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Basics of Site Work

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Chapter 5

Site Work

Topics

1.0.0 Site Survey
2.0.0 Permits
3.0.0 Surveying Instruments
4.0.0 Differential Leveling
5.0.0 Site/Building Layout
6.0.0 Classifying Soils
7.0.0 Soils Testing
8.0.0 Soil Stabilization

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Overview

Your job as the Builder petty officer is to direct your crewmembers in preparing the construction site before pouring foundations or erecting walls. Your work begins with site surveys using specialized surveying equipment and methods. You will pull building permits for various aspects of the project, working closely with local authorities. Once that work is underway, begin site and building layout. ***Leveling*** and grading are key components in building sound structures, with competent work taking into account the types of soils with which you are working. Soils testing can help you determine whether you need to perform any soil stabilization before construction begins.

This chapter introduces you to the concepts of site surveys, including construction surveys, bench marks, datum, and mean sea level. You will learn about earthwork operations, including pioneering, grubbing, stripping, and drainage. You will get an introduction to permits that need to be coordinated with local agencies for construction projects, including utility interruption requests, excavation requests, and road closure requests.

This chapter describes the common types of leveling instruments; including their principles, uses, procedures of establishing ***elevations***, and techniques of laying out building lines. As a Builder, you will find the information especially useful in performing such duties as setting up a level, reading a ***leveling rod***, interpreting and setting ***grade*** stakes, and setting batter boards.

Information on classifying and testing soils is included in this chapter. You will learn about practices and measures to stabilize soil on construction sites, which can also help prevent slides and cave-ins at excavation sites.

1.0.0 SITE SURVEY

There are a number of concepts used in surveying a site for a construction project. Construction surveys, sometimes called engineering surveys, are conducted to obtain data essential for planning, estimating, locating, and layout for the various phases of construction activities or projects. Surveys rely on Bench Marks (BM) to establish a known elevation on a construction site. Construction projects on the edge of or in the water utilize tidal datum and mean sea level measurements when sites are established.

Earthwork operations are some of the earliest operations that occur on a construction site. Pioneering, the earliest process makes the area accessible to the equipment that will be used on the project. Clearing is the next step, which consists of cleaning the site surface of vegetation, boulders, and rubbish. Clearing may include grubbing, which is removing roots and stumps, as well as stripping the site of sod and poor topsoil. All of this preparation needs to be done while maintaining or improving the drainage of the site.

1.1.0 Construction Survey

Construction surveys include reconnaissance, preliminary, location, and layout surveys. The objectives of engineering or construction surveying include the following:

1. Gathering reconnaissance information and preliminary data engineers require for selecting suitable routes and sites and for preparing structural designs
2. Defining selected locations by establishing a system of reference points
3. Guiding construction forces by setting stakes or otherwise marking lines, grades, and principal points and by giving technical assistance
4. Measuring construction items in place for the purpose of preparing progress reports
5. Dimensioning structures for preparation of as-built plans

All of the above objectives are called engineering surveys by the American Society of Civil Engineers (ASCE). The term construction surveys is applied to the last three objectives only. The Army Corps of Engineers, on the other hand, generally applies the term construction surveying to all of the objectives listed above.

Engineering and/or construction surveys form part of a series of activities leading to the construction of a man-made structure. The term structure is usually confined to something, such as a building or a bridge that is built of structural members. It is used here in a broader sense, however, to include all man-made features, such as graded areas; sewer, power, and water lines; roads and highways; and waterfront structures.

Construction surveys normally cover areas considered small enough to use plane surveying methods and techniques.

1.2.0 Bench Mark

A Bench Mark (BM) is a relatively permanent object, natural or artificial, bearing a marked point whose elevation is known. BMs are established over an area to serve as (1) starting points for leveling operations so the topographic parties can determine other unknown elevation points and (2) reference marks during later construction work. BMs are classified as Permanent or Temporary. Generally, BM indicates a permanent bench mark, and TBM a temporary bench mark. TBMs are established for a particular job and retained for the duration of that job. Throughout the United States, a series of BMs has been established by various government agencies. These identification markers are set in stone, iron pipe, or concrete, and are generally marked to show the elevation above sea level. When the elevation is not marked, you can find out what it is by contacting the government agency that originally set the BM. Be sure you give them the identification number on the marker.

Bench Marks may be constructed in several ways. *Figure 5-1* shows brass shaft stocks in the tops of permanent horizontal control points, also known as monuments. Monuments of this type are sometimes also used for vertical control BMs. Original BMs may be constructed in the same manner. When regular BM disks are not available, brass, not steel, 50-caliber empty shell casings may be used. The shank of the empty shell casings should be drilled crosswise and a nail inserted to prevent its being pulled out or forced out by either expansion or contraction.

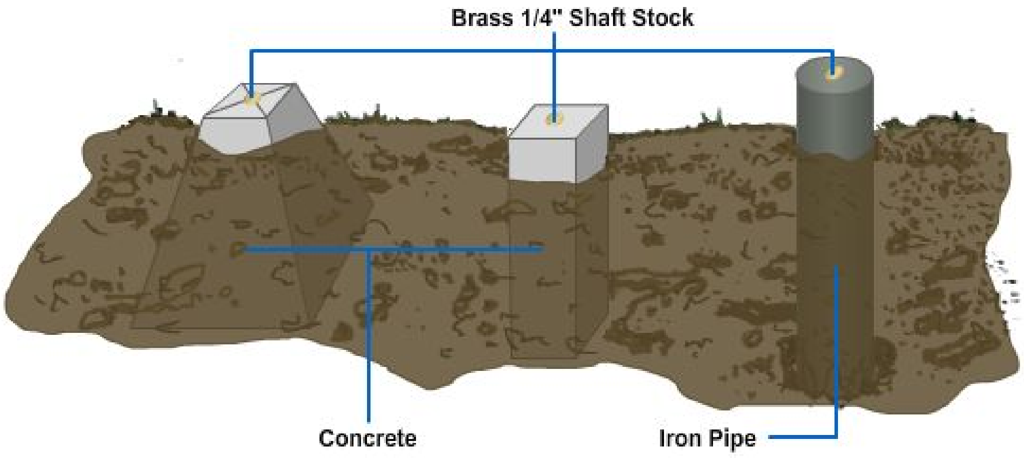


Figure 5-1 – Horizontal control points used also as bench marks.

For short lines and a level circuit of a limited area, any substantial object may be used for vertical control BMs. The remark in the field notes should bear the proper identification of the BMs used.

Figure 5-2 shows a mark like those commonly used on tops of concrete walls, foundations, and the like. Lines are chiseled out with a cold chisel or small star drill and then marked with paint or keel. The chiseled figures should be about the same size as the base area of the rod. They should be placed on some high spot on the surface of the concrete structure.

Figure 5-2 – Points on existing structures used as bench marks.

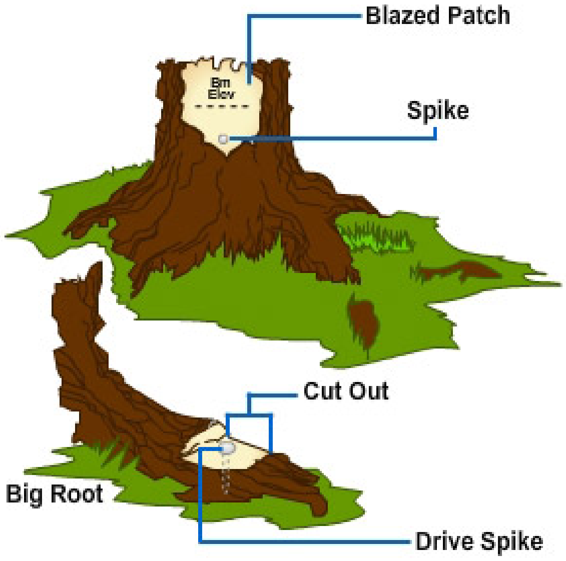


Figure 5-3 – Spikes used as bench marks on trees and roots.

A spike may be driven into the root of a tree or placed higher up on the trunk of the tree when the limb clearance allows higher rod readings. *Figure 5-3* shows the recommended way to do this. Hold the rod on the highest edge of the spike, and mark the elevation on the blazed portion of the tree.

Figure 5-4 shows a spike driven on a pole or post that also represents a BM. Drive the spike in horizontally on the face of the post in line with the direction of the level line. For the reading, hold the rod on the uppermost edge of the spike. After figuring the elevation, mark it on the pole or post for future reference.

Stakes driven into the ground can also be used as TBMs, especially if no frost is expected before they are needed. A detailed description of these points is just as important as one for a monument station.

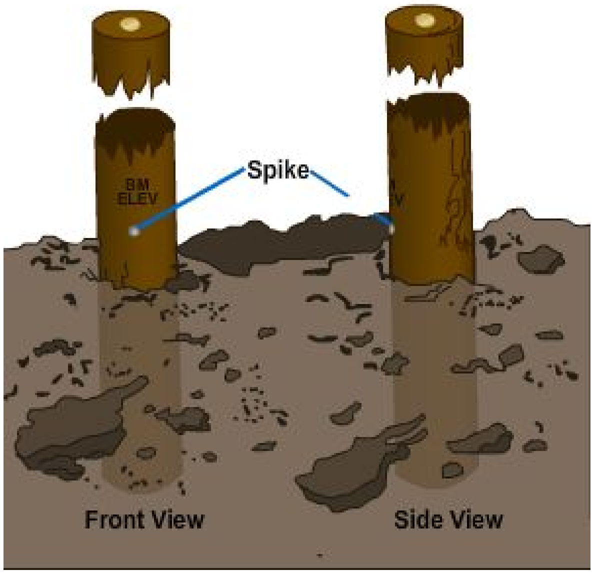


Figure 5-4 – Spikes used as bench marks on poles or posts.

In most permanent military installations, monument BMs are established in a grid system approximately one-half mile apart throughout the base to have a ready reference for elevations of later construction in the station. These BMs are generally fenced to mark their locations. The fence also serves to protect them from being accidentally disturbed.

BM systems or level nets consist of a series of BMs established within a prescribed order of accuracy along closed circuits and tied to a datum. These nets are adjusted by computations that minimize the effects of accidental errors and are identified as being of a specific order of accuracy.

In certain areas, Tidal Bench Marks must be established to obtain the starting datum plane or to check previously established elevations. Tidal bench marks are permanent BMs set on high ground and are tied to the tide station near the water surface.

Tide stations are classified as primary and secondary. Primary stations require observations for periods of nineteen years or more to derive basic tidal data for a locality. Secondary stations are operated over a limited period, usually less than one year, and for a specific purpose, such as checking elevations. The secondary station observations are always compared to, and computed from, data obtained by primary stations.

A tide station is set up, and observations are made for a period that is determined by a desired accuracy. These observations are compared with a primary tide station in the area then furnished with a mean value of sea level in the area.

A closed loop of spirit levels is run from the tide station over the tidal BMs and is tied back to the tide station. The accuracy of this level line must be the same as or higher than the accuracy required for the BMs.

For permanency, tidal BMs usually are set in sets of three and away from the shoreline where natural activity or future construction will not disturb or destroy them.

1.3.0 Datum

Tidal datums are specific tide levels that surveyors (?) use as surfaces of reference for depth measurements in the sea and as a base for determining elevations on land. In leveling operations, the tidal datum most commonly used is the Mean Sea Level.

Surveyors (?) sometimes use other datums, such as mean low water, mean lower low water, mean high water, and mean higher high water, depending upon the purpose of the survey. Still other datums have been used in foreign countries. When conducting leveling operations overseas, check into this matter carefully to avoid mistakes.

1.4.0 Mean Sea Level

Mean sea level (MSL) is the average height of the sea for all stages of the tide after long periods of observations. It is obtained by averaging the hourly heights as they are tabulated on a form similar to that shown in *Figure 5-5*.

Day & Mo		1 Mar	2	3	4	5	6	7	Sum	Remarks:
Hour	0	15.1 Ft.	15.5 Ft.	15.4 Ft.	13.9 Ft.	12.0 Ft.	9.0 Ft.	6.6 Ft.	87.5 Ft.	Tides: Hourly Heights
	1	14.4	15.7	16.6	15.9	14.8	12.1	9.5	99.0	Station: Portsmouth
	2	13.5	15.4	17.0	17.3	17.1	15.1	12.8	108.2	Lat. 44° 50' N
	3	12.5	14.8	16.9	17.9	19.2	19.0	18.0	116.2	Long. 68° 10' W
	4	11.7	14.0	16.5	17.8	19.2	19.0	18.0	116.2	Party Chief EA2 Long
	5	11.6	13.3	15.7	17.3	19.1	19.6	19.4	116.0	Tide Gauge No. 85
	6	12.3	13.2	14.9	16.4	18.5	19.5	19.8	114.6	Scale 1:24
	7	13.7	13.7	14.6	15.5	17.4	18.7	19.5	113.1	Tabulated by EA2 Smith
	8	15.4	15.0	15.0	15.0	16.3	17.6	18.6	112.9	
	9	17.6	16.5	15.9	15.2	15.6	16.3	17.1	114.2	
	10	19.2	18.2	17.2	16.0	15.8	15.6	15.9	117.9	
	11	20.1	19.4	18.5	17.2	16.6	15.6	15.1	122.5	
	12	19.9	19.8	19.4	18.4	17.7	16.3	15.4	126.9	
	13	19.0	19.3	19.7	19.2	18.7	17.5	16.2	129.6	
	14	17.3	18.0	18.9	19.2	19.5	18.4	17.3	128.6	
	15	15.0	15.9	17.3	18.2	19.4	19.0	18.3	123.3	
	16	12.2	13.1	14.8	16.3	18.1	18.6	18.9	112.0	
	17	10.3	10.5	11.8	13.6	15.9	17.1	18.4	97.7	
	18	9.5	8.5	9.2	10.5	13.0	14.7	16.8	82.2	
	19	9.7	7.8	7.4	7.8	9.8	11.5	14.1	68.1	
	20	10.5	8.3	6.7	6.1	7.0	8.1	10.9	57.6	
	21	11.8	9.5	7.5	5.8	5.3	5.6	7.8	53.3	
	22	13.4	11.4	9.1	7.0	5.1	4.2	5.4	55.6	
	23	14.8	13.6	11.4	9.1	6.6	4.6	4.2	64.3	
Sum		340.5	340.4	347.5	346.6	357.1	351.2	352.0	2435.3	

Figure 5-5 – Sample format showing hourly heights of tide required for computing average mean sea level (MSL).

The heights on this form are added both horizontally and vertically. Enter the total sum covering seven days of record in the lower right-hand corner of the page. Find the mean for each calendar month by combining all daily sums for the month and dividing by the total number of hours in the month. Enter the monthly mean, to two decimal places, on the sheet that includes the record for the last day of the month. Yearly means are determined from the monthly means, and a mean is taken of all yearly means for the period of record. Use three or more years of records for a good determination of sea level. The actual value varies somewhat from place to place, but this variation is small.

For MSL determinations, use a station on the open coast or on the shore of bays or harbors having free access to the sea. Stations on tidal rivers at some distance from the open sea will have a mean river level that is higher than mean sea level because of the river slope. Note that mean sea level is NOT identical with mean tide level (MTL). The latter is derived from the mean of all high and low points on the tidal curve. But MSL is derived from the mean of a much larger number of points taken at hourly intervals along the tidal curve.

