in open country, the spindle should always be clamped slightly to prevent the wearing of the centers by swinging, and the instrument should be carried with the objective end of the telescope down. In wooded country where underbrush is dense, the level should always be carried with the spindle unclamped , so that the telescope may turn freely on the spindle and yield readily to any pressure. A blow that would inflict no damage upon an unclamped instrument might seriously damage one clamped rigidly.

A self-leveling level should be transported with the eye-piece end of the telescope down, but it may be carried with the objective end down. It should never be carried with the telescope on its side, because the weight of the pendulum of the compensator puts a severe strain on the screws holding the damping piston in position and may cause displacement of the piston.

Care should be exercised not to use unnecessary force in screwing the instrument onto the tripod, in tightening the clamp screw, or in turning the leveling screws. If the leveling screws bind, two adjacent screws should be loosened slightly. When the instrument is in use, all screws should bear firmly, but excessive pressure is likely to cause damage.

Principle of Direct Leveling

When an adjusted level is set up and leveled up, its line of sight is horizontal. Also, since the line of sight is at right angles to the vertical axis of the instrument, the line of sight rotates about this axis in a horizontal plane, called the plane of the instrument. The elevation of this plane is the elevation of the instrument, usually called the height of instrument, and every line lying in the plane is a horizontal line having the same elevation as the instrument. This elevation may be assumed arbitrarily or may be determined from the known elevation of some other point by measuring the vertical distance from the plane of the instrument, as defined by the line of sight, to the point of known elevation. A leveling rod is usually employed for this purpose.

Kinds of Leveling Rods

In general, a leveling rod is a graduated wooden rod. There are several kinds of leveling rods, which differ in construction details but not in principle. The two types most commonly used are known as the Philadelphia rod and the California rod.

Philadelphia Rods

The Philadelphia rod is made in two sections, held together with brass sleeves. The rear section slides with respect to the front section, and it can be held in any desired position by means of the clamp screw

on the upper sleeve. A closed rod is sometimes called a short rod. When the rod is extended, no matter how little, it is known as a high rod. The divisions are alternate black and white spaces, each 0.01 ft high, painted on the rod. Each fifth hundredth is indicated by a longer graduation mark, so that an acute angle is formed at one corner of the black space of which the graduation is a part. The tenths of a foot are shown by large black numbers half above and half below the graduation mark, and the feet are shown in a similar manner by large red figures. The graduations on these rods can be seen distinctly through the telescope of a level at a great distance. Therefore, such are sometimes called direct-reading rods.

The highest reading for the closed rod is either 6.5 or 5 ft, and the corresponding highest reading for the extended rod is 12 ft or 9 ft.

California Rods

A California rod has three sections. These are two common lengths of California rods: 4.5 ft long when closed, extend to a length of 12 ft; other rods are 5.5 ft long when closed, extend to 15 ft. When a California rod is fully extended, the graduations are continuous. There are no graduations on the back of a California rod.

Philadelphia rods for architects and builders are graduated in feet, inches, and eighths of an inch.

For work in mines and tunnels and for other purposes, it is sometimes convenient to use a very short

rod. Therefore, two-section rods are made which are 3 ft long when closed and 5 ft long when extended.

A type of rod known as a Chicago rod consists of three or four comparatively short sections which are fitted together one above another by rigit telescopic brass joints.

For use with levels having inverting telescopes, some leveling rods have the graduations on them upside down. The graduations then appear upright when the rod is viewed through the telescope.

Rodman

The man who carries the rod and holds it on the points whose elevations are to be taken is called a rodman. A good rodman is essential to accurate and rapid leveling. A man who is slow and inattentive to the work is not suitable for a rodman. In most localities, a line of levels of any considerable length will have enough rough places in it--that is, places where abrupt and considerable changes in elevation occur -- to retard progress, however diligent the level party may be. The laziness or carelessness of an individual should never be allowed to delay the progress of the party.

Using the Rod

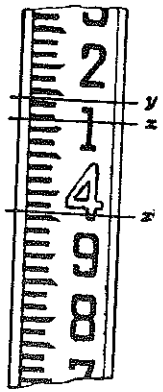
A rod can be held on a point and carried more easily when it is closed. Therefore, it is usually extended only when the reading exceeds the highest

graduation on the lower section. In all cases, the rod is held with the front toward the level. The levelman reads the position of the horizontal cross line directly from the telescope.

To make a high-rod reading, the rod is extended to its full length. Then the graduations on the front appear continuous and the reading of the horizontal cross line can be taken from the telescope.

Reading the Rod Directly

The reading of a rod is made directly from the telescope in the following manner. The number of feet is given by the red figure below the horizontal cross line. The number of tenths is shown by the black figure directly below the cross line. If the reading is required to the nearest hundredth on the rod, the number of hundredths is found by counting the divisions between the last tenth and the graduation mark nearest the cross line. If thousandths of a foot are required, the number of hundredths is equal to the number of divisions between the last tenth and the graduation mark below the cross line, and the number of thousandths is estimated by judgement. For example, the readings on the Philadelphia rod for the positions x, y and z in the figure below are determined as follows.



For x, the number of feet below 4 and the number of tenths below is 1. The cross line coincides with the first graduation above the tenth mark. Consequently the reading is 4.11 ft. to the nearest hundredth, or 4.110 ft. to the nearest thousandth.

For y, the feet and tenths are again 4 and 1, respectively. The cross line is just midway between the graduations indicating 4 and 5 hundredths. So the reading to the nearest hundredth may be taken as either 4.14 or 4.15 feet. In determining the hundredths, it is convenient to observe that the cross line is just below the acute-angle graduation denoting the fifth hundredth, and it is therefore innecessary to count up from the tenth graduation. If thousandths are required, the following method is used for finding the hundreths and thousandths: There are 4 divisions between the tenth mark and the graduation below the cross line. Hence, the number of hundredths is 4. Since the cross line is midway between the two graduation marks on the rod, and since the distance between graduations is 1 hundredth or 10 thousandths of a foot, the number of thousandths in the required reading is ½ X 10, or 5. So the reading to the nearest thousandth is 4.145 ft.

For z, the foot just above is 4 and the foot below must therefore be 3 (not shown in the illustration). The number of tenths is evidently 9, and the number of hundredths is 6. The distance to the cross line from the hundredth mark below is about one-third of a graduation, as nearly as can be estimated. So the number of thousandths is 1/3 X 10 or 3. Thus, the reading to the nearest hundredth is 3.96 ft. and the reading to the nearest thousandth is 3.963 ft.

Direct readings on a long rod are made in the same way as are those on a short rod, because the rod is fully extended and the graduations appear continuous.