CHAPTER 4 - CONSTRUCTION SURVEYS AND WORKING DRAWINGS

CONTENTS

FIGURES

CONSTRUCTION SURVEYS AND WORKING DRAWINGS

4-1 WORKING DRAWINGS

See *FAR Clause 52.236-21 - Specifications and Drawings for Construction.*

The Contract states the time requirements for submission and approval of working drawings.

The Project Engineer should go over the Contractor's schedule for submissions at the preconstruction conference so that the Government can schedule its own resources. The Contractor should also be advised to promptly submit information on suppliers and subcontractors whose work will require Government inspection and testing, particularly offsite inspection.

4-1.1 Submittal and Approval Procedures for Working Drawings

Procedures for submittal and approval of working drawings will be in accordance with Division policy.

4-2 CONSTRUCTION STAKING

The Contract establishes specific staking responsibilities and requirements, including survey tolerances.

4-2.1 General

An FLH survey to obtain final design information and to set initial control for staking during construction is usually completed before the award of the construction contract. Practices vary among Divisions. Individual project situations may also vary. Some contracts will require more survey effort from the Contractor than others.

4-2.2 Staking Verification

The first step in verifying the accuracy of the survey control is taken before any work has been done by the Contractor. The Project Engineer is to receive copies of such documents as: an earthwork listing, cross sections, clearing book, slope stake book, coordinate listing, etc. A list of such documents is called out in the special contract requirements to be made available to the contractor. The Project Engineer needs to cross check this information with the plans to insure consistency. Sometimes the plans contain coordinates of control points. The Project Engineer should compare these coordinates with the data listing. The Project Engineer should calculate some coordinates of PC's, PT's, etc., using data from the plans. Then the Project Engineer should compare the calculated coordinates with the design listing. The Project Engineer should contact the Design Section for help, if discrepancies are found or if questions develop.

4-2.3 Government Field Control

The next phase of staking verification is in the field. Initial project surveys are done by the FLH or a consultant surveyor under a separate contract, before the award of the construction contract. Such surveys will provide control points to be used later by the Contractor.

The Project Engineer is responsible for verifying that the information in both the special contract requirements and the plans match what is in the field. The Project Engineer should walk the design line to make sure that enough reference points, control points, elevation benchmarks, etc., physically exist. It is not uncommon for some of these points to be destroyed or moved between the time of staking and the time of award of the construction contract. Some common causes of missing or damaged survey control are: nearness to a campground (stakes and hubs make good kindling), farming activities, road and ditch maintenance, or removal by vandals.

The Project Engineer should assume the quality of the Government control is adequate for the project, unless there is reason to believe it may have been disturbed, or unless the Contractor's beginning survey efforts lead to questions or allegations of errors. If errors are alleged or suspected for any reason, the Construction Operations Engineer is to be quickly consulted to arrange for or provide expert advice and/or assistance.

If so many Government control points have been lost or disturbed that replacement by available project staff is not feasible, the Project Engineer should contact the Construction Operations Engineer. Options available to reset the control points include:

- A contract modification to have the Contractor do the work
- Contracting with a local surveyor
- Bringing in a Government survey crew
- Temporary additional project staff

Any needed work relating to control points should be done as soon as possible to avoid delaying the Contractor's operations.

4-2.4 Establishing and Referencing Centerline and/or other Roadway Control

At some point during construction of the project, the centerline is established by the Contractor. Shoulder points are often set in the same operation. The degree of accuracy depends on the phase of construction taking place. Most staking tolerances are found in the specifications. When they are not, standard practice for the type of work will govern.

During initial grading, the inspector can check work by measuring from the slope stakes or the slope stake reference hubs. When doing this, the inspector should line up with the reference hub or the slope stake on the other side of the road. This insures that centerline is intercepted at the station listed on the stake. Use of a cloth tape and hand level should be adequate at this stage, so long as the Contractor's work is being found generally in compliance. Tools such as the Rhodes Arc or Easy Arc are convenient for steep terrain. If it appears there are serious or chronic errors, more accurate checking methods may be warranted.