The datum universally used in leveling is mean sea level (MSL), and it is the zero unit. The vertical distance of a given point above or below this datum then becomes the elevation of that point.

1.5.0 Earthwork Operations

Pioneering refers to the first working over of an area that is overgrown or rough. This makes the area accessible for the equipment needed for the project.

In pioneering, the operations of clearing, stripping, grading, and drainage are all done essentially at the same time, rather than performed as separate operations. A dozer starts out along a predetermined route and leaves a road behind it. This may be a haul road which trucks and equipment will use in later operations.

Suppose you, as a dozer operator, get the job of cutting a road on the side of a mountain to be used for access to a proposed airstrip or to reach a mountain stream to be developed into a water supply system. Where should you start and how should you proceed? A survey party will stake out the route your mountain road is to follow. Start your road at the highest point possible and let the force of gravity help the dozer.

In clearing on sidehill cuts, cast brush and trees far enough to the side of the road that they will not be covered with the earth. It is even better if you can cast them over the edge with an angle blade of the dozer when the road is cut. When cutting the road, do not watch the grade stake immediately ahead or you will find yourself below grade. Instead, watch the third or fourth stake down.

NOTE

It is better to be above grade and come back and cut down to grade than to be below grade and have to come back and fill.

Clearing is a construction operation consisting of cleaning a designated area of trees, timber, brush, other vegetation, and rubbish; removing surface boulders and other material embedded in the ground; and disposing of all material cleared.

Clearing, grubbing, and stripping are different in every climatic zone because each has different types of forests and vegetation. The nature of a forest can be determined from records of the principal climatic factors, including precipitation, humidity, temperature, sunlight, and the direction of prevailing winds. The types of forests can be generally classified as temperate, rain, monsoon, or dry, according to the climates in which they exist.

Clearing usually consists of pushing uprooted trees, stumps, and brush in both directions from the center of the area to be cleared. Clear so that you place debris, also known as spoil material, in a designated spot with only one handling. In clearing landing strips, for example, it is generally necessary to dispose of material along each side of the strip outside the construction site. If the site permits burning, you can reduce the haul distance by piling brush, stumps, and trees on the site and burning them. Production in this field must be estimated, rather than calculated.

Grubbing is uprooting and removing roots and stumps. In grubbing, burn or blast stumps that are difficult or impossible to pull out, even with winches. Your supervisor will decide the method. If the stumps are to be removed by blasting, call upon a qualified blaster to do the job. If they are to be burned, you may be assigned the task. Green stumps require continuous application of heat before they catch fire. Check with your supervisor about safety measures to keep the fire from getting out of control if you have to do any stump burning. Remember, it may take as long as three or four days for a stump to burn out. Keep a check on the burning during this period. If a project has a high priority and time must be saved, you will probably blast stumps, rather than burn them. After removing stumps, fill the holes and level the area to prevent the accumulation of water.

Stripping is removing and disposing of objectionable topsoil and sod. It may either follow or be done with clearing and grubbing. Actual earthmoving begins with stripping; surface soil and rocks are removed from the area to be excavated. Deeply embedded rocks and large boulders may have to be blasted before they can be removed.

The material removed by stripping is called spoil. Unless otherwise directed, dump spoil along the area to be excavated within range of the earthmoving equipment. If the spoil will not be put to some use like turfing or finishing the shoulder of a road or runway, waste it along the edges of the project, as shown in *Figure 5-6*. Take care not to disturb necessary drainage.

Figure 5-6 – Stripping.

Equipment commonly used in stripping consists of a dozer, a scraper, and a grader. As mentioned earlier, the dozer is the most often used when removing trees. Dozers can handle all short-haul excavations up to 300 feet. For long-haul excavations over 300 feet, use scrapers. You may also use a scraper on fine soils for shallow stripping. Use a grader mainly for shaping and finishing a stripped surface. It is adaptable also for ditching, side casting, and sloping banks.

Drainage is the construction of facilities needed to allow excess surface and subsurface water to flow from the construction site. Properly designed and constructed drainage systems are one of the most important parts of a construction project. Without proper drainage, rainwater and water running off the surrounding ground could turn the area into a lake. It is also necessary to drain off surface water that would soak down and wet the subgrade.

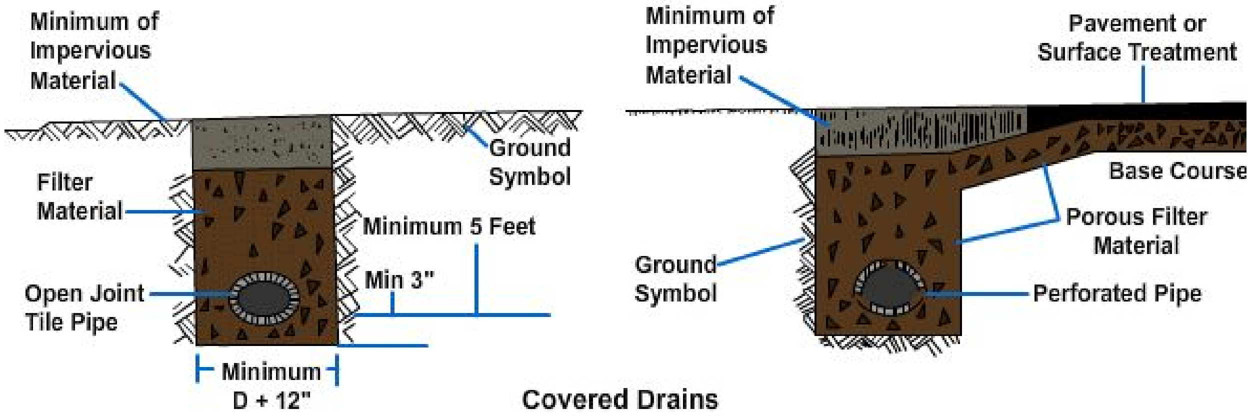
The elements determining drainage needs for a road or project site are the amount of annual rainfall in the area and the routes or areas that can be used to collect or channel excess surface and subsurface water. These areas include lakes, ponds, streams, or voids such as gullies.

The type of soil is critical to the design and construction of a road. It is poor judgment to construct a road over or through clay, sand, or other undesirable material if it cannot be properly compacted. Bypassing this type of material is best.

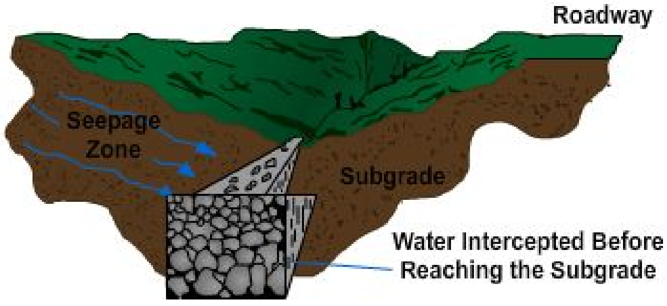
If a road surface is to endure continued use for years, it must have firm support from the subgrade. Remove all organic materials, such as living or decayed vegetation, from the area of the subgrade unless the road is for emergencies or is temporary, such as a detour or military road. In designing and building a road, consider the type of drainage, the type of soil, and the amount of clearing or grubbing necessary.

To facilitate drainage, excavate diversion ditches to conduct all surface water into natural channels or outfall ditches. Construct outfall ditches to drain low or boggy spots. At the point or the end of the system where the accumulated runoff discharges into the disposal point, the runoff is technically known as discharge**.** The discharge point in the system is called the outfall**.** This preliminary drainage work is done at the same time the area is cleared and grubbed.

The finished drainage system usually consists of ground slopes, ditches, culverts, gutters, storm drains, and underground water drains. Use open channels to intercept or control surface water. These should be dug by bulldozers, scrapers, backhoes, or motor graders, depending on the circumstances. Construct culverts to drain water across a construction site. Subdrains to drain groundwater are usually excavated with ditchers or backhoes. The drains used are French drains, which are perforated or open-joint tile pipes. *Figure 5-7* shows typical covered and French drains.



Covered Drains



French Drains

Figure 5-7 – Typical sections of covered and French drains.

Remove runoff water from rain or melted snow from the area by constructing an adequate transverse slope or crown. This runoff collects in ditches and drains into the nearest natural drainage channel. Drainage for construction sites can be provided by building the ends of the site sloping towards the middle or sloping from one end to the other. These types of drainage construction are shown on the runways in *Figure 5-8*.

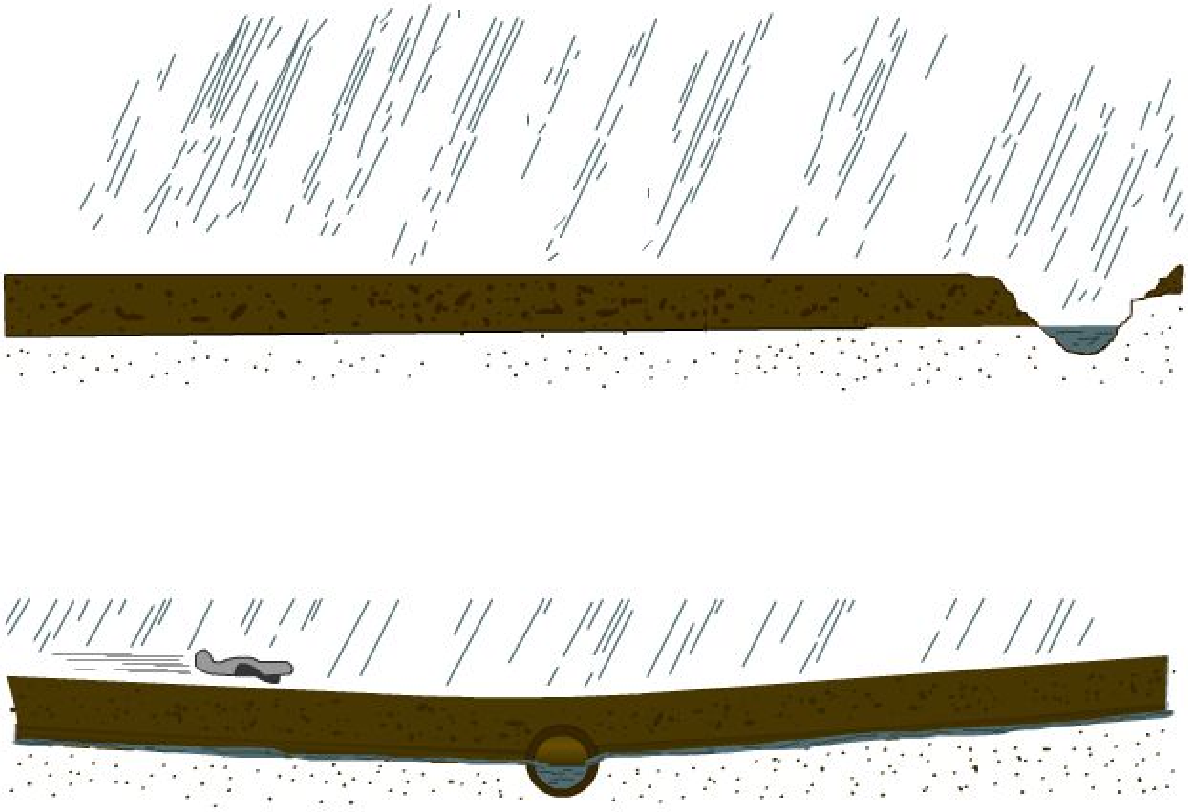
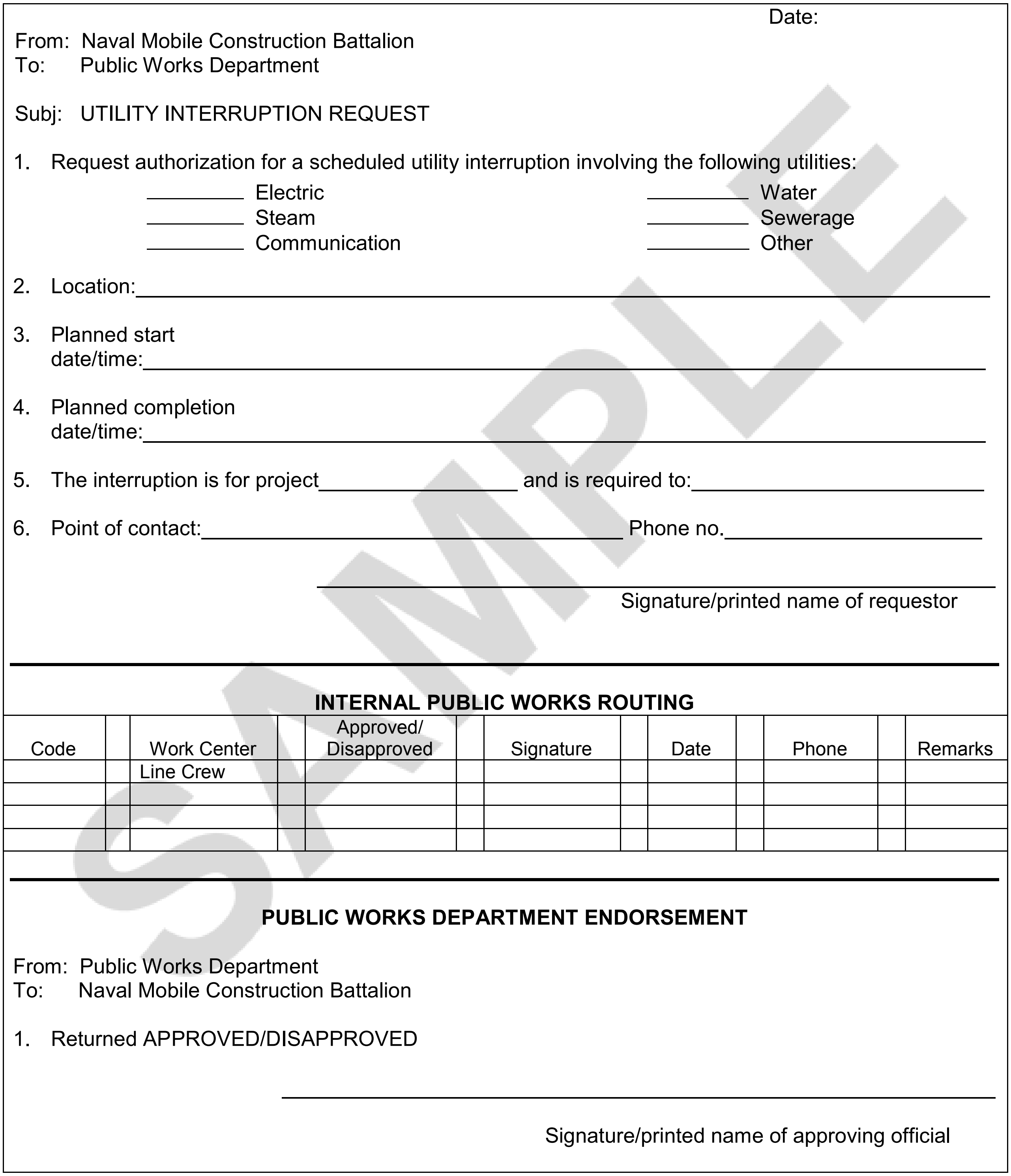


Figure 5-8 – Longitudinal drainage of runways.

