STATE OF VERMONT
AGENCY OF TRANSPORTATION
CONSTRUCTION SECTION

2009
ENGLISH/METRIC
CONSTRUCTION MANUAL

SECTION III

ENGINEERING AND CONSTRUCTION SURVEYING

3-100 GENERAL

This part of the manual outlines methods for accomplishing the field work necessary to provide the Contractor with the project layout and elevations. The methods described have proven efficient for many Resident Engineers, but it is recognized that other methods and procedures may work well for other individuals.

It is one of the duties of the Resident Engineer to see that the Contractor is furnished with the initial layout and engineering at the time that it is needed. The work includes surveying for line and grades, engineering work for drainage, and the design of special features. Please reference Section 105.09, Construction Stakes of the Standard Specifications for Construction for further information.

The accuracy of surveying and engineering work must be consistent with its intended use. The centerline control points should be carefully and accurately tied in so that the centerline can later be easily and accurately reproduced. Usually, during the original stake-out, the work is performed in the woods over rough terrain. The resulting accuracy of the work will not be exceptionally good, but must be adequate for determining the location of the offset stakes from which the Contractor will start operations. Later, when the line and grades are produced at the sub-grade level, a greater accuracy is desirable and easily obtainable.

It must be kept in mind that incorrect methods and/or procedures at the time of staking a project will normally result in less accuracy being obtained and in the end will result in an increased amount of time being required to accomplish acceptable work. Time spent, whether short or long, is no guarantee of quality stake-out work; correct method and procedure used to accomplish the work will give the best results. Advice on proper operation of survey equipment follows, but is far from being all inclusive:

1. Keep the total station, data collector, GPS Receiver, and transit in good working order. It is recommended that you frequently check these instruments to see if they are out of adjustment:
    - Alignment – (1) Double center; (2) Turn direct angles.
    - Levels – Keep backsights and foresights even. Peg level as needed (this procedure is outlined later in this section).
2. Except when slope taping, the tape should be kept horizontal and vertical transfer of measurement should be accomplished by use of the plumb bob. The plumb bob is an instrument; when it is required, use it.
3. Check the level rod with a tie tape to see that it is marked correctly. Sections may have been inadvertently interchanged with other rods or, through wear, the joints have worn together. Both incidences will give incorrect level elevations.

It is assumed in the following discussions that personnel are familiar with the use of the total station, data collector, transit, level, tape, and other related surveying equipment.

3-110 ENGINEERING REQUIREMENTS

VTrans' obligations to the Contractor on all projects is described under Subsection 105.09, Construction Stakes of the Standard Specifications for Construction:

- Initial layout including the alignment & elevation, horizontal & vertical control.
- Layout of subgrade (rerun centerline alignment & finished grades).
- Layout permanent pavement markings.

Subsection 105.09, Construction Stakes of the Standard Specifications for Construction describes any construction layout that is to be performed by VTrans project personnel to support the Contractor's operation. The initial layout will generally establish the location and elevations of the various work items, with any additional layout work being the responsibility of the Contractor. The Contractors responsibilities include:

- Preservation of all survey stakes set by VTrans.
- Replacement of any and all stakes or grades disturbed by their operations.

3-120 DEFINITIONS

Alignment: A series of tangents and curves identifying a centerline for an existing or proposed highway.

Azimuth: The direction of one point or object, with respect to another, where the direction of the line is expressed as the clockwise angle from 0° to 360°

Bar-code Level: A level instrument designed to electronically read a special leveling rod with a bar-code face. Readings are automatically recorded on an electronic data recorder.

Bench Mark: A relatively permanent material object, bearing a marked point whose elevation above or below an adopted datum is known.

Central Angle: The angle at the center of radius of a circular arc included between the radii that pass through the beginning point (P.C.) and the ending point (P.T.) of the arc. Also known as the delta angle.

Coordinate System: A reference system for defining points in space or on a particular surface by means of distances or angles, or both, with relation to designated axes, planes, or surfaces.

Corner, Quarter Section: A corner midway between the controlling section corners, depending on location within the township.

Corner, Section: A corner established at the junction of surveyed section lines established by the United States Public Land System (USPLS).

Cross-Section: The elevations of the surface of the ground measured along a line perpendicular to the centerline or base line at any given station on the alignment.

Datum: A reference system whereby the position of one point can be directly related to another.

Deflection Angle: The horizontal angle measured from the prolongation of the preceding tangent line, right or left, to the following tangent line.

Digital Terrain Model (DTM): A model of the existing terrain that is developed from elevation data collected with reference to a coordinate system.

Easement: A non-possessing interest held by one person or agency in land of another whereby the first person is accorded partial use of such land for a specific purpose. Easements fall into three broad categories: surface; subsurface; and overhead.

EDMI: An Electronic Distance Measuring Instrument used to measure distances between points by using phase differences between transmitted and returned electromagnetic waves of known frequency and speed.

GPS: The Global Positioning System. The navigational and positioning system that provides location of a position on or above the Earth by a special receiver that interprets signals received simultaneously from several of a constellation of satellites.

Level Circuit: The measurement of elevations commencing on a known elevation point and ending on a known elevation point.