When finishing subgrade, fine grade control stakes (*blue tops*) or stakes for string lining are usually set by the Contractor. Most of the time a Contractor sets the horizontal location of grade control stakes for about 1,000 meters of roadway, then comes back to set the proper elevations. To check the work at this stage, the inspector should have a theodolite and an electronic distance measuring device. Radial survey methods can then be used. By occupying a point of known coordinates and having a similar backsight, the Contractor's grade control stakes can be checked by comparison with points set at their coordinates.

An older method of checking the alignment and grade control is to occupy a centerline point, backsight a point with a known azimuth (or bearing), and run in the centerline by using deflection angles and distances. This is what could be termed the *classic* method of laying out a road. Most books on route surveying illustrate the procedure. After running in centerline, the inspector turns right angles off each centerline point to get the shoulder locations. This method can be rather time consuming and usually requires three people (minimum) to do it efficiently with a transit and steel tape. Using an electronic distance meter speeds the work. However, with that available, the *radial* method mentioned above is usually superior.

Regardless of the method chosen for checking, the Project Engineer should require as independent a check as is feasible. Occupying points different from those used by the Contractor, or using a different method, are approaches to that. The purpose of an independent check is to lessen the chance of duplicating any error. Points set for checking may not match the Contractor's points exactly, but they should fall within tolerances.

Referencing centerline, as used in this section, means to set additional control outside of the construction limits, and out of harm's way generally. These references are used to reestablish centerline or other control points. The control referenced may be any of PC's, PT's, P-line points, state coordinate points, etc.

A wide range of methods exist to reference centerline depending on the equipment available and the importance of the point. **Examples of Referencing Methods** are shown in **Figures 4-2.4a through 4-2.4e**. Regardless of how the Contractor references centerline, a record is to be given the Project Engineer, in an acceptable format. The Project Engineer should mathematically check a sampling of calculations, and should field-check some of the reference points in order to verify the competence of the Contractor's work. Field verification consists of making sure the references do exist, insuring that references are out of harm's way, and checking that the points match the data submitted by the Contractor. The Project Engineer should check enough points to feel satisfied that all are correct. The Contractor is to be notified of any discrepancies found and required to correct anything that will be left in place.

Where construction plans show equations in the stationing, these equations must be left in, and the station ahead must not be altered. The back station may be corrected if any error or distance is found when rerunning the line. This is necessary to preserve the relation of centerline to landmarks.

If the stationing at the crossing of property lines does not agree with the original plans (except minor differences in chainage), it will be necessary to equate to the original station ahead. The Project Engineer should coordinate with Project Development when any changes are necessary, which affect the right-of-way description.

The terminal stations of the project should be left as shown on the plans unless a change has been approved by Project Development through the COE. If errors, equations or centerline corrections cause a terminal station to be in a significantly different location relative to the geometrics of the road and physical features of the right-of-way, the Project Engineer should coordinate with the COE to see if an equation or a revision to the terminal station is appropriate. Such actions should be kept to a minimum.

4-2.5 Permanent Monuments

Permanent monuments such as United States Coast and Geodetic Survey (USCGS) monuments, Public Lands corners, State coordinate points, Corps of Engineers' monuments, or property corners might be in the way of the work. The Contract should provide for relocation of such monuments before construction, in accord with legal and/or agency requirements. If a monument is discovered that is not called out in the Contract, the Project Engineer should contact the owning agency as soon as possible for instructions.

4-2.6 Bridges

The Government provides initial control from which the Contractor can locate the bridge. The Contractor determines what additional control is needed for construction purposes and is responsible for staking it. The Contractor is required to submit this staking information to the Project Engineer. The Project Engineer should check its accuracy.

The Project Engineer must verify that Government field control matches the control listed in the Contract. If not, the field control will have to be reset. The Project Engineer should contact the Construction Operations Engineer to get input on the best method of accomplishing this. Various options are given in Section 4-2.4. If the control is good, the Project Engineer may want to set additional control for checking purposes outside the construction limits. Usually, points set at right angles and even distances are best. The points should be clearly marked, i.e. *"offset from bridge chord"*, *"end of bridge"*, etc. Vertical control should be set close to the bridge to reduce the number of turning points required. Complete level circuits should always be done. Refer to a book on surveying for technical information on staking.