2.0.0 PERMITS

Construction projects require pulling of permits at many stages. These permits include the Utility Interruption Request shown in *Figure 5-9*, the Excavation Request shown in *Figure 5-10*, and the Road Closure Request shown in *Figure 5-11*.



Date:

From: Naval Mobile Construction Battalion
To: Public Works Department

Subj: UTILITY INTERRUPTION REQUEST

1. Request authorization for a scheduled utility interruption involving the following utilities:

_________ Electric
_________ Steam
_________ Communication
_________ Water
_________ Sewerage
_________ Other

2. Location:____

3. Planned start date/time:____

4. Planned completion date/time:____

5. The interruption is for project_________________ and is required to:_________________________

6. Point of contact:_____________________________________ Phone no._______________________

____
Signature/printed name of requestor

INTERNAL PUBLIC WORKS ROUTING

Code		Work Center		Approved/ Disapproved		Signature		Date		Phone		Remarks
		Line Crew										

PUBLIC WORKS DEPARTMENT ENDORSEMENT

From: Public Works Department
To: Naval Mobile Construction Battalion

1. Returned APPROVED/DISAPPROVED

____
Signature/printed name of approving official

Figure 5-9 – Form for a Road Closure Request.

Date:

From: Naval Mobile Construction Battalion
To: Public Works Department

Subj: EXCAVATION REQUEST

1. Request authorization to excavate for the purpose of (describe excavation):

2. Method of excavation:____

3. Planned start date:

4. Planned completion date (including backfill, compaction, ground cover, paving repair, etc.):

5. The excavation is for project________________ and is required to:____________________

6. Point of contact:__________________________________ Phone no.__________________

7. Sketch showing location of planned excavation is attached (mandatory).

____
Signature/printed name of requestor

INTERNAL PUBLIC WORKS ROUTING

Code		Work Center		Approved/ Disapproved		Signature		Date		Phone		Remarks
		Line Crew										
		Water Crew										
		Engineering										

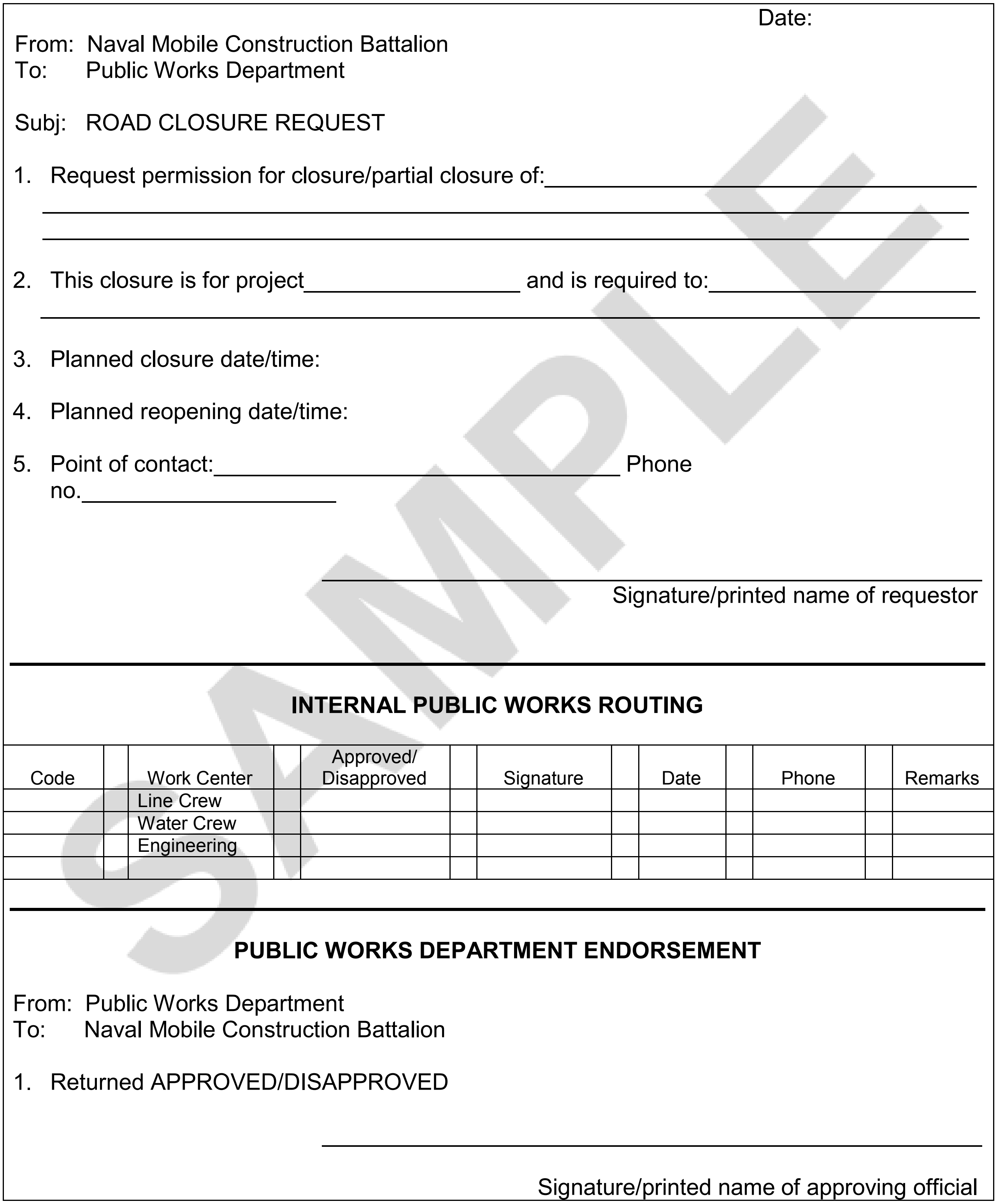
PUBLIC WORKS DEPARTMENT ENDORSEMENT

From: Public Works Department
To: Naval Mobile Construction Battalion

1. Returned APPROVED/DISAPPROVED

____
Signature/printed name of approving official

Figure 5-10 – Form for an Excavation Request.



Date:

From: Naval Mobile Construction Battalion
To: Public Works Department

Subj: ROAD CLOSURE REQUEST

1. Request permission for closure/partial closure of:___________________________________
____
____

2. This closure is for project_________________ and is required to:______________________
____

3. Planned closure date/time:

4. Planned reopening date/time:

5. Point of contact:_________________________________ Phone no.____________________

____
Signature/printed name of requestor

INTERNAL PUBLIC WORKS ROUTING

Code		Work Center		Approved/ Disapproved		Signature		Date		Phone		Remarks
		Line Crew										
		Water Crew										
		Engineering										

PUBLIC WORKS DEPARTMENT ENDORSEMENT

From: Public Works Department
To: Naval Mobile Construction Battalion

1. Returned APPROVED/DISAPPROVED

____
Signature/printed name of approving official

Figure 5-11 – Form for an Excavation Request.

3.0.0 SURVEYING INSTRUMENTS

The engineer's level, often called the ***dumpy level***, is the instrument most commonly used to attain the level line of sight required for differential leveling, which is defined later. The dumpy level and the self-leveling level can be mounted for use on a tripod, usually with adjustable legs, shown in *Figure 5-12*.

Mount the level by engaging threads at the base of the instrument, called the footplate, with the threaded head on the tripod. These levels are the ones most frequently used in ordinary leveling projects. For rough leveling, use the ***hand level***.

Figure 5-12 – Tripod.

3.1.0 Dumpy Level

Figure 5-13 shows a dumpy level and its nomenclature. Notice that the telescope is rigidly fixed to the supporting frame.

Inside the telescope is a ring, or diaphragm, known as the reticle, which supports the cross hairs. The cross hairs are brought into exact focus by manipulating the knurled eyepiece focusing ring near the eyepiece, or the eyepiece itself on some models. If the cross hairs get out of horizontal adjustment, they can be made horizontal again by slackening the reticle adjusting screws and turning the screws in the appropriate direction. Only trained personnel should perform this adjustment.

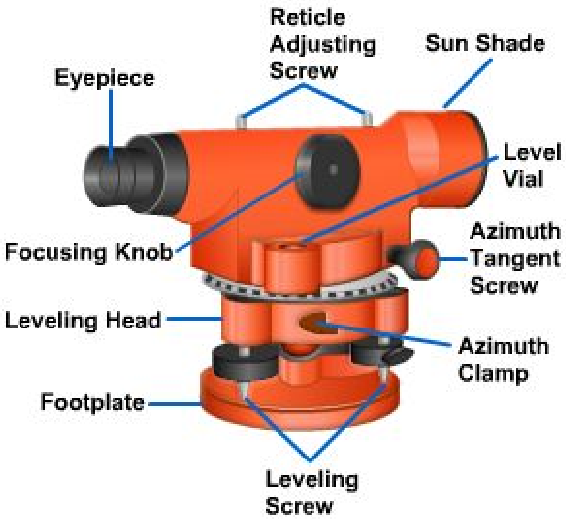


Figure 5-13 – Dumpy level.

The object to which you are sighting, regardless of shape, is called a target. Bring the target into clear focus by manipulating the focusing knob shown on top of the telescope. The telescope can be rotated only horizontally, but before it can be rotated, release the azimuth clamp. Train the telescope as nearly on the target as you can, and then tighten the azimuth clamp. Bring the vertical cross hair into exact alignment on the target by rotating the azimuth tangent screw.

The level vial, leveling head, leveling screws, and footplate are all used to adjust the instrument to a perfectly level line of sight once it is mounted on the tripod.

3.2.0 Self-Leveling Level

Figure 5-14 – Self-leveling level.

The self-leveling, or automatic, level, shown in *Figure 5-14* is a precise, time-saving development in leveling instruments. It did away with the tubular spirit level, whose bubble takes time in centering as well as in resetting to its correct position from time to time during operation.

The self-leveling level is equipped with a small bull's-eye level and three leveling screws. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull's-eye level approximately. The line of sight automatically becomes horizontal and remains horizontal as long as the bubble remains approximately centered. A prismatic device called a compensator makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that defines a horizontal sight. The level maintains this horizontal line of sight despite a slight out of level of the telescope or even when a slight disturbance occurs on the instrument.

3.3.0 Hand Level

Figure 5-15 – Locke level.

The hand level, like all surveying levels, combines a level vial and a sighting device. *Figure 5-15* shows the ***Locke level***, a type of hand level. A horizontal line, called an index line, is provided in the sight tube as a ***reference line***. The level vial is mounted atop a slot in the sighting tube in which a reflector is set at a 45° angle. This permits the observer sighting through the tube to see the object, the position of the level bubble in the vial, and the index line at the same time.

To get the correct sighting through the tube, stand straight, using the height of your eye, if known, above the ground to find the target. When your eye height is not known, you can find it by sighting the rod at eye height in front of your body. Since the distances over which you sight a hand level are rather short, no magnification is provided in the tube.

3.4.0 Setting Up a Level

After you select the proper location for the level, your first step is to set up the tripod.

1. Spread two of the legs a convenient distance apart and then bring the third leg to a position that will bring the protector cap, which covers the tripod head threads, about level when the tripod stands on all three legs.
2. Unscrew the protector cap, exposing the threaded head, and place it in the carrying case where it will not get lost or dirty. The tripod protective cap should be in place when you are not using the tripod.
3. Lift the instrument out of the carrying case by the footplate, not by the telescope.
4. Set the instrument squarely and gently on the tripod head threads and engage the head nut threads under the footplate by rotating the footplate clockwise. If the threads will not engage smoothly, they may be cross threaded or dirty. Do not force them if you encounter resistance; instead, back off, and, after checking to see that they are clean, square up the instrument, and then try again gently.
5. Screw the head nut up firmly, but not too tightly. Screwing it too tightly causes eventual wearing of the threads and makes unthreading difficult.
6. After you have attached the instrument, thrust the leg tips into the ground far enough to ensure that each leg has stable support, taking care to maintain the footplate as nearly level as possible.
7. With the instrument mounted and the legs securely positioned in the soil, firmly tighten the thumbscrews at the top of each leg to prevent any possible movement.

Quite frequently, you must set up the instrument on a hard, smooth surface, such as a concrete pavement. When you do, you must take steps prevent the legs from spreading. *Figure 5-16* shows two good ways of doing this. In *View A*, the tips of the legs are inserted in joints in the pavement. In *View B*, the tips are held by a wooden floor triangle.

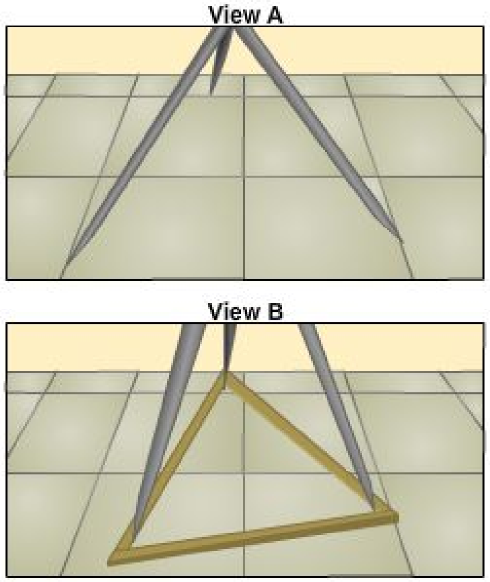


Figure 5-16 – Methods of preventing tripod legs from spreading.

3.5.0 Leveling a Level

To function accurately, the level must provide a perfectly horizontal line of sight in any direction you train the telescope. To ensure this, you must level the instrument as discussed in the next paragraphs.

When you first set up the tripod and instrument, make the footplate as nearly level as possible.

1. Train the telescope over a pair of diagonally opposite leveling screws, and clamp it in that position.
2. Manipulate the leveling thumbscrews, as shown in *Figure 5-17,* to bring the bubble in the level vial exactly into the marked center position. Manipulate the thumbscrews by simultaneously turning them in opposite directions. This shortens one spider leg, the threaded member running through the thumbscrew, while it lengthens the other. It is helpful to remember that the level vial bubble will move in the same direction that your left thumb moves while you rotate the thumbscrews. In other words, when your left thumb pushes the thumbscrew clockwise, the bubble will move towards your left hand; when you turn the left thumbscrew counterclockwise, the bubble moves toward your right hand.
3. After leveling the telescope over one pair of screws, train it over the other pair and repeat the process. As a check, set the telescope in all four possible positions and be sure that the bubble centers exactly in each.

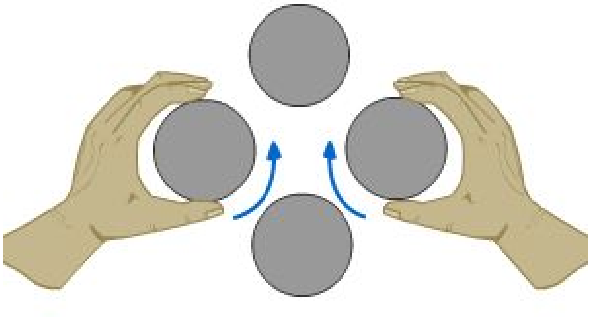


Figure 5-17 – Manipulating leveling thumbscrews.