Leveling Rod: A straight rod or bar with a flat face graduated in linear units with zero at the bottom, used in measuring the vertical distance between a point on the ground and the horizontal line of sight of a leveling instrument.

NAD83: The North American Datum of 1983. It is an adjustment of the horizontal coordinate system.

NGS: The National Geodetic Survey.

Trigonometric Leveling: The determination of differences in elevation using trigonometric procedures with observed vertical angles and measured or computed horizontal or inclined distances.

USGS: The United States Geological Survey.

USPLS: The United States Public Land System. It consists of a set of rules by which boundaries and subdivision of public lands have been established in the United States. The USPLS is often used for designating the location of a parcel of land.

3-130 CARE OF EQUIPMENT

Construction Headquarters is responsible for maintaining an inventory of all construction equipment. Examples include: total stations, data collectors, GPS receivers, levels, fall protection lanyards and harnesses, planimeters, torque wrenches, transits, digital cameras, turbidity meters, and other miscellaneous equipment (level rods, tripods, portable signs, etc.). Each piece of equipment and the name of the employee responsible for it is entered into the inventory database through the use of the *Equipment Assignment Record Form* (Appendix C-1). Cell phone and pager inventory, assignment, and maintenance are conducted through the Program Development Business Office.

3-130.10 Assignment and Transfer

Equipment will be assigned to employees as required by the job on which they are or will be working. Regional Construction Engineers may sign for and retain spare equipment. In this case, the Regional Construction Engineer will be held responsible for the equipment.

The Equipment Assignment Record form (Appendix C-1) and a completed example (Appendix C-2) can be found at the following locations: G:\Forms\(current year) Construction Field Forms\General\Equipment Transfer Forms or in the current year Construction Field Forms CD under the Survey\Equipment Transfer Forms. The equipment transfer forms are specific to the individual Green State tag number which is assigned to the equipment. Before taking possession, returning or transferring the specific piece of equipment, it's corresponding Equipment Transfer Form must be filled out completely.

The original of Equipment Transfer Form must be sent to the assigned Regional Technician who will then send a scanned copy to the Administrative Services Technician at Headquarters for recordkeeping and updating of the inventory database.

If this update is not done and the piece of equipment turns up missing, the person who originally signed out the equipment will be held responsible and may be liable for a replacement.

3-130.20 Maintenance and Reassignment

The Construction Section has yearly maintenance contracts with various vendors, requiring equipment to be turned in to Construction Headquarters annually during the winter months. Equipment is sent out for cleaning, calibration, and any repairs needed at that time. When bringing equipment in for maintenance, make sure all items are returned; including legs, batteries, cords, manuals, cases, etc., in case reassignment of the equipment is necessary. Once the maintenance has been completed, equipment will be reassigned and redistributed per the Regional Construction Engineer based on need and availability.

Steel tapes that are to be stored for any length of time should be cleaned and lightly oiled. Transit legs and range rods should be repainted, if needed. Level rods which are damaged, or hard to read, should be exchanged for new or reconditioned ones at Construction Headquarters. Axes and sledge hammers should be painted orange or red to expedite locating them if left lying on the ground. Transits should be kept clean on the external surfaces, but should not be taken apart to clean or repair. Minor adjustments for accuracy, as described in any good surveying book, may be made in the field. Notify your immediate supervisor for assistance if major repairs or adjustments are necessary.

3-130.30 Repairs/Adjustments

Resident Engineers should make a habit of verifying the accuracy of the equipment being assigned to them. In the event that a piece of equipment is bumped, the accuracy should be verified. If it is not operating precisely, the Administrative Services Technician IV should be contacted to have the piece of equipment adjusted.

3-130.40 Care of Equipment

The Resident Engineer shall inspect all equipment at the start of the day for its physical condition and cleanliness. The exterior of the all pieces of equipment shall be cleaned frequently. All equipment shall be kept in its original case, which contains padding to prevent damage from shock and vibration. If the original equipment case becomes damaged or lost, a suitable replacement will be provided from Construction Headquarters.

All instruments shall only be handled by the designated grip points. Failure to properly handle instruments will lead to premature wear and eventual breakage, causing them to be out of service for repair. Don't attempt to repair an instrument yourself. Please contact the

Administrative Services Technician IV at Construction Headquarters if your instrument is in need of repair.

The instrument shall be taken off its tripod while moving to a new setup or location. Damage to the instrument can result if this practice is not followed.

Do not leave your instrument unattended. This is especially important during windy conditions caused by storms or high-speed traffic adjacent to the instrument. Any sudden gust of wind can throw an instrument off level or topple it causing severe damage.

If you are operating the instrument in dusty or misty conditions, it is recommended you carry a plastic bag with you to place over the instrument while not in use. This will minimize the amount of dust and moisture that enters the instrument. Never use an instrument in rainy or snowy weather, as moisture can easily penetrate the instrument.

Make sure to thoroughly dry out any equipment or instruments that have been exposed to wet conditions. Do not leave a wet instrument in an enclosed case. Towel dry the instrument and leave in a well ventilated area so any moisture residing inside the instrument can evaporate. Failure to do this will lead to corrosion and eventual failure of critical electronic components inside the instrument.