Bridge tolerances are much tighter than roadway tolerances. The Project Engineer should allow enough time to do checking prior to scheduled concrete operations.

4-2.7 Retaining Walls

This section is written for cast-in-place concrete, cantilever retaining walls. The Project Engineer can apply most of the ideas presented here to other types of walls as well. However, each wall type (cast in place, reinforced earth, gabion, bin wall, keystone block, ...) has some things unique to it. For an unfamiliar wall type, the Project Engineer may contact the manufacturer to gain insight for laying it out. Actual layout is done by the Contractor.

Unlike bridges, locations of retaining walls may not be precisely established on the plans. In many situations, the Contract requires the Project Engineer to field check the beginning and ending station of the wall before the Contractor can order materials or begin work.

A common method used to check the Contractor's staking involves setting an offset line parallel to the wall. The inspector measures from this line to check the wall. On walls, setting the radius points is sometimes more practical and useful. Once the footing for a wall is complete, the Contractor often places control on it. This is convenient to use. It is a good idea to check the location of the top of the form. This is to insure the proper batter is being obtained.

The Project Engineer might rely the Contractor's control after checking its accuracy. However, this is not an independent check.

4-2.8 Slope Stakes

This section assumes that project personnel have some experience with slope staking. If not, the Project Engineer should request or provide special training. Many survey books give only a brief description of the subject as compared to traversing, running levels, and other aspects of surveying which are well explained. When explanations are given, they are often of flat country work, not practical for most Federal Lands' projects. See **Figure 4-2.8** for an **Example Slope Stake and Reference Stake** markings and notes.

The Project Engineer should closely review the printed earthwork listings and the plotted cross-sections for knowledge of the overall earthwork and stakeout required. Close study of plotted cross-section data proves very helpful in understanding the intended template for the road. The Project Engineer should note anything appearing odd, or contrary to the plans or Contract, for later field checking.

The Project Engineer should review the earthwork and staking data with the Contractor and its staking crew before the contractor does any staking. The Project Engineer should discuss write-up and color coding of slope stakes and their reference stakes, and whether or not the cuts marked on the slope stakes are to ditch grade or shoulder grade. The Project Engineer should ask the Contractor and its staking crew to demonstrate how they will mark the catch and reference stakes. The Contractor also should explain where substantial differences between the data contained in the furnished field notes and actual ground shots will be recorded. The Project Engineer should point out that care must be taken to assure measuring is accurate, particularly when staking is done with a hand level, rod and cloth tape. The Contractor must submit accurate and timely staking notes throughout the life of a project. Failure to furnish staking notes on time prevents or delays review of that work, and causes delay to the total operation.

Once the Contractor has started placing slope stakes in the ground, the Project Engineer should look at the staked line to see if it flows smoothly with the terrain. If there is a slope stake out of line, the Project Engineer should check the plans to see if there is a reason for it. An inlet basin for a culvert may cause a station to appear out of line. If there is no apparent reason for the misalignment, the Project Engineer should check the slope stake book and compare it to the writing on the slope stake. The Project Engineer should check data recorded on slope stakes and R.P.'s for legibility, as well as for content.

The Project Engineer's method for review of the Contractor's staking depends on the equipment available. If a theodolite and electronic distance meter or a total-station theodolite are on the job, the Project Engineer can shoot catches (slope stake positions) in from a control point. These can be compared to slope stakes the contractor has set. Unless something was wrong with the original topographic data, the two should compare closely. The Project Engineer should check the Contractor's stakes to see that they meet the horizontal and vertical tolerances for the Contract.

Sampling is permissible for checking staking. Unless sample size is specified, the Project Engineer may select about 10% of the stakes in any group being tested. The sample selection method must insure all stakes in the group have an equal selection chance. The average error in the sample is taken to represent the mean error in the work being checked. Vertical and horizontal errors are best considered separately.

If the mean error exceeds specification tolerances, or normal industry tolerances if none are specified, corrective action is warranted. Some time spent at that point to determine why the error is so large will likely be worthwhile. Check both parties equipment, methodology, and conventions such as measuring from and to the center of stakes or hubs. Government staff might work with the Contractor's crew for a time, or observe its work very closely. The Construction Operations Engineer might be asked to provide or arrange for help if necessary to find problems.