Various techniques for using the level will develop with experience. In this section, we will discuss only the techniques we believe essential to the Builder rating.

3.6.0 Care of Levels

An engineer’s level is a precision instrument containing many delicate and fragile parts. Handle it gently and with the greatest care at all times; never subject it to shock or jar. Movable parts, if not locked or clamped in place, should work easily and smoothly. If a movable part resists normal pressure, something is wrong. Forcing the part to move will probably damage the instrument. Tightening clamps and screws excessively will also cause wear or damage.

The only proper place to stow the instrument when it is detached from the tripod is in its own carrying box or case. The carrying case is designed to reduce the effect of jarring to a minimum. It is strongly made and well padded to protect the instrument from damage. Before stowing, slightly tighten the azimuth clamp and leveling screws to prevent movement of parts inside the box. When transporting it in a vehicle, place the case containing the instrument as near as possible midway between the front and rear wheels. This is the point where jarring of the wheels has the least effect on the chassis.

Never lift the instrument out of the case by grasping the telescope. Wrenching the telescope in this manner will damage a number of delicate parts. Lift it out by reaching down and grasping the footplate or the level bar.

When you attach the instrument to the tripod and carry it from one point to another, set up the azimuth clamp and level screws tightly enough to prevent part motion during the transport but loosely enough to allow give in case of an accidental bump against some object. When you are carrying the instrument over terrain that is free of possible contacts, such as across an open field, you may carry it over your shoulder like a rifle. When there are obstacles around, carry it as shown in *Figure 5-18*. Carried in this manner, the instrument is always visible to you, and this makes it possible for you to avoid striking it against obstacles.

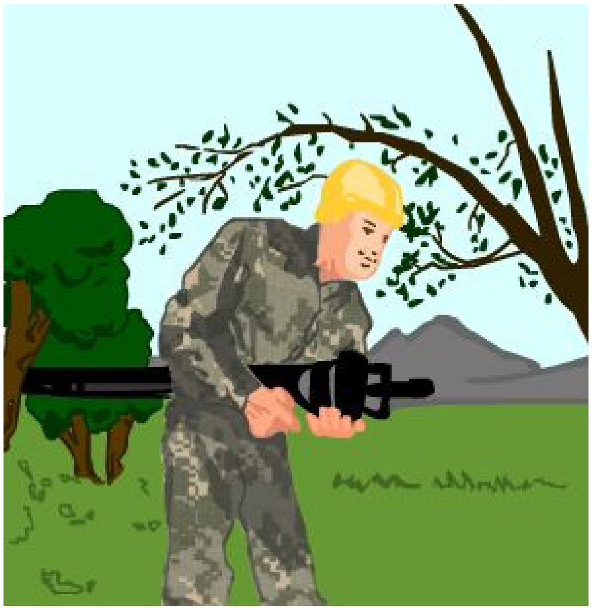


Figure 5-18 – Safest carrying position for instrument when obstacles may be encountered.

3.7.0 Leveling Rods

A leveling rod is a vertically supported tape used to measure vertical distance, which is the difference in elevation, between a line of sight and a required point above or below it. Although there are several types of rods, the most popular and frequently used is the ***Philadelphia rod***. *Figure 5-19* shows the face and back of this rod.

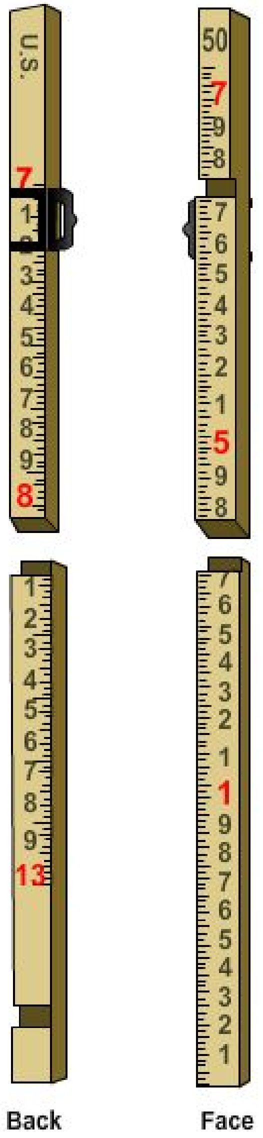


Figure 5-19 – Back and face of Philadelphia leveling rod.

The Philadelphia rod consists of two sliding sections, which can be fully extended to a total length of 13.10 feet. When the sections are entirely closed, the total length is 7.10 feet. For direct readings, or readings on the face of the rod, of up to 7.10 and 13.10 feet, the rod is used extended and read on the back by the rodman. If you are in the field and don't have a Philadelphia rod, you can use a 1 by 4 with a mark or a 6 foot wooden ruler attached to a 2 by 4.

In direct readings, the person at the instrument reads the graduation on the rod intercepted by the cross hair through the telescope. In target readings, the rodman reads the graduation on the face of the rod intercepted by a target. In *Figure 5-19* the target does not appear; it is shown in *Figure 5-20*. It is a sliding, circular device that can be moved up or down the rod and clamped in position. The rodman places it on signals from the instrumentman.

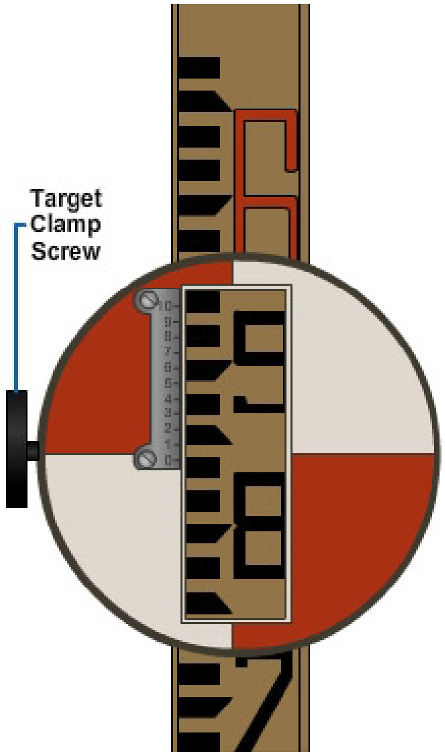


Figure 5-20 – Philadelphia rod set for target reading of less than 7,000 feet.

The rod shown in the figures is graduated in feet and hundredths of a foot. Each even foot is marked with a large red numeral. Between each pair of adjacent red numerals, the intermediate tenths of a foot are marked with smaller black numerals. Each intermediate hundredth of a foot between each pair of adjacent tenths is indicated by the top or bottom of one of the short, black dash graduations.

3.7.1 Direct Readings

As the levelman, you can make direct readings on a self-reading rod held plumb on the point by the rodman. If you are working to tenths of a foot, it is relatively simple to read the footmark below the cross hair and the tenth mark that is closest to the cross hair. If greater precision is required, and you must work to hundredths, the reading is more complicated, as shown in *Figure 5-21*.

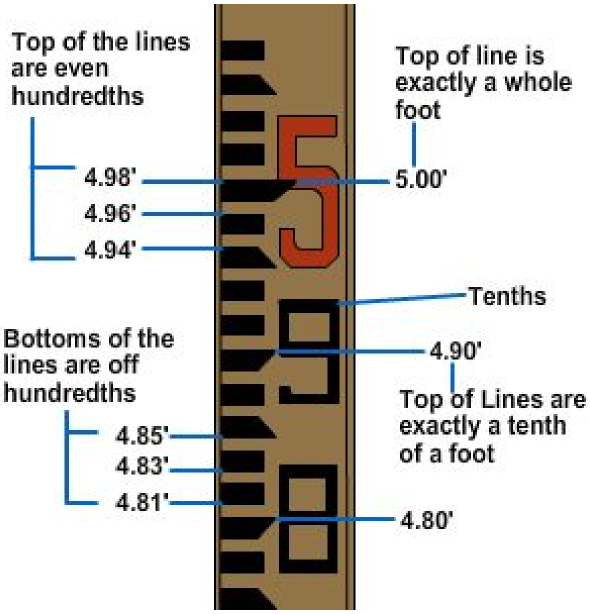


Figure 5-21 – Philadelphia rod marking.

For example, suppose you are making a direct reading that should come out to 5.67 feet. If you are using a Philadelphia rod, the interval between the top and the bottom of each black graduation and the interval between the black graduations each represent 0.01 foot.

This is shown in *Figure 5-22*, where each graduation represents 0.01 foot. For a reading of 5.76 feet, there are three black graduations between the 5.70 foot mark and the 5.76 foot mark. Since there are three graduations, a beginner may have a tendency to misread 5.76 feet as 5.73 feet.

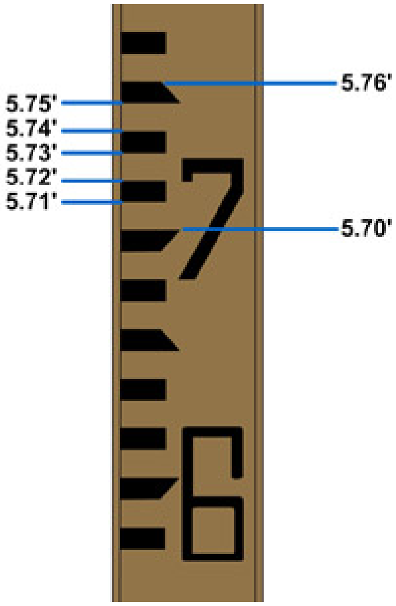
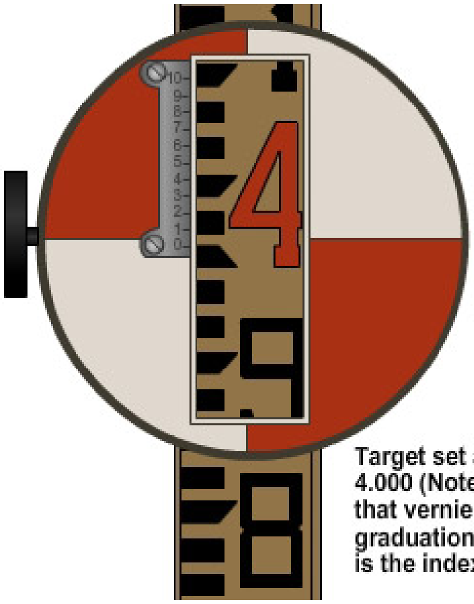


Figure 5-22 – Direct reading of 5.76 feet on a Philadelphia rod.

Neither the 5 foot mark nor the 6 foot mark is shown in *Figure 5-22*. Sighting through the telescope, you might not be able to see the foot marks to which you must refer for the reading. When you cannot see the next lower foot mark through the telescope, it is a good idea to order the rodman to “raise the red”**.** On the Philadelphia rod, whole feet numerals are in red. Upon hearing this order, the rodman slowly raises the rod until the next lower red figure comes into view.

3.7.2 Target Readings



Target set at 4.000 (Note that vernier graduation 0 is the index)

Figure 5-23 – Target.

For more precise vertical measurements, level rods may be equipped with a rod target that can be set and clamped by the rodman at the direction of the instrumentman. When the engineer's level rod target and the vernier scale are being used, it is possible to make readings of one thousandth of a foot (0.001), which is slightly smaller than one sixty-fourth of an inch. Either the rodman or the instrumentman can read the indicated reading of the target. In *Figure 5-23*, you can see that the 0 on the vernier scale is in exact alignment with the 4 foot mark. If the position of the 0 on the target is not in exact alignment with a line on the rod, go up the vernier scale on the target to the line that is in exact alignment with the hundredths line on the rod, and the number located will be the reading in thousandths.

There are three situations in which target reading, rather than direct reading, is done on the face of the rod:

- When the rod is too far from the level to be read directly through the telescope.
- When a reading to the nearest 0.001 foot, rather than to the nearest 0.01 foot, is desired. A vernier on the target or on the back of the rod makes this possible.
- When the instrumentman wants to ensure against the possibility of reading the wrong foot designation on the rod, indicated by a large red number.

For target readings up to 7.000 feet, the rod is used fully closed, and the rodman, on signals from the instrumentman, sets the target at the point where its horizontal axis is intercepted by the cross hair, as seen through the telescope. When the target is located, it is clamped in place with the target screw clamp, shown in *Figure 5-20*. When a reading to only the nearest 0.01 foot is desired, the graduation indicated by the target's horizontal axis is read; in *Figure 5-20*, this reading is 5.84 feet.

If reading to the nearest 0.001 foot is desired, the rodman reads the vernier, the small scale running from 0 to 10, on the target. The 0 on the vernier indicates that the reading lies between 5.840 feet and 5.850 feet. To determine how many thousandths of a foot over 5.840 feet, examine the graduations on the vernier to determine which one is most exactly in line with a graduation, the top or bottom of a black dash, on the rod. In *Figure 5-20*, this graduation on the vernier is the 3; so the reading to the nearest 0.001 foot is 5.843 feet.

For target readings of more than 7.000 feet, the procedure is a little different. If you look at the left-hand view of *Figure 5-19* showing the back of the rod, you will see that only the back of the upper section is graduated and that it is graduated downward from 7.000 feet at the top to 13.09 feet at the bottom. You can also see there is a rod vernier fixed to the top of the lower section of the rod. This vernier is read against the graduations on the back of the upper section.

For a target reading of more than 7.000 feet, the rodman first clamps the target at the upper section of the rod. Then, on signals from the instrumentman, the rodman extends the rod upward to the point where the horizontal axis of the target is intercepted by the cross hair. The rodman then clamps the rod, using the rod clamp screw shown in *Figure 5-24*, and reads the vernier on the back of the rod, also shown in that figure. In this case, the 0 on the vernier indicates a certain number of thousandths more than 7.100 feet. Remember that in this case, you read the rod and the vernier down from the top, not up from the bottom. To determine the thousandths, determine which vernier graduation lines up most exactly with a graduation on the rod. In this case, it is the 7, so the rod reading is 7.107 feet.

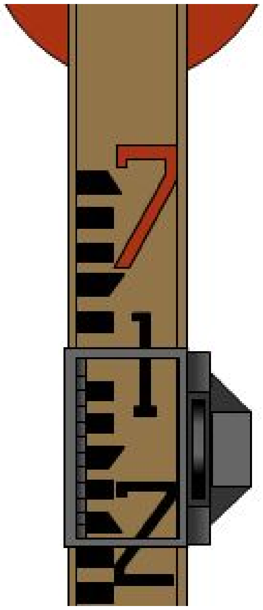


Figure 5-24 – Philadelphia rod target reading of more than 7,000 feet.

3.7.3 Rod Levels

A rod reading is accurate only if the rod is perfectly plumb, or vertical, at the time of the reading. If the rod is out of plumb, the reading will be greater than the actual vertical distance between the height of instrument (HI) and the base of the rod. On a windy day, the rodman may have difficulty holding the rod plumb. In this case, the levelman can have the rodman wave the rod back and forth, allowing the levelman to read the lowest reading touched on the engineer's level cross hairs.

The use of a rod level ensures a vertical rod. A bull's-eye rod level is shown in *Figure 5-25*. When it is held as shown and the bubble is centered, the rod is plumb. Note that the rod is held on a part of the rod where readings are not being taken to avoid interference with the instrumentman's view of the scale.

A vial rod level has two spirit vials, each of which is mounted on the upper edge of one of a pair of hinged metal leaves. The vial level is used like the bull's-eye level, except that two bubbles must be watched instead of one.