All prisms shall be checked daily to ensure that they are clean, not cracked, and that they are assembled correctly.

Make sure all batteries, such as Ni-Cad units, are completely discharged before attempting to recharge them. Failure to do this will result in diminished battery life due to the "memory" developed by the battery. Newer nickel metal hydride or lithium-ion batteries are not as prone to this phenomenon.

3-130.50 Tips for Proper Instrument Setup

Push the tripod leg shoes or "feet" firmly into the ground. Do not stomp on the feet of the tripod legs, as this may damage the tripod. Even pressure, that is parallel to the tripod leg, should be applied to each tripod foot.

Place the tripod legs in a position that will result in a minimal amount of walking around the setup. The tripod should be set at a height that enables the eye piece of the instrument to be at a comfortable position for the operator. It is not good practice to have to hunch over or stand on the tip of your toes to operate the instrument. Keep in mind that others may also need to use your instrument setup, so try to find a happy medium regarding tripod height.

When setting up an instrument in windy conditions, be sure to set one leg of the tripod downwind to gain additional stability. This will minimize the potential for the instrument to topple over.

When setting up an instrument on frozen ground, place flat boards under the tips of the tripod legs. If possible, place snow around the bottom of the legs to minimize any potential shifting or settling of the setup.

When setting up an instrument in hot weather on bituminous concrete pavement, place flat boards under the tips of the tripod legs to prevent the setup from settling into the hot asphalt.

3-130.60 Adjustment for Line of Sight or "Peg Test"

The following is a simple procedure and example of how to perform a line of sight or "peg" test.

Setup #1: Required to find the difference between two line of sight shots that are opposite of each other.

Example:
First height of rod shot = 3.50 feet
Second height of rod shot = 4.25 feet
This results in a difference of 0.75 feet (4.25' – 3.50' = 0.75')

Setup #2: Required to determine the theoretical height of rod. Make sure to reposition the tripod legs and level the instrument again before performing Setup #2.

Example:
Third height of rod shot = 2.55 feet
Forth height of rod shot = 1.70 feet

Theoretical height of rod = 1.80 feet

[2.55 feet (3rd shot) – 0.75 feet (difference between 1st & 2nd shots) = 1.80 feet]

Theoretical height of rod – the reading on 4th shot determines whether the level needs adjustment.

Example:
The following provides the simple calculation used to determine whether or not the level needs to be adjusted. A difference of "zero" means the level is OK. Any difference (+ or -) greater than 0.02 feet means the level needs adjustment.

Theoretical height of rod – 4th shot reading = 1.80 feet – 1.70 feet = 0.10 feet. This level is out of adjustment.

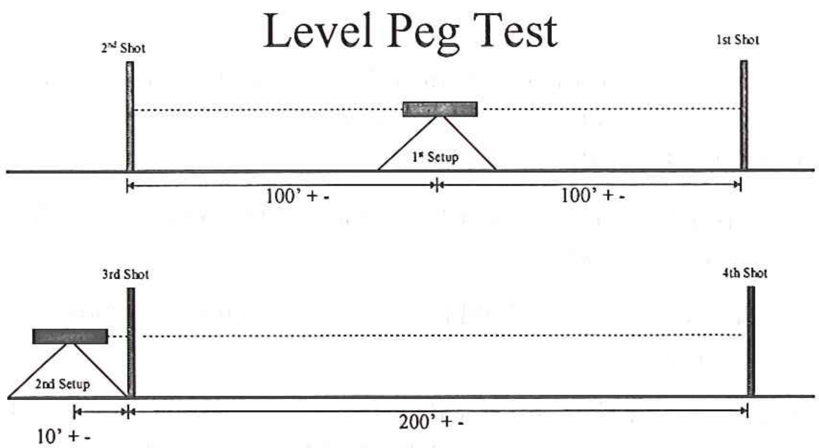


FIGURE 3-1: Level Peg Test Setup

To adjust the level, sight the forth shot of 1.70 feet again as shown under Setup #2.

Using the adjustment screw shown in the picture below, adjust the crosshairs of the level so that they now read the theoretical height of rod of 1.80 feet.

Once the crosshairs are adjusted, perform the setups shown in Setups #1 and #2 again to check the adjustment of the level. Perform the calculations again to determine whether or not the level is still out of adjustment.

If the theoretical height of rod and actual height of rod are within the tolerance limit of 0.02 feet (+ or -), the level is in adjustment and nothing further is required.

If the difference is outside the tolerance limit, continue to perform this test until the level falls within the tolerance limit.