When re-checking a rejected unit of work, one should take a new sample and proceed as above.

4-2.9 Fine Grade Control Stakes

Fine grade control stakes (red tops, blue tops etc.) can initially be checked similarly to checking slope stakes. The eyeball method will usually show any large bust in the staking. The Project Engineer should require complete level circuits, always tying into a benchmark to close the circuit. To meet the horizontal tolerances, the grade control stakes must be set and checked, using a survey instrument of some type. Taping off slope stakes or slope stake reference hubs does not assure the required accuracy. Section 4-2.4 contains additional information on checking grade control stakes. Discussion of sampling in Section 4-2.8 may be applied to checking fine grading control points. The checking procedures are the same for all fine grading control points. Definition of various grade control stakes by color code is often in the special contract requirements.

In some situations, the grade control stakes have to be fine-tuned by the Project Engineer to get a smooth ride, and/or to insure proper drainage of the surface. In a very curvilinear alignment, the tangent runouts can get shortchanged. The Project Engineer may have to adjust the designed superelevation to soften dips or humps.

4-2.10 Sight Levels

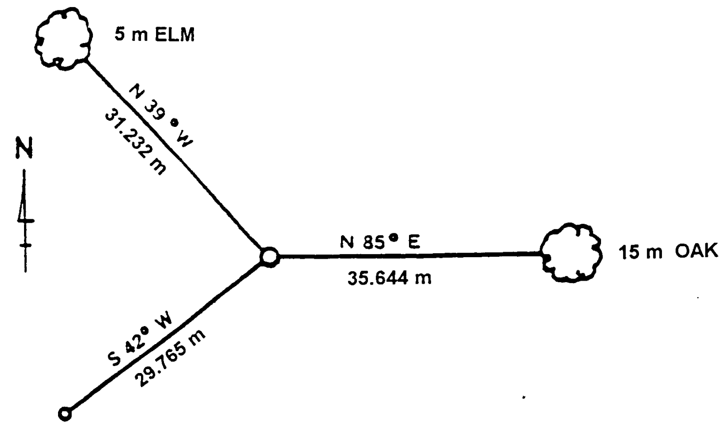
See **Figure 4-2.10**. These are tools with which one person can check the crown, superelevation or linear grade without a level and rod. These are three metal rods each welded to a small base to enable them to stand vertically unsupported. The main rod has a small *tee* section of tubing welded horizontally to the top that serves as a sight and target. To see if the three levels are all on the same plane, the inspector chooses any random cross-section of the roadway, places a level on the right shoulder, one on the center of the road, and the third on the left shoulder. The inspector then sights from one on either shoulder to the one on the other shoulder. The inspector measures the amount of crown by how far the top of the center level is above the line of sight on centerline. A string line will settle arguments. The levels are usually painted with alternating colored stripes at fixed increments.

To check a roadway section that has a turnout or passing lane, the inspector places one level on centerline and another on the shoulder. Then the third level is placed in between to see that the crown at centerline is carried over the entire length of the template.

The inspector may use this same method of placing three levels across the roadway at a cross-section to check the superelevation by sighting over the top of the handles. This method also works for checking the linear grade of the roadway between stations. The inspector places two levels on consecutive control stakes, and the third level in between and sights over the top to see if they line up.

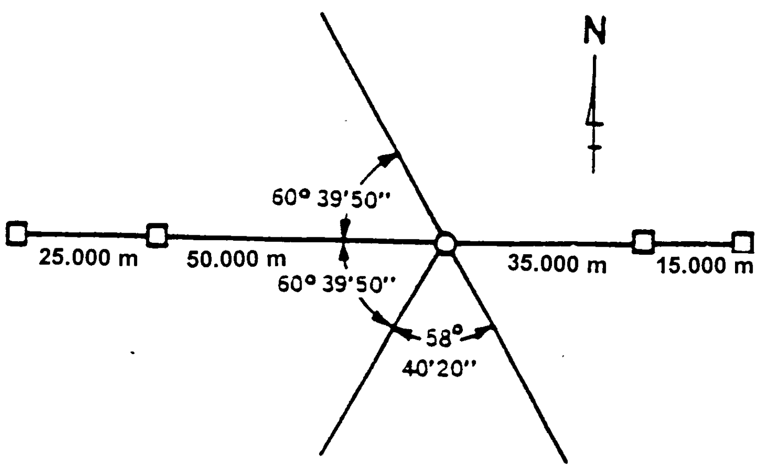
The levels give a quick check of uniformity and smoothness of the subgrade, base aggregate course, and later courses. Using levels on vertical curves, horizontal curve transitions and curvilinear alignment will not work as described.