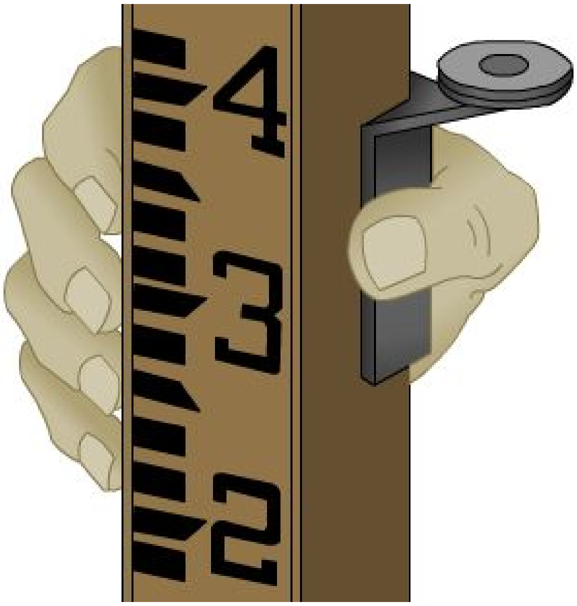


Figure 5-25 – Bull's eye rod level.

3.7.4 Care of Leveling Rods

A leveling rod is a precision instrument and must be treated as such. Most rods are made of carefully selected, kiln dried, well seasoned hardwood. Scale graduations and numerals on some are painted directly on the wood; on most rods they are painted on a metal strip attached to the wood. Unless a rod is handled at all times with great care, the painted scale will soon become scratched, dented, worn, or otherwise marked and obscured. Accurate readings on a damaged scale are difficult.

Allowing an extended sliding section rod to close on the run by permitting the upper section to drop may jar the vernier scale out of position or otherwise damage the rod. Always close an extended rod by easing the upper section down gradually.

A rod will read accurately only if it is perfectly straight. Anything that might bend or warp the rod must be avoided. Do not lay a rod down flat unless it is supported throughout, and never use a rod for a seat, lever, or pole vault. In short, never use a rod for any purpose except the one for which it is designed.

Store a rod that is not in use in a dry place to avoid warping and swelling caused by dampness. Always wipe off a wet rod before putting it away. If there is dirt on the rod, rinse it off, but do not scrub it off. If you must use a soap solution; to remove grease, for example; use a very mild one. A strong soap solution will soon cause the paint on the rod to degenerate.

Protect a rod as much as possible against prolonged exposure to strong sunlight. Such exposure causes paint to chalk, to degenerate into a chalk-like substance that flakes from the surface.

4.0.0 DIFFERENTIAL LEVELING

The most common procedure for determining elevations in the field, or for locating points at specified elevations, is known as differential leveling. This procedure is finding the vertical difference between the known or assumed elevation of a bench mark (BM) and the elevation of the point in question. Once the difference is measured, it can be added to or subtracted from the bench mark elevation to determine the elevation of the new point.

4.1.0 Elevation and Reference

The elevation of any object is its vertical distance above or below an established height on the earth’s surface. This established height is called either a reference plane or a simple reference. The most commonly used reference plane for elevations is mean, or average, sea level, which has been assigned an assumed elevation of 000.0 feet. The reference plane for a construction project is usually the height of some permanent or semi-permanent object in the immediate vicinity, such as the rim of a manhole cover, a rod, or the finish floor of an existing structure. This object may be given its relative sea level elevation, if it is known; or it may be given a convenient, arbitrarily assumed elevation, usually a whole number, such as 100.0 feet. An object of this type, which is used to determine the elevations of other points with a given, known, or assumed elevation, is called a bench mark.

4.1.1 Principles of Differential Leveling

Figure 5-26 illustrates the principle of differential leveling. The instrument shown in the center is an engineer's level. This optical instrument provides a perfectly level line of sight through a telescope, which can be trained in any direction. Point A in the figure is a bench mark having a known elevation of 365.01 feet. It could be a concrete monument, a wooden stake, a sidewalk curb, or any other object. Point B is a ground surface point whose elevation needs to be determined.

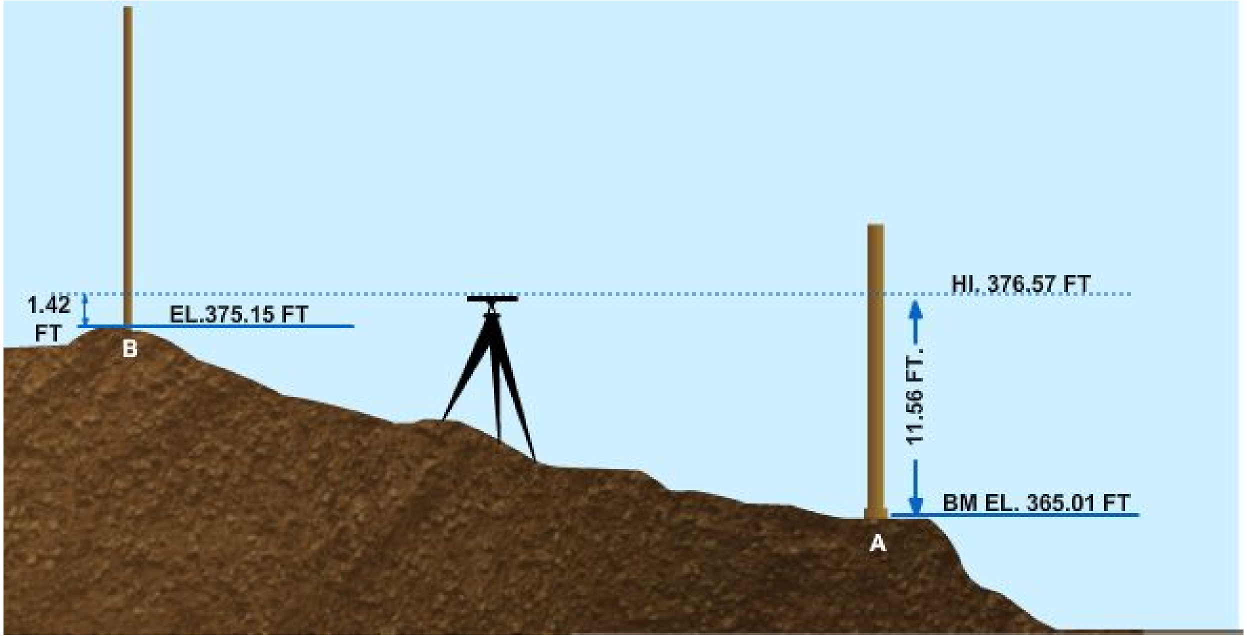


Figure 5-26 – Procedure for differential leveling.

The first step in finding the elevation point of point B is to determine the elevation of the line of sight of the instrument. This is known as the height of instrument and is often written and referred to simply as HI.

1. To determine the HI, take a backsight on a level rod held vertically on the bench mark (BM) by a rodman. A backsight (BS) is always taken after setting up a new instrument position by sighting back to a known elevation to get the new HI. A leveling rod is graduated upward in feet, from 0 at its base, with appropriate subdivisions in feet.

   In *Figure 5-25*, the backsight reading is 11.56 feet. The elevation of the line of sight (HI) must be 11.56 feet greater than the bench mark elevation, point A. The HI is 365.01 feet plus 11.56 feet, or 376.57 feet as indicated.
2. Train the instrument ahead on another rod; or more likely, on the same rod carried ahead, held vertically on B. This is known as taking a foresight. After reading a foresight (FS) of 1.42 feet on the rod, you see that the elevation at point B must be 1.42 feet lower than the HI. The elevation of point B is 376.57 feet minus 1.42 feet, or 375.15 feet.

5.0.0 SITE / BUILDING LAYOUT

Before foundation and footing excavation for a building can begin, the building lines must be laid out to determine the boundaries of the excavations. Points shown on the plot plan, such as building corners, are located at the site from a system of horizontal control points established by the battalion engineering aids. This system consists of a framework of stakes, driven pipes, or other markers located at points of known horizontal location. A point in the structure, such as a building corner, is located on the ground by reference to one or more nearby horizontal control points.

5.1.0 Locating Corner Points

We cannot describe here all the methods of locating a point with reference to a horizontal control point of a known horizontal location. We will take the situation shown in *Figure 5-25* as an example. This figure shows two horizontal control points, consisting of monuments A and B. The term monument doesn’t necessarily mean an elaborate stone or concrete structure. In structural horizontal control, it simply means any permanently located object, either artificial, such as a driven length of pipe, or natural, such as a tree, of known horizontal location.

In *Figure 5-27*, the straight line from A to B is a control base line from which you can locate the building corners of the structure. You can locate corner E, for example, by first measuring 15 feet along the base line from A to locate point C; then measuring off 35 feet on CE, laid off at 90° to, or perpendicular to, AB. By extending CE another 20 feet, you can locate building corner F. Corners G and H can be similarly located along a perpendicular run from point D, which is itself located by measuring 55 feet along the base line from A.

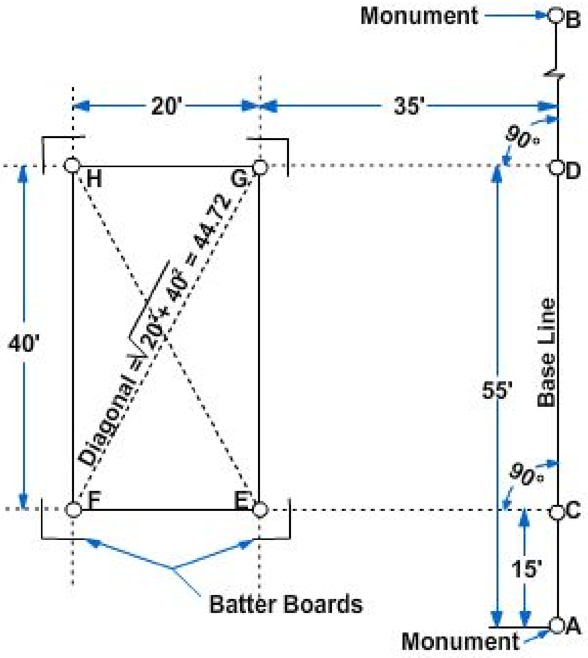


Figure 5-27 – Locating building corners.

5.1.1 Perpendicular by Pythagorean Theorem

The easiest and most accurate way to locate points on a line or to turn a given angle, such as 90°, from one line to another is to use a surveying instrument called a transit. If you do not have a transit, you can locate the corner points with tape measurements by applying the Pythagorean Theorem.

1. Stretch a cord from monument A to monument B.

2. Locate points C and D by tape measurements from A.
3. If you examine *Figure 5-25*, you will observe that straight lines connecting points C, D, and E form a right triangle with one side 40 feet long and the adjacent side 35 feet long. By the Pythagorean Theorem, the length of the hypotenuse of this triangle, the line ED, is equal to the square root of $35^2 + 40^2$, which is approximately 53.1 feet. Because figure EG DC is a rectangle, the diagonals both ways, ED and CG, are equal. The line from C to G should also measure 53.1 feet.
4. Have one person hold the 53.1 foot mark of a tape on D, have another hold the 35 foot mark of another tape on C, and have a third person walk away with the joined 0 foot ends. When the tapes come taut, the joined 0 foot ends will lie on the correct location for point E. The same procedure, but this time with the 53.1 foot length of tape running from C and the 35 foot length running from D, will locate corner point G. Corner points F and H can be located by the same process, or by extending CE and DG 20 feet.

The equation for the Pythagorean Theorem is as follows:

$$C^2 = A^2 + B^2$$

C is the hypotenuse that you are solving for. A and B are the lengths of the two known sides. When you solve for C, you get the following formula:

$$C= \sqrt{A^2 + B^2}$$

5.1.2 Perpendicular by 3:4:5 Triangle

If you would rather avoid the square root calculations required in the Pythagorean Theorem method, you can apply the basic fact that any triangle with sides in the proportions of 3:4:5 is a right triangle. In locating point E, you know that this point lies 35 feet from C on a line perpendicular to the base line. You also know that a triangle with sides 30 and 40 feet long and a hypotenuse 50 feet long is a right triangle.

1. To get the 40 foot side, measure off 40 feet from C along the base line. In *Figure 5-25*, the segment from C to D happens to measure 40 feet.
2. Run a 50 foot tape from D and a 30 foot tape from C. The joined ends will lie on a line perpendicular from the base line, 30 feet from C.
3. Drive a hub at this point.
4. Extend the line to E, 5 more feet, by stretching a cord from C across the mark on the hub.

5.2.0 Batter Boards

Hubs driven at the exact locations of building corners will be disturbed as soon as the excavation for the foundation begins. To preserve the corner locations, and to provide a reference for measurement down to the prescribed elevations, erect batter boards as shown in *Figure 5-28*.

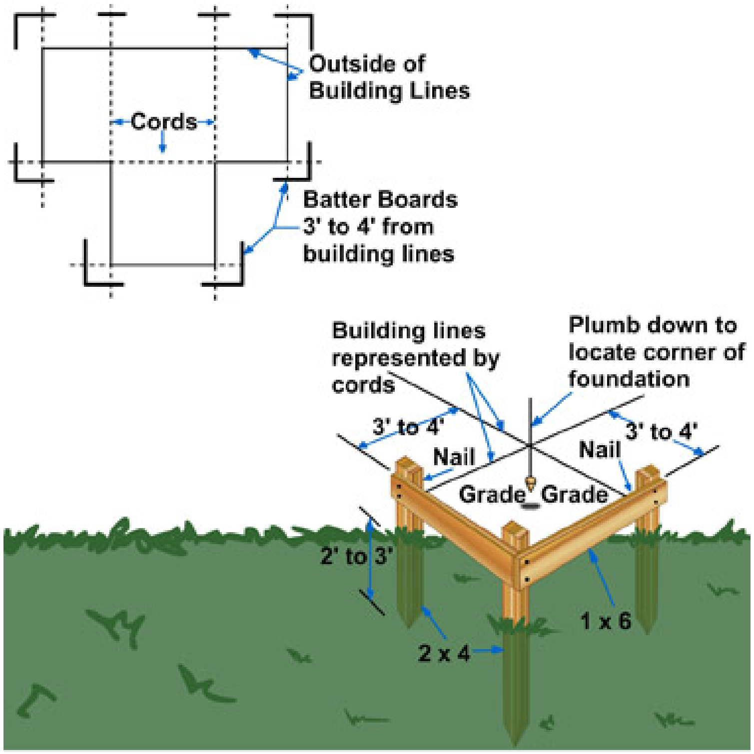


Figure 5-28 – Batter boards.

Nail each pair of boards to three 2 by 4 corner stakes as shown. Drive the stakes far enough outside the building lines so that they will not be disturbed during excavation. The top edges of the boards are located at a specific elevation, usually some convenient number of whole feet above a significant prescribed elevation, such as the top of the foundation. Nail to the batter boards cords located directly over the lines through corner hubs, placed by holding plumb bobs on the hubs. *Figure 5-28* shows how to locate a corner point in the excavation by dropping a plumb bob from the point of intersection between two cords.