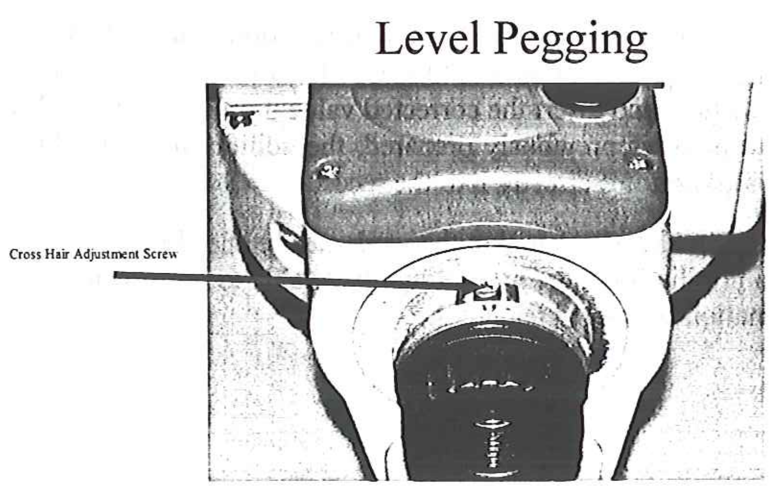


FIGURE 3-2: Detail of a level adjustment screw

3-140 FIELD NOTES

Field notes are the written record of pertinent information, layout, measurements, and observations of the project. They should be kept according to uniform practices and conform, as a minimum, to the following general requirements:

Neatness: Use a sharp pencil of at least 3-H hardness. Avoid crowding the information and keep the book as clean as possible.

Legibility: Use standard symbols and abbreviations to keep notes compact. Use plain lettering to avoid confusion.

Clarity: Plan work ahead of time so that data can be clearly indicated. Do not make ambiguous statements. Line up descriptions and make sketches for clarity. Record data in a consistent way. Assume that the person who will use your notes has no familiarity with the work.

Completeness: Show all pertinent measurements and observations. Use a degree of accuracy consistent with the operation. If in doubt about the need for the data, record it. Review data before leaving the field. All entries must include:

- The date and weather conditions.
- Title of task.
- Names of all persons in the survey crew and their assignments.

The title page must be completed as the book or project is started. The VTrans return address must be noted on the title page in case the book is lost. The book must be adequately indexed, pages numbered and cross-referenced to contents.

Permanence: All entries should be made directly into bound books. At the completion of the project, the books should be filed as part of the permanent record in keeping with Finals Unit policies.

Accuracy: Record exactly what was done at the time it was done, rather than depending on memory at a later time. Never erase in a field book. If an item is incorrectly entered, draw a line through the item and insert the corrected value immediately above. When it is necessary to add data to notes previously prepared, the additional item should be dated and initialed. Always enter notes directly into the record.

Self-checking: Notes should be kept so that the work can be checked without returning to the field. Any person familiar with the project should be able to verify the accuracy of the work from the information contained in the notes.

3-150 COOPERATION WITH THE CONTRACTOR AND PROPERTY OWNERS

Property owners should be contacted before any construction surveying is done on land bought from them. Introduce yourself to the property owners and tell them what your function will be in connection with the project and answer any questions that they may have. This takes time, but makes for a better relationship between VTrans, the Contractor, and the property owner.

Inform the property owner how to contact you during the normal working day. This can be done simply by handing them your VTrans business card. Record in your diary the date and any part of the conversation that is vital to the project.

Care must be taken to avoid damage to private property. Bench marks, ties, and stakes must be placed within the Right-of-Way (ROW) when possible. Nailing and cutting must not be done on private structures, trees, and bushes. Use only non-destructive, temporary marking, such as flagging and stakes driven in the ground. Information may be written on the flagging. Avoid painting any surface which will be visible after construction is completed.

Prior to the beginning of any construction activity the Resident Engineer should have a meeting with the Contractor or the Contractor's representatives to go over the procedures that will be used to stake-out the project. This should include all phases of the construction engineering. In addition, the Resident Engineer should address the following:

1. How control points are established for centerline, bridges, drainage, etc. and the importance of this procedure and the Contractor's cooperation in preserving all stakes encountered in the field.
2. Arrange for help from the Contractor in the form of personnel to assist in taking original cross-sections; borrow pit cross-sections, final cross-sections, structure cross-sections, etc. This will help prevent any future claims against the project, if both the Contractor and VTrans are represented in this work.
3. Explain to the Contractor that they should verify that there are no mistakes or errors in the plans before working on the various items. If errors are found, the Contractor is to give the Resident Engineer ample time to make the necessary corrections. The Resident Engineer should inform the Contractor that no claims will be brought against VTrans or the project if the Contractor is negligent in this respect.

3-160 ALIGNMENT

3-160.10 Running Centerline

The original survey line, as run for design purposes, is very often the only line that will have been run before the project is turned over to the Construction Section. This line is the one that will be used initially as the basis for all construction surveying. Often portions of the original line have been revised during the design phase of the project and have never been run in the field. The original line, with any revisions, will normally be reproduced by the stake-out party, using the following procedure. For the most part, this procedure will also be followed while running the centerline throughout the duration of the project.

Transfer of Curve Data: Enter all curve data given on the plans into a hardbound Field Book; specifically in Field Book# 4 or a handheld data collector. Check the given curve data and compute the required deflection angles. Check for line revisions. Refer to Subsection 5-130.25, Field Book #4 – Control, of this manual for other information to be entered in Field Book #4. The handheld data collector software will automatically calculate deflection angles for you. Should any problems be encountered when entering information into the data collector, please contact either Construction Headquarters or the Route Survey Unit.