The main use of levels is to rough check that the grade is conforming to the template shown in the Contract drawings.



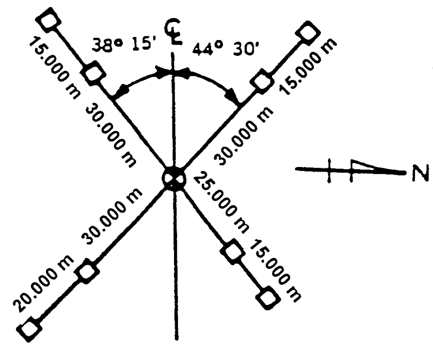
Application: Used on resurfacing projects, etc., where references will remain undisturbed and an offset line will not be needed.

Bearing/Distance Reference
Figure 4-2.4a



Application: The preferred method of referencing alignment points is by angle and distance to instrument point. Install tacked hubs set at convenient distances and in line with a prominent distant object when possible. The hubs, or more permanent points, should be set where they will not be disturbed during construction and are accessible enough for a transit to be set over them.

Angle/Distance Reference
Figure 4-2.4b



Application: Often used when referencing PI's. If the interior angle is bisected, the midpoint can easily be established. Another similar method has two sets of references (tacked hubs) at angles and distances from centerline. It is desirable to have the two lines approximately 90 degrees from one another.

Double Angle/Distance Reference

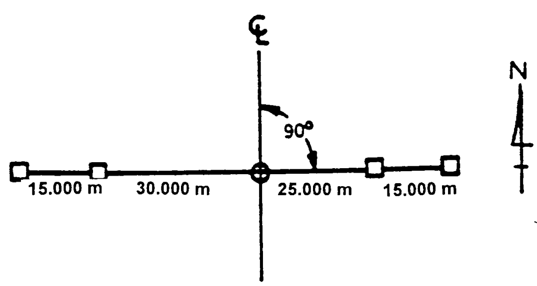
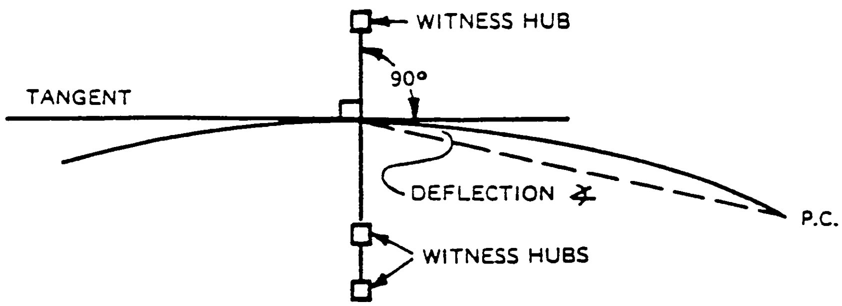


Figure 4-2.4c

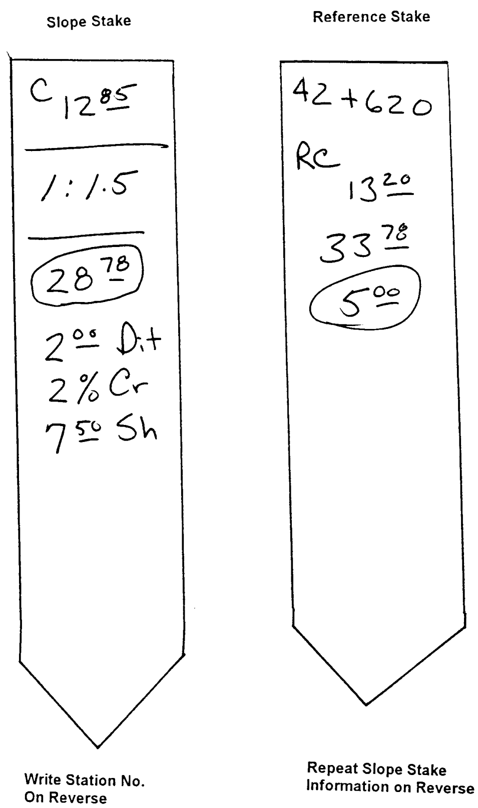
Application: Frequently used for section and quarter corners and control points that fall within an intersection. This is a very accurate method because two instruments can be used, thereby eliminating distance measurements. Another method also makes use of tacked hubs, but the witnesses are set 90 degrees to the construction centerline. This allows the survey crew to establish offset lines with minimal instrument setups.