In addition to their function in horizontal control, batter boards are also used for vertical control. Place the top edge of a batter board at a specific elevation. You can locate elevations of features in the structure, such as foundations and floors, by measuring downward or upward from the cords stretched between the batter boards.

Always make sure that you have complete information as to exactly what lines and elevations are indicated by the batter boards. Emphasize to your crewmembers that they must exercise extreme caution while working around batter boards. If the boards are damaged or moved, additional work will be required to replace them and relocate reference points.

5.3.0 Utilities Stakeout

Utilities is a general term applied to pipelines, such as sewer, water, gas, and oil pipelines; communications lines, such as telephone or telegraph lines; and electric power lines.

5.3.1 Aboveground Utilities

For an aboveground utility, such as a pole mounted telephone, telegraph, or power line, the survey problem consists simply of locating the line horizontally as required and marking the stations where poles or towers are to be erected. Often, the directions of guys and anchors may be staked as well, and sometimes pole height for vertical clearance of obstructions is determined.

5.3.2 Underground Utilities

For an underground utility, you will often need to determine both line and grade. For pressure lines, such as water lines, it is usually necessary to stake out only the line, since the only grade requirement is maintaining the prescribed depth of soil cover. However, staking elevations may be necessary for any pressure lines being installed in an area that (1) is to be graded downward or (2) is to have other, conflicting underground utilities.

Gravity flow lines, such as storm sewer lines, require staking for grade to be sure the pipe is installed at the design elevation and at the gradient, or slope, the design requires for gravity flow through the pipe.

Grade for an underground sewer pipe is given in terms of the elevation of the invert. The invert of the pipe is the elevation of the lowest part of the inner surface of the pipe. *Figure 5-29* shows a common method of staking out an underground pipe.

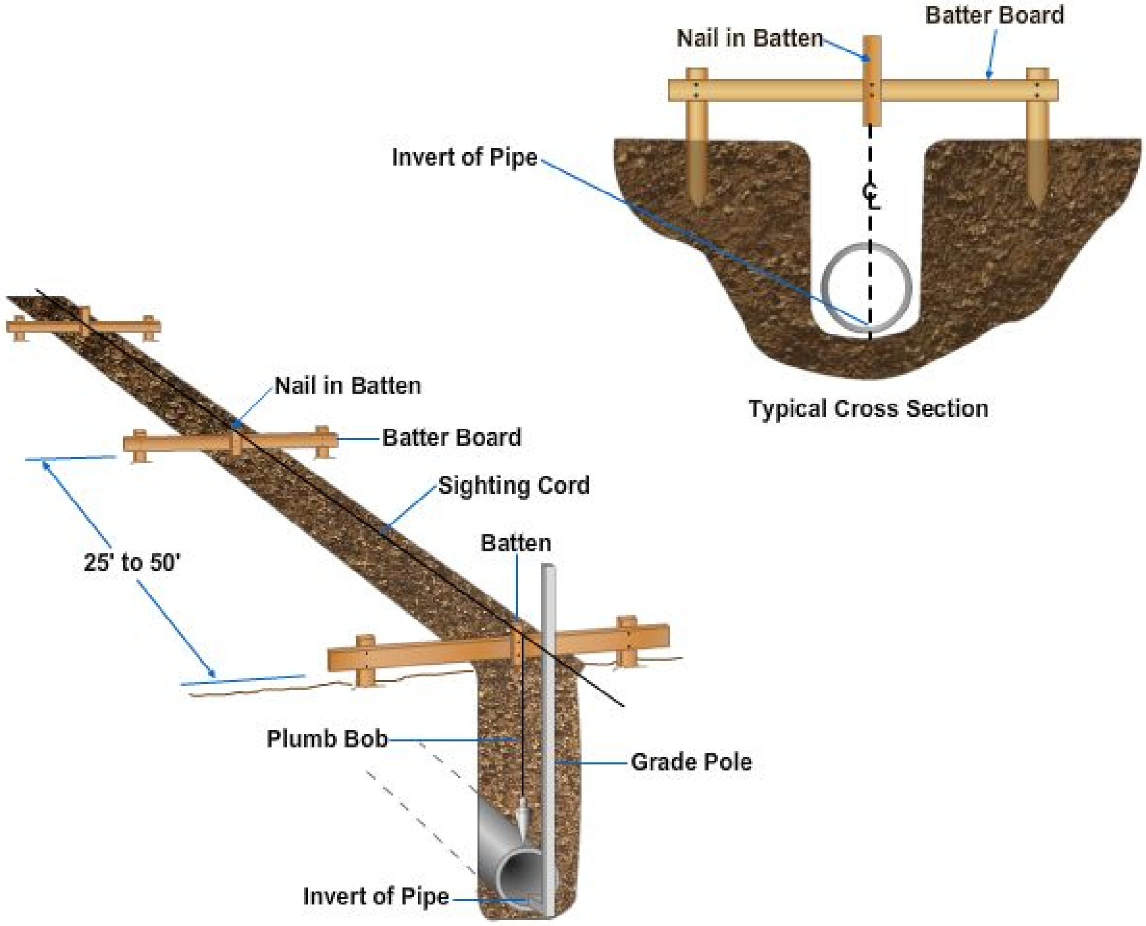


Figure 5-29 – Use of batter boards (with battens) for utility stakeout.

Notice that both alignment and elevation are facilitated by a line of batter boards and battens, or small pieces of wood, set at about 25 to 50 foot intervals. The battens, nailed to the batter boards, determine the horizontal alignment of the pipe when placed vertically on the same side of the batter boards and with the same edges directly over the center line of the pipe. As the work progresses, check the alignment of these battens frequently. A sighting cord, stretched parallel to the center line of the pipe at a uniform distance above the invert grade, is used to transfer line and grade into the trench. The center line of the pipe, therefore, will be directly below the cord, and the sewer invert grade will be at the selected distance below the cord. A measuring stick, also called a grade pole, is normally used to transfer the grade from the sighting cord to the pipe, as shown in *Figure 5-29*. The grade pole, with markings of feet and inches, is placed on the invert of the pipe and held plumb. The pipe is then lowered into the trench until the mark on the grade pole is on a horizontal line with the cord.

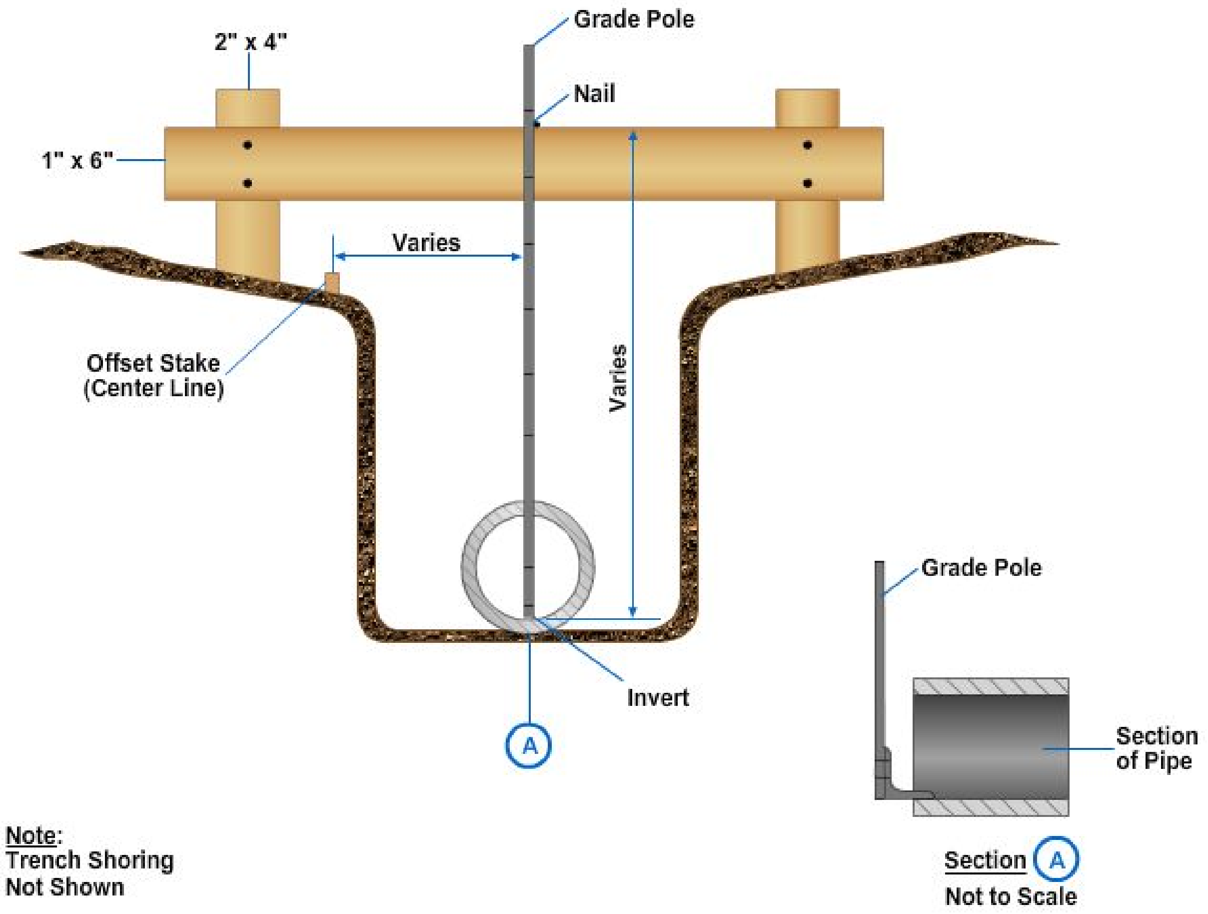


Figure 5-30 – Batter boards (without battens) for utility stakeout.

Figure 5-30 shows another method of staking out an underground sewer pipe without the use of battens. Drive nails directly into the tops of the batter boards so that a string stretched tightly between them will define the pipe center line. Keep the string or cord taut by wrapping it around the nails and hanging a weight on each end. Similarly, the string, or cord, gives both line and grade.

5.4.0 Grade Stakes

Grade work is the plotting of irregularities of the ground, making cuts or fills, to a definite limit of grade, or elevation, and alignment. This is performed by reading information placed on construction, or grade, stakes.

5.4.1 Construction Stakes

Construction stakes, sometimes referred to as grade stakes, are the guides and reference markers for earthwork operations to show cuts, fills, drainage, alignment, and boundaries of the construction area. The number of stakes and the information contained on them will vary with the project as to whether they are temporary or permanent. Stakes are usually placed by a three- to five-person survey party using a level, a level rod, a tape, and range poles.

A stake is defined as any wooden lath, stake, or hub. Hub stakes are 2 inches by 2 inches by approximately 12 inches and are used primarily for well-defined surveyors' reference points, with the red and blue tops used in finished grade work. Stakes will vary in shape and size according to their use and the materials available for their manufacture. Several stakes are shown in *Figure 5-31*. Stakes range in size from the ordinary rough plaster lath to 1- by 2- by 3-inch cross-sectional lumber with lengths varying from 18 inches to 48 inches.

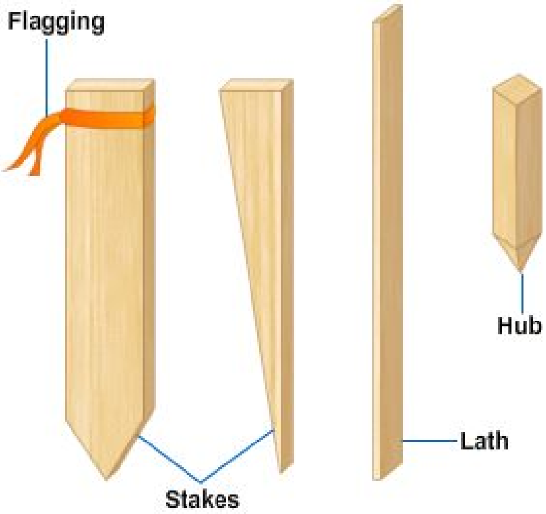


Figure 5-31 – Types of stakes.

All reference hubs, markers, and bench marks established by the Engineering Aids (EAs) for project control or alignment are protected by guard stakes. Guard stakes are used as a means of locating the points needed. Some color of bunting or flagging, a narrow strip of cloth or plastic, may be tied around the top of the stake. Station identification is placed on the front of the stake and any other pertinent data on the back.

In some situations, the survey crew will establish grades only on the centerline stakes, while edge-of-road and slope stakes are set by the project supervisor and helpers. Alignment, shoulder, and slope stakes should be 1 inch by 2 inches in cross section, smooth on four sides, and about 2 feet in length. Actual grade desired is indicated by a reference mark, called a crowfoot, and numbers to show the amount of cut or fill.

These stakes should be marked with the following information:

- The stationing or location of any part of the road, runway, or taxiway relative to a starting point or reference
- The amount of cut and fill from the existing ground surface or reference mark on the stake

- The distance from the center line to the stake location and from the center line to the ditch line

In most earthworks, measurements are made and written by the decimal system as used in construction engineering. Most markings on construction stakes will be in feet and tenths of a foot. A stake marked C35 means that a cut must be made 3.5 feet. To convert .5 foot to inches, multiply the decimal fraction by 12. For example: .5 x 12 inches = 6 inches; .25 x 12 inches = 3 inches.

5.4.2 Starting Point

The starting point of a survey is also called the starting station and is numbered 0 + 00. The next station is 100 feet farther away and is numbered 1 + 00. The next station, which is 200 feet beyond the starting point, is then numbered 2 + 00, and so forth. All stations that end with 00 are called full stations**.** *Figure 5-32* shows that stations may be abbreviated STA on the stakes.

On sharp curves or on rough ground, the stakes may be closer together than on the straightaway. Stations located at a distance shorter than 100 feet from the preceding station are known as plus stations, such as 3 + 25, 3 + 53, and 3 + 77. These examples are plus stations of station 3 + 00.

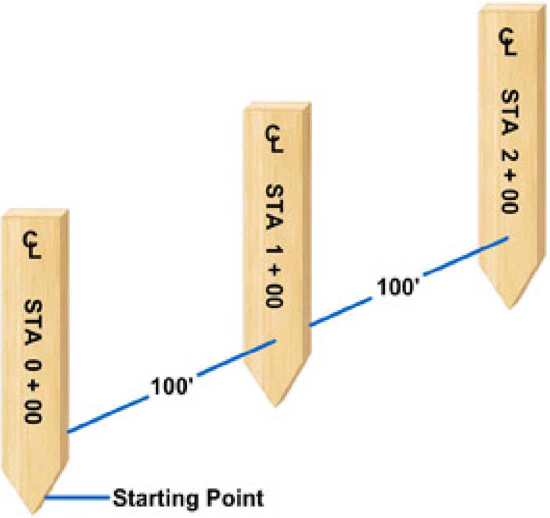


Figure 5-32 – Starting point.

5.4.3 Line Stakes

Line (or alignment) stakes – Line (or alignment) stakes mark the horizontal location of the earthwork to be completed and give the direction of the proposed construction. Running over stakes or otherwise damaging them before they have served their purpose results in many hours of extra work to replace them and delays the completion of the project.

Rough alignment stakes are placed far ahead of the clearing crew to mark boundaries of the area to be cleared and grubbed. These stakes, or markers, are not of a control nature and their loss is expected. On some stakes, the alignment information and the grade requirement are combined on the same stake, as shown in *Figure 5-33*.