Locate Control Points: Locate the original control point ties and re-establish the control points; PI's, PC's, PT's, POT's, and POC's. Refer to Subsection 3-160.30, Control Point Ties, of this manual for re-tying control points.

Run the Line: Using standard surveying methods, run the line including curves, tangents, and sub-tangents as necessary. Running the line by way of the coordinate stakeout method is also an acceptable approach and will be defined in a subsequent edition of this manual.

Mark the centerline at 20 meter (50 foot) intervals, using sixteen (16) penny spikes. Use a piece of flagging on the head of the spike to improve its visibility. To mark a line on a bituminous concrete surface, use a short roofing nail, or a masonry nail.

Note the error of closure when coming into each original control point, both as to distance and deflection. If the error is greater than that acceptable for the type of survey being done, it may be necessary to re-measure the deflection angle at the PI or to re-tape the sub-tangent. As a last resort on a long curve that will not close, it may be necessary to run the curve from the PC and the PT towards the middle of the curve, in order to distribute the error.

While running the centerline, establish any new control points, which may be necessary for future line location (Subsection 3-160.30, Control Point Ties) or for the running of parallel offset lines (Subsection 3-160.20, Parallel Offset Lines). When the transit is set up over a control point, hubs may be put out at right angles to the centerline for use as centerline ties (Subsection 3-160.30, Control Point Ties) or as offset line control points (Subsection 3-160.20, Parallel Offset Lines).

3-160.20 Parallel Offset Lines

It is often advantageous to run a line which is parallel to the survey centerline. This line may be used as an aid for the original staking of the project or as an aid in determining right angles for the taking of cross-sections.

Determine Offset Distance: Study the plans and cross-sections to determine the distance to offset the parallel line. The line should fall outside the limits of construction but inside the Project Demarcation Fence (PDF), and be close enough to the top of cut or toe of fill to be useful. The offset distance will vary for different sections of the project, depending on the depth of the cut or fill.

Set Out Control Points: Using the transit at the control points on the centerline, (PC's, PT's, POC's, POT's) set out points at right angles to the centerline, at a distance equal to the offset of the proposed offset line. If a hub with a nail in the top is used for this point, it may also serve as a control point tie for the centerline (Refer to Subsection 3-160.30, Control Point Ties). In a hilly terrain, the procedure of slope taping is useful. (Refer to Subsection 3-200.10, Slope Taping). Coordinate stakeout method can also be used.

Run the Offset Line: With the transit over the offset control point, either sight the centerline control point and turn 90 degrees, or sight on the next offset control point, if visible.

Proceed to run a line to the next offset control point, marking the line at full, half, and odd stations with spikes.

To run a parallel offset curve, the same deflections are used as are used when running the centerline curve. However, the chord length must be corrected, being longer on the outside of the curve and shorter on the inside of the curve. The chord distance is proportional to the offset distance and is computed by the formula.
Co = C ℄ x (R℄ + 0)/R℄
Where: Co = Length of the chord on the offset line
C℄ = Length of the chord on the centerline
R ℄ = Radius of the centerline curve
0 = Offset distance

Example (Metric): The length of the chord between 20 meter stations on a line which is offset 30 meters on the inside of a 582-125 meter radius curve is computed as follows:

Co = 20.00 x (582.125 - 30.00)/582.125 = 18.969

3-160.30 Control Point Ties

Control points are those points that are used to define the survey line and include PI's, PC's, PT's, POT's and POST's. Control point ties are measurements used to relocate these control points once the original points have been removed during the construction operations. The original control point ties are normally within the construction limits, so new ties must be established which fall outside the construction limits and which will survive throughout the duration of the project.

The preferred control points to be tied are those mentioned above, but often ties to these points will be difficult to use after excavation has been performed because the points fall in deep cuts or high fill sections. Therefore it may be necessary to establish supplementary control points on the survey centerline that can be more easily tied and used; such as points that fall in shallow cuts and fills or at the transition between a cut and a fill. The best time to establish these supplementary control points is at the time the centerline is rerun prior to the staking operation, as this will save a transit set up during the process of tying the control points.

Control points may be tied in several ways with the method chosen, depending on the terrain and the width of the construction area. In narrow construction areas, where tie distances of less than one hundred feet may be used and the tape can be properly plumbed, control points may be tied by measurements to fixed objects such as ledges, trees, buildings, or wood hubs driven into the ground. Where the construction area is wider and especially where a parallel offset line is to be run, the control points are normally tied by a line of hubs placed at right angles to the centerline, with distances measured from the hubs to the control point. These hubs must be set by the use of a transit and the distances must be carefully measured. The use of slope taping (Subsection 3-200.10, Slope Taping) is often helpful. When a parallel offset line is to be run, it is normal to place one of the tie hubs at the offset line distance, so that the hub then becomes a control point on the offset line. A third method of tying which may be used is to set up two lines of sight intersecting at the control point. This method is normally used only where taping is impossible or impractical.