Right Angle/Distance Reference
Figure 4-2.4d



Application: Commonly used on widening and relocation projects where normally, offset lines run parallel to construction centerline. When POC's on long curves are to be referenced, this method should be used. In order to witness a POC at right angles to the curve, the instrument is set on the station. After taking a backsight, the deflection angle for the instrument station is turned. Ni nety degrees are added or subtracted, depending on which way the references are to be established.

Right Angle/Distance Reference at P.T.
Figure 4-2.4e



Slope Stake

The intersection of the stake and ground is 12.85 meters above grade of ditch.

The cut slope ratio is 1 unit vertical to 1.5 units horizontal.

The stake is 28.78 meters from centerline. Some conventions show distance to bottom of slope.

(Optional) The template at this station has a 2.00 meters wide ditch. Ditch depth might be shown if it varies.

(Optional) The roadbed is crowned at 2% at this station.

(Optional) The subgrade shoulder break is 7.50 meters from centerline at this station.

Reference Stake

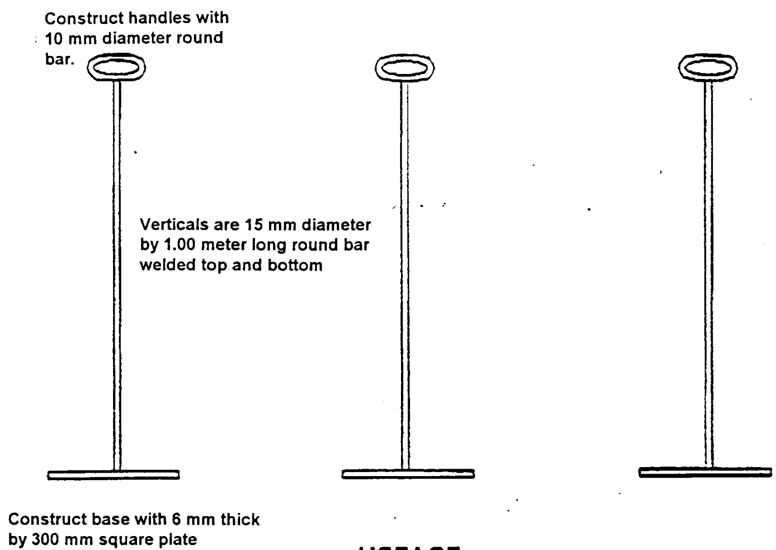
The stake is at Station 42+620

The stake is a reference cut (RC), 13.20 meters above the grade of the ditch.

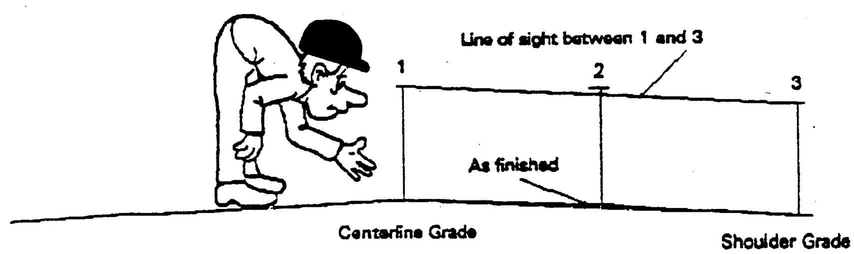
The stake is 33.78 meters from centerline.

The stake is 5.00 meters horizontally behind the slope stake.

Example Slope Stake and Reference Stake
Figure 4-2.8



USEAGE



Sight Level
Figure 4-2.10