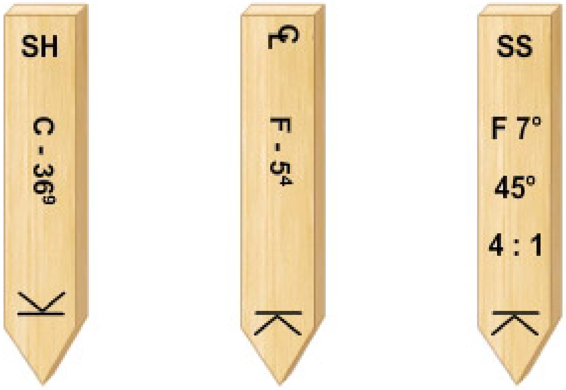


Figure 5-33 – Combined alignment and grade stakes.

Figure 5-34 – Centerline stake.

Centerline Stakes **–** Centerline stakes are set along the center line of a project and are identified by letters, shown in *Figure 5-34*. Most stakes are marked on both the front and back.

On centerline stakes, the station number is written on the front of the stake, such as the 0 + 00, 1 + 00, 4 + 75, and 5 + 25 shown in *Figure 5-35*.

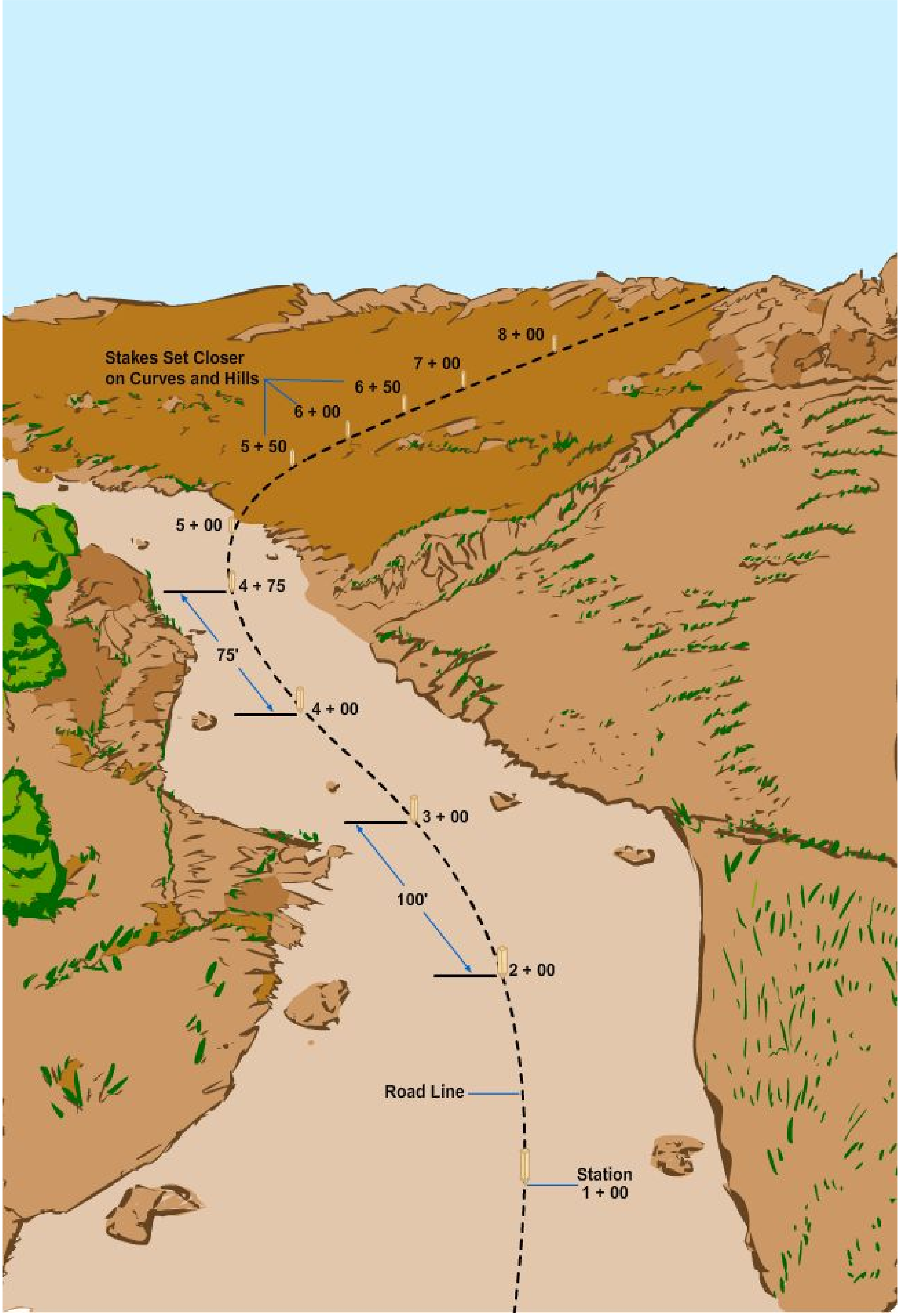


Figure 5-35 – Station numbers.

The required grade is always established at the center line of the project. The amount of change in elevation is written on the back of the centerline stake with a cut or fill symbol, which is known as the crowfoot, shown in *Figure 5-36*. The crowfoot is the reference point of the vertical measure or grade.

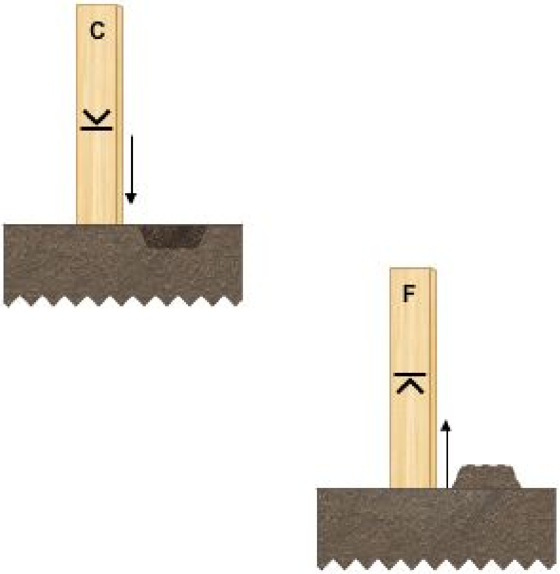


Figure 5-36 – Cut and fill crowfoot symbol.

Shoulder Stakes – Stakes that are set on a line parallel, in the same direction and interval with the center line are called shoulder stakes and are identified by the symbol SH at the top of the stake, as shown in *Figure 5-37*.

Figure 5-37 – Shoulder stake symbol.

Shoulder stakes mark the outer edge of the shoulders and are set with the broad side facing the center line of the road on the shoulder line. Shoulder stakes carry the same station number as the centerline stake to which they are set, but the station number is placed on the back of the stake, the side facing away from the center line. The amount of cut or fill is marked on the side of the shoulder stake facing the center line, the front, and represents the amount of cut or fill required at that location. The horizontal distance from the shoulder stake to the center line is sometimes placed beneath the cut-or-fill figure.

The basic difference between centerline stakes marked with the symbol and shoulder stakes marked SH is (1) centerline stakes are set along the center line of the project and (2) shoulder stakes are set parallel with the center line, defining the shoulder of the road or runway, and face the center line as shown in *Figure 5-38*.

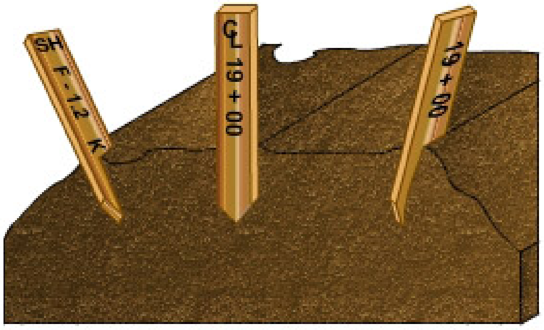


Figure 5-38 – Center line and shoulder stakes.

Cut-and-Fill Stakes – Lowering the elevation of a grade is known as making a cut. Cut stakes are designated by the letter C written on the stake. The numerals following the letter C indicate the amount of ground to be cut to obtain the desired grade and are measured from the crowfoot down.

Raising the elevation of the ground is known as making a fill. A fill stake is designated by the letter F written on the stake. The numerals that follow the letter F indicate the amount of ground material needed to bring the existing ground to the desired grade and are measured from the crowfoot mark on the stake up.

In going from a cut to a fill or vice versa, there may be one or more stakes representing points on the desired grade, as shown in *Figure 5-39*. These stakes are marked with GRADE**,** or GRD and a crowfoot mark even with the desired grade.

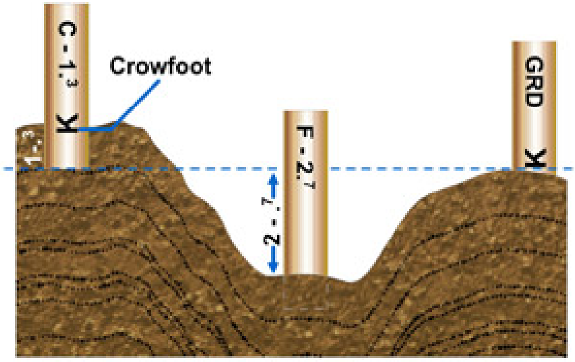


Figure 5-39 – Cut, fill, and on-grade stakes.

Basically, the difference in cut, fill, or on-grade stakes is as follows:

- Cut stakes indicate lowering the ground or elevation.
- Fill stakes indicate raising the ground or elevation.
- On-grade stakes indicate the ground is at the desired grade and does not need a cut or fill.

Offset Stakes – After a survey of a project has been completed and the stakes are set and marked, the required amount of work needed to complete the job is determined by using the information on these stakes. Since this information has to be used often during construction and the original stakes can be destroyed or covered up by carelessness or inexperienced operators, it is necessary to document this information.

To prevent the loss of reference information, transfer the required information from the stake located in the immediate area of construction to a new stake. Set this stake far enough away so that it will not be damaged or destroyed by equipment being operated in the construction area. This new stake is called an offset stake and is identified by the symbol OF or an O as shown in *Figure 5-40*.

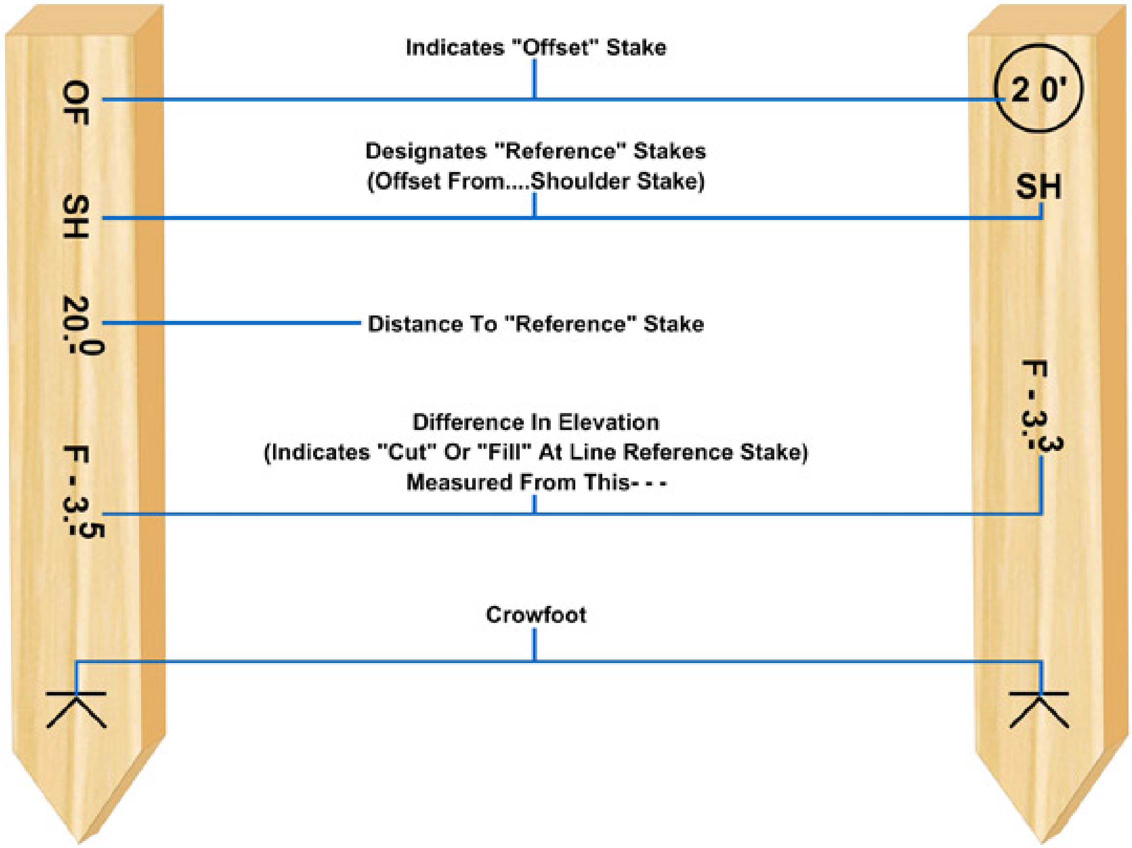


Figure 5-40 – Reference information found on an offset stake.

You should note the number of linear feet that separates the offset stake from the original reference stake. This is written on the offset stake below the OF or within the circle, followed by the amount of cut or fill, in feet, which may be required. A stake marked OF 35'CL C-1° means that the stake is offset 35 feet from the centerline stake and that a cut of 1 foot is required to attain the desired final grade.

The difference in elevation must be noted on the offset stake. The symbol, representing the stake from which the information was originally transferred, is also noted on the offset stake. If the offset stake is offset from a shoulder stake, the symbol is SH instead of CL.

The amount of cut or fill, if any, must be noted on the offset stake. However, because of existing terrain, this information on the offset stake may not be the same as that on the original stake. In *Figure 5-41*, you can see that the offset stake reads for a cut to be made to reach a desired elevation at the center line, while a centerline stake would be marked for a fill to reach the same elevation.