Regardless of the method used to establish control point, enough reference points should be set to provide assurance that the control point can always be reestablished. Because the Contractor's operations invariably destroy some of the reference points, enough points should be used so that the control point can be replaced even though one or two of the reference points have been destroyed. For this reason and to serve as a check on the field work, a minimum of three reference points should be established for tying each control point. Hubs used as a tie point should have a small nail in the top to be used as the actual reference point and these hubs should be witnessed with two tall witness stakes to aid in their location. The station of the control point and the tie distance should be written on the witness stakes.

The following sketches illustrate some of the methods used to tie control points.
(Note: The following sketches are in English Units.)

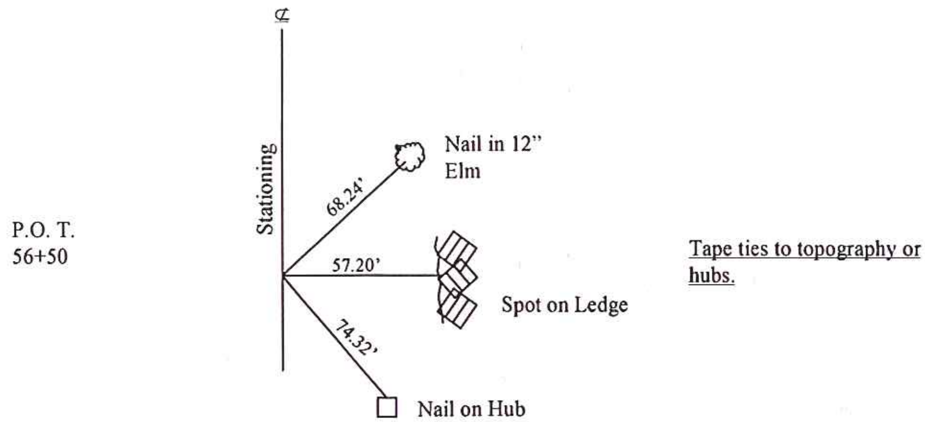


FIGURE 3-3: Example of Control Point Ties (Tape ties to topography or hubs)

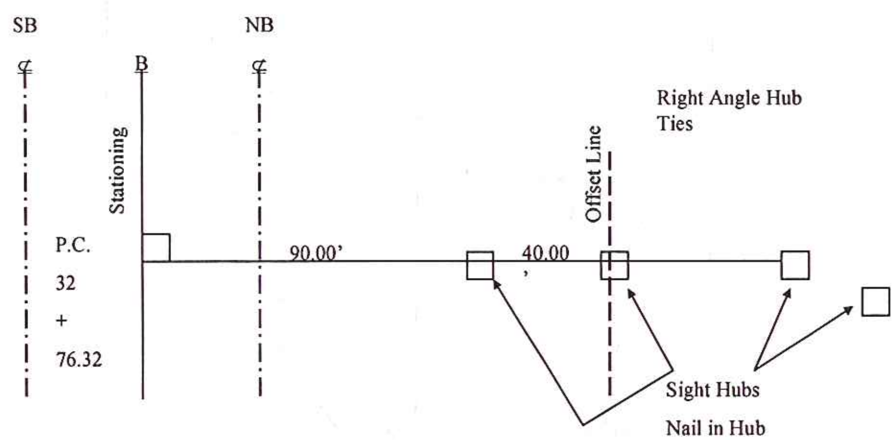


FIGURE 3-4: Example of Control Point Ties (Right angle hub ties)

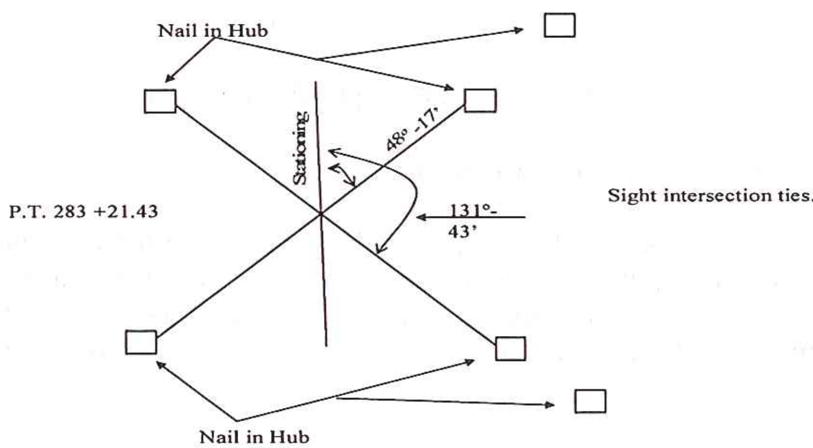


FIGURE 3-5:Example of Control Point Ties (Sight intersection ties)

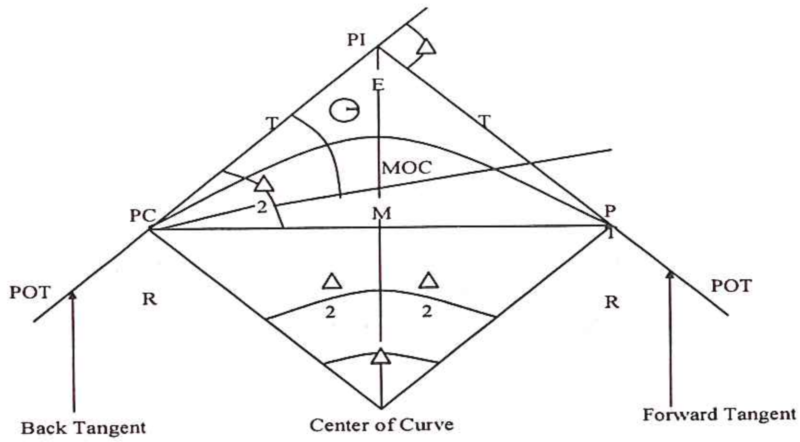


FIGURE 3-6: Example of Simple Circular Curve

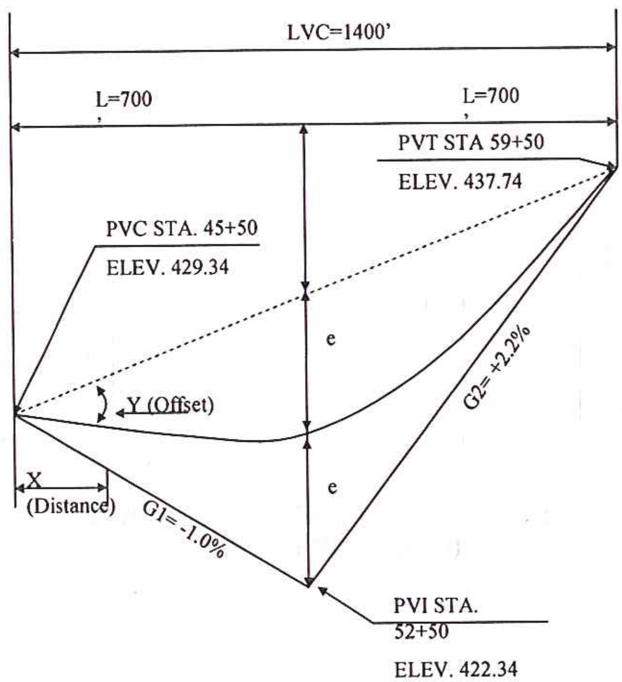


FIGURE 3-7: Example of Vertical Curve

3-160.40 Offset Staking of Centerline

When sufficient control has been established to ensure the reproduction of the original alignment, generally before construction, the centerline must be referenced to construction stakes. Construction stakes are placed at right angles on the left and right on each 20 meter (50 foot) station and on stations where an equation exists.

The usual staking methods are as follows:

1. Right Angle Prism: On tangents alignment - Sight ahead or back, holding the prism over the centerline point, establishing a line which will be right angles to the centerline of the roadway.

2. Transit: The transit may be used to obtain right angles when setting stakes; however, this accuracy is time consuming and is not usually warranted for stake-out of centerline.

After determining the right angle line, a stake is driven at an offset outside the limits of clearing and grubbing. If a parallel offset line has been run (Subsection 3-160.20, Parallel Offset Lines), this line may be used to aid in the staking. The stake is driven approximately 150 millimeters (6 inches) beyond the nail, which marks the station on the offset line, and the distance from the nail to the front of the stake is measured. From this measurement and the known offset distance of the parallel line, the stake offset distance from the survey centerline is computed. It is common practice to mark the stake elevations on the back of each stake. This gives you many benches that may be used for sectioning and drainage where a high degree of accuracy is unnecessary. After construction is complete and the final sections have been taken, all stakes should be pulled and destroyed.

The following examples show how to mark offset, station, and cuts and fills on construction stakes. The following examples illustrate the required information and the method of marking it on the stakes. Offset distances are measured and marked to the nearest 30 millimeters (1 inch), and the cuts and fills are computed and marked to the nearest millimeter (tenth of a foot).
(Note: English Units used)