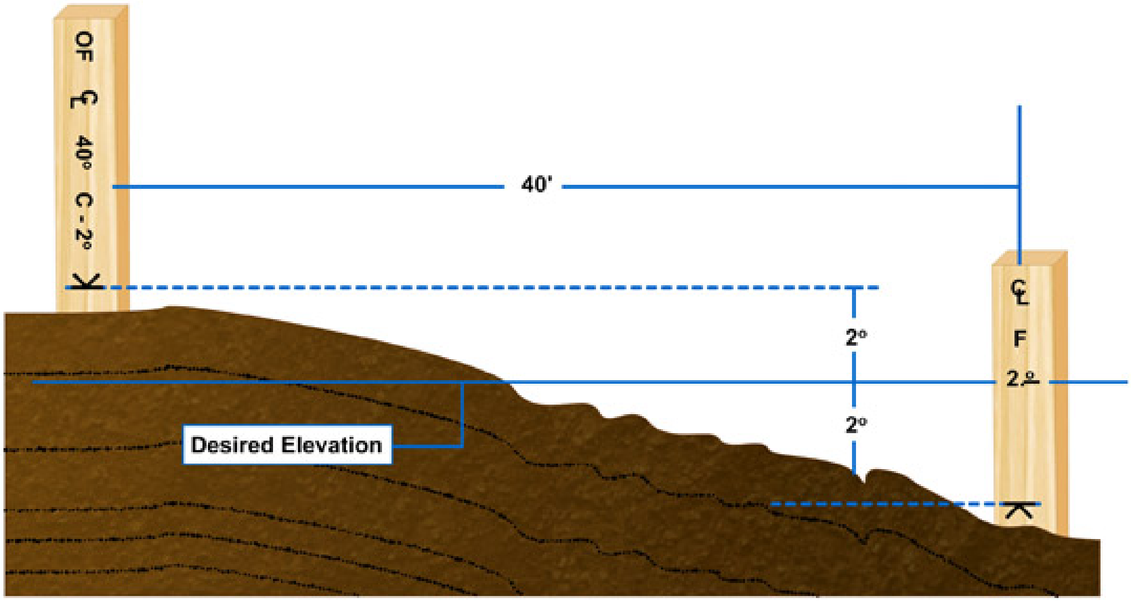


Figure 5-41 – Difference in elevation between the offset stake crowfoot and desired grade at center stake.

Slope Stakes – The identification markings on slope stakes may vary according to survey parties, the symbol SS is the most commonly used slope stake symbol. The information normally found on a slope stake, shown in *Figure 5-42*, is any cut or fill requirements, the distance from the center line, and the slope ratio. When it becomes necessary to offset the slope stake, the offset distance from where the slope stake should be is written at the bottom of the offset stake. Slope stakes indicate the intersection of the cut-or-fill slope with the existing natural groundline and limit of earthwork on each side of the center line shown in *Figure 5-43*.

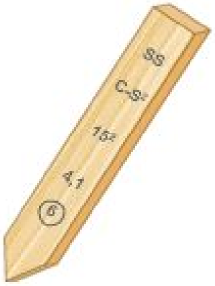


Figure 5-42 – Slope stake.

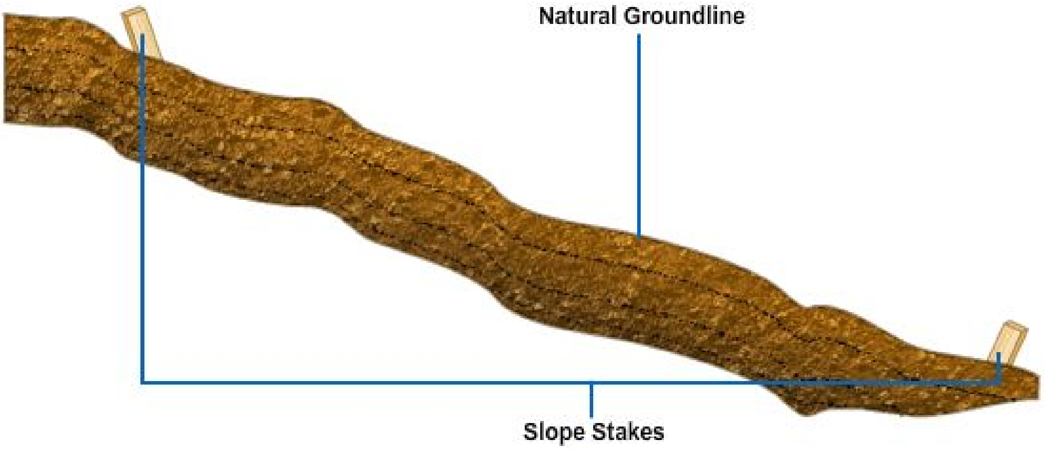


Figure 5-43 – Slope stakes set in existing natural groundline.

Right-of-Way Stakes – Stakes set on the property line of a construction site are known as right-of-way stakes**.** These stakes mark the boundaries of the site or project. You must not operate equipment outside the property line defined by the right-of-way stakes. The right-of-way stakes are usually marked by with colored cloth, called bunting, or flagging. Occasionally right-of-way stakes may be marked with the symbol R/W shown in *Figure 5-44*.

Figure 5-44 – Right-of-way stake.

Finish Grade Stakes – When performing final grading, you are likely to work with stakes called blue tops**.** These are hub stakes which are usually 2 inches by 2 inches by 6 inches. These hubs are driven into the ground until the top is at the exact elevation of the finished grade as determined by the surveying crew. They are colored with a blue lumber crayon, or keel, to identify them as finish grade stakes. Red crayon is normally used to indicate the subgrade elevation. Blue top stakes are placed when the existing grade is within 0.2 feet, or 2.4 inches, above the final or desired grade. The desired grade is obtained by lowering or raising the compacted grade with a grader until it is flush or even with the top of the hub, as shown in *Figure 5-45*.

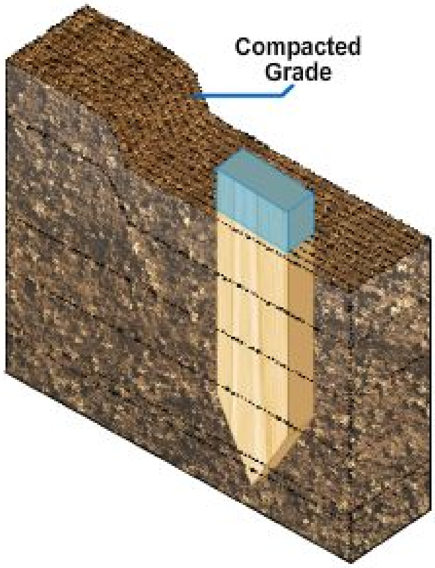


Figure 5-45 – Finish grade stake.

6.0.0 CLASSIFYING SOILS

The Unified Soil Classification System (USCS) is a common soil classification reference or system that has a universal interpretation. In this system, all soils are divided into three major divisions, including coarse-grained soils, fine-grained soils, and highly organic soils.

Coarse-grained soils are those in which at least half of the material, by weight, is larger than, or retained on, a No. 200 sieve. This division is further divided into gravels and sands. If more than half of the coarse fraction, by weight, is retained on a No. 4 sieve, it is classified as a gravel. If less than half is retained on a No. 4 sieve, then it is a sand. Gravels and sands are further subdivided into additional categories dependent upon the amount and characteristics of any plastic fines the soil sample contains.

Fine-grained soils are those in which more than half of the material, by weight, is smaller than, or passes, a No. 200 sieve. The fine-grained soils are not classified on the basis of grain size distribution but according to plasticity and compressibility.

Highly organic soils are those organic soils, such as peat, that have too many undesirable characteristics from the standpoint of their behavior as foundations and their use as construction materials. A special classification is reserved for these soils, and no laboratory criteria are established for them. Highly organic soils can generally be readily identified in the field by their distinctive color and odor, spongy feel, and frequently fibrous textures. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils.

7.0.0 SOILS TESTING

Soil compaction and density testing are two of the most common and important soils tests that an Engineering Aid (EA) must learn to perform. Those tests, as well as the California bearing ratio test and hydrometer analysis, are discussed in this section.

7.1.0 Compaction Test

Compaction is the process of increasing the density, or the amount of solids per unit volume, of soil by mechanical means to improve such soil properties as strength, permeability, and compressibility. Compaction is a standard procedure used in the construction of earth structures, such as embankments, subgrades, and bases for road and airfield pavement.

In the field, compaction is accomplished by rolling or tamping the soil with special construction equipment. In the laboratory, compaction can be accomplished by the impact of hammer blows, vibration, static loading, or any other method that does not alter the water content of the soil. Usually, however, laboratory compaction is accomplished by placing the soil into a cylinder of known volume and dropping a tamper of known weight onto the soil from a known height for a given number of blows. The amount of work done to the soil per unit volume of soil is called compactive effort.

For most soils and for a given compactive effort, the density of the soil will increase to a certain point as the moisture content is increased. That point is called the maximum density. After that point, the density will start to decrease with any further increase in moisture content. The moisture content at which maximum density occurs is called the optimum moisture content (OMC). Each compactive effort for a given soil has its own OMC. As the compactive effort increases, the maximum density generally increases and the OMC decreases.

7.2.0 Density Tests

From the preceding discussion, you know that compaction testing is performed to determine the OMC and the maximum density that can be obtained for a given soil at a given compactive effort. You also know that, using the maximum density, you can determine a range of densities and moisture contents that will satisfy the compaction requirements for a project. During the construction of that project, a control must be in place to measure whether or not the compaction requirements have been met. That control is density testing. If the results of the density test determine that the compaction process has produced a density within the range specified, then the compaction is complete. If the test results reflect densities that are not within the specified range, additional rolling may be necessary or the moisture content may have to be adjusted.

Several different methods are used to determine the in-place density of a soil; however, the methods that EAs are most apt to use are the sand-displacement method and the nuclear moisture-density meter method.

7.2.1 Sand-Displacement Method

A full discussion of the procedures used in the sand-displacement method can be found in *Test Method for Pavement Subgrade, Subbase, and Base-Course Material,* MIL-STD-621A, and in NAVFAC MO-330. This method, often called the sand-cone method, may be used for both fine-grained and coarse-grained materials. In general, the test consists of digging out a sample of the material to be tested, using calibrated sand to determine the volume of the hole from which the sample was removed and the dry unit weight of the sample.

7.3.0 Bearing Tests

The bearing capacity of a soil is expressed in terms of shear resistance, which means the capacity of the load-bearing portion of a material or member to resist displacement in the direction of the force exerted by the load.

There are various types of load-bearing tests. For description purposes we will briefly discuss the California bearing ratio (CBR) test. The California bearing ratio is a measure of the shearing resistance of a soil under carefully controlled conditions of density and moisture. The CBR is determined by a penetration shear test and is used with empirical curves for designing flexible pavements.

The test procedure used to determine the CBR consists of two principal steps. First, the soil test specimens are prepared; second, a penetration test is performed upon the prepared soil samples. Although one standardized procedure has been established for the penetration portion of the test, it is not possible to establish one procedure for the preparation of test specimens since soil conditions and construction methods vary widely. The soil test specimens are prepared to duplicate the soil conditions existing, or expected to occur later, in the field. Although penetration tests are most frequently performed on laboratory-compacted test specimens, they may also be performed upon undisturbed soil samples or in the field upon the soil in place. Detailed procedures for preparing the test samples and performing the test can be found in NAVFAC MO-330.

7.4.0 Hydrometer Analysis

A soil is considered susceptible to frost when it contains 3 percent or more by weight of particles smaller than 0.020 mm in diameter. To determine whether or not a soil contains an excessive amount of that size particle, you must perform a particle-size analysis of the materials passing the No. 200 (0.074-mm) sieve. Do this by hydrometer analysis. For a full discussion of the procedures, refer to NAVFAC MO-330 or to ASTM D 422.

8.0.0 SOIL STABILIZATION

There are three purposes for soil stabilization. The first one is strength improvement. This increases the strength of the existing soil to enhance its load-bearing capacity. The second purpose is for dust control. This is done to eliminate or alleviate dust generated by the operation of equipment and aircraft during dry weather or in arid climates. The third purpose is soil waterproofing, which is done to preserve the natural or constructed strength of a soil by preventing the entry of surface water.

There are two methods of applying soil stabilization materials. The first is the admix way. Use this method where it is necessary to combine two different soils together for stabilization. Do this as follows:

- In-place mixing: blend soil and stabilization materials on the jobsite.
- Off-site mixing: use stationary mixing plants.
- Windrow mixing: mix the materials using a grader.

The second way is the surface penetration application, which is accomplished by placing a soil treatment material directly to the existing ground surface by spraying or other means of distribution. Some of the additives used in soil stabilization are cement, lime, bituminous products, and calcium chloride. Cement-treated bases are the most commonly used for the purpose of upgrading a poor quality soil. Soil-cement is a mixture of pulverized soil and measured amounts of Portland cement and water, compacted to a high density.

There are three types of soil-cement. The first is compacted soil-cement that contains sufficient amounts of cement to harden the soil and enough moisture for both compaction and hydration of the cement. The second is cement modified soil which is an unhardened or semi-hardened mixture of soil and cement. Only enough cement is used to change the physical properties of the soil. The third is plastic soil-cement. It is a hardened mixture of soil and cement that contains enough water at the time of placing to produce a consistency similar to that of plastering mortar. The three basic materials needed when working with soil-cement are soil, Portland cement, and water. The soil can be almost any combination of gravel, sand, silt, or clay.

The three major control factors when working with soil-cement are as follows:

1. The proper cement content is needed. A rule of thumb: use one 50-pound bag per square yard.
2. Proper moisture content. A soil sample, should make a firm cast when squeezed in your hand without squeezing out any water.
3. Adequate compaction. The principles of compacting soil-cement are the same for compacting the same soils without cement treatment. Compact the soil-cement mixture at optimum moisture content to maximum density and finish it immediately. Moisture loss by evaporation during compaction, as indicated by the graying of the surface, should be replaced with light applications of water.

Occasionally during compaction, the treated area may yield under the compaction equipment. This may result from one or more of the following causes: (1) the soil-cement mix is much wetter than optimum moisture content, (2) the soil may be too wet and unstable, and (3) the roller may be too heavy for the soil. If the soil-cement mix is too damp, aerate it using the scarifier on the grader. After it has dried to near optimum moisture content, then compact it.

Summary

You learned concepts important to surveying a site for a construction project. Construction surveys are made to help with planning, estimating, locating, and layout for construction projects. Surveys rely on Bench Marks (BM) to establish a known elevation on a construction site. Earthwork operations are some of the earliest operations that occur on a construction site. These operations include pioneering, clearing, grubbing, and stripping. Drainage of the site is important to maintain.

You will work closely with local agencies while planning and executing construction projects. Permits needed for each construction project might include Utility Interruption Requests, Excavation Requests, and Road Closure Requests.

You have been introduced to the common types of leveling instruments, including levels, the tripods that support them, and leveling rods. You should be familiar with their principles and uses, as well as procedures of establishing elevations, and techniques of laying out building lines. As a Builder, you will find the information especially useful in performing such duties as setting up a level, reading a leveling rod, interpreting and setting grade stakes, and setting batter boards.

The types of soil on a site can affect how the construction project will proceed. It is important to perform appropriate soils testing to determine if any soil stabilization strategies will be needed.

Trade Terms Introduced in this Chapter

Dumpy level	A surveying instrument consisting of a telescope rigidly attached to a vertical spindle. Used to determine relative elevation.
Elevations	Vertical distance relative to a reference point.
Grade	(1) The surface or level of the ground. (2) The existing or proposed ground level or elevation on a building site or around a building.
Hand level	In surveying, a hand-held sighting level having limited capability.
Leveling	The procedure used in surveying to determine differences in elevation.
Leveling rod	A graduated straight rod used in construction with a leveling instrument to determine differences in elevation. The rod is marked in feet and fractions of feet, and may be fitted with a movable target or sighting disc.
Locke level	A hand level.
Philadelphia rod	A leveling rod in two sliding parts with color-coded graduations. The rod can be used as a self-reading leveling rod.
Reference line	A series of two or more points in line to serve as a reference for measurements.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Engineering Aid 3 & 2, Vol. 3, NAVEDTRAA 10629-1, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1987.