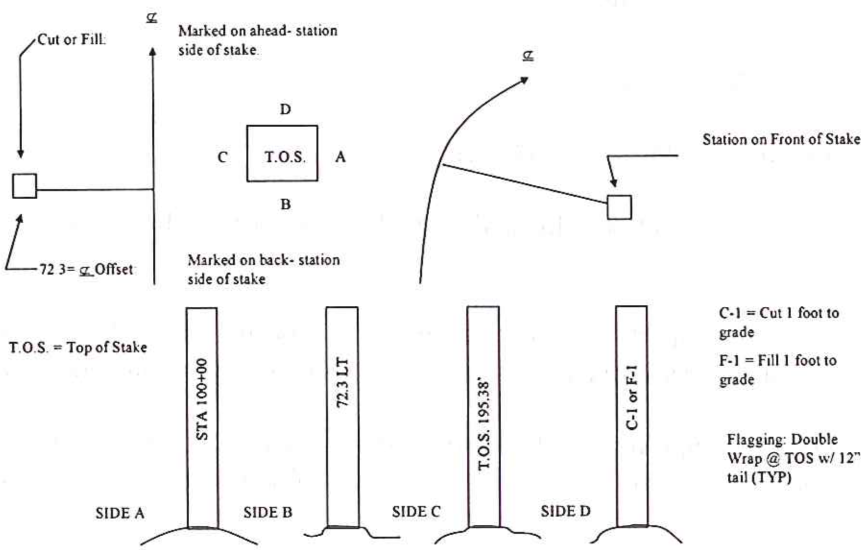


FIGURE 3-8: Offset Stake Markings

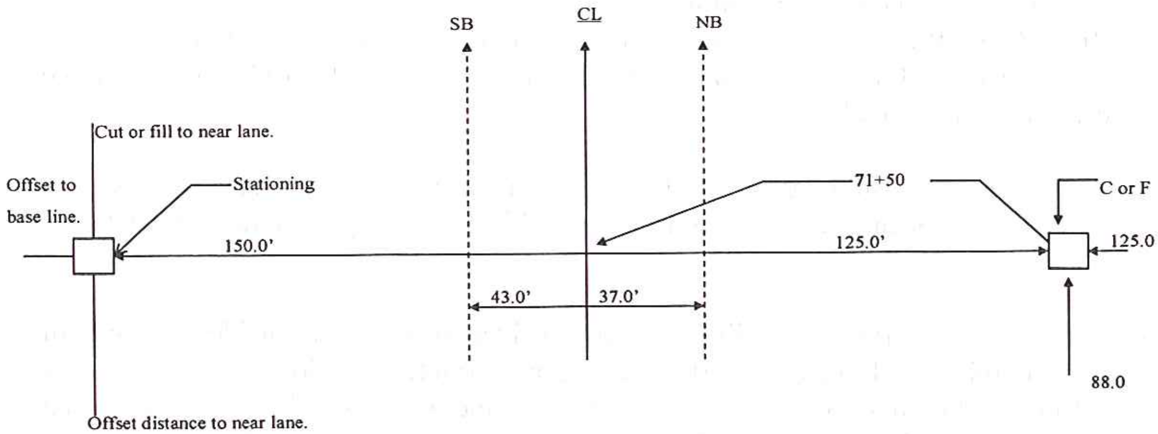


FIGURE 3-9: Cut and Fill Stake Markings

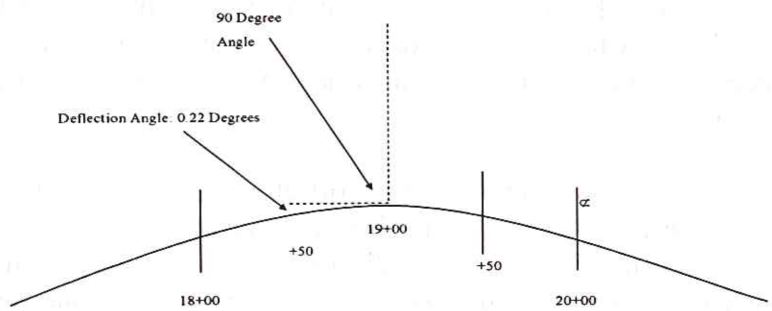


FIGURE 3-10: Offset Staking Method - Curve

3-170 VERTICAL CONTROL

3-170.10 Bench Lines and Bench Mark Transfers

Retain original benches that are located outside construction limits, but are within working distances.

Pick locations for bench marks, keeping in mind that the bench mark will be used for leveling the offset stakes, as well as other requirements that exist during construction.

Establish a bench mark approximately every 150 meters (500 feet) in addition to those that should be placed for reference when layout work of a structure or large pipe will be required.

Transfer the elevation of the original bench mark to the new location. Run separate levels both ways to ensure the accuracy of the new bench mark.

To reference bench marks, use a flat stake with the bench mark number and elevation on it and nail it to a tree or other suitable location. Never establish bench marks outside right-of-way unless you have obtained permission from the property owner.

Bench marks must be recorded in a permanent field book. Benches which have been destroyed must be crossed out of the book and the list kept current in Field Book #4.

The original bench line is a balanced line, but the original benches may have been disturbed in one way or another and may not check between bench marks. After bench marks have been transferred and before the project is too far along, all original and transferred benches must be balanced and then used throughout the project.

The following method may be used when transferring bench marks:

1. The elevations are computed from bench mark to bench mark.
2. To check your computations, add the backsights and foresights columns.
3. The net difference added to or subtracted from the previous bench mark should prove the new elevation.

Example:

	B.S.	H.I.	F.S.	Elevation
B.M. #1				30.48
	1.524	32.004		
TP			-0.914	31.09
	3.353	34.442		
B.M. #2			-0.610	33.833

B.S. = 1.524 + 3.353 = + 4.877
F.S. = -0.914 + -0.610 = - 1.524
+3.353

BM#1 Elev. = 30.48
+ 03.353
33.833

3-170.20 Offset Stake Leveling

Construction stakes require leveling before they can be used by the Contractor for grading work. Notes may be taken on either loose leaf paper or in a bound book. Loose leaf paper is more practical when a project is leveled in sections, or where only one side of the road can be leveled at a time. The level notes must be kept for the duration of the project. The Resident Engineer must give some thought to the leveling process before it is started.

Usually, it is just as well to hold off until the clearing and grubbing is complete, then replace the missing stakes and decide on a course to follow. On larger projects, it is just as well to go up one side of the road or line of stakes at a time; making sure that the notes are set up according to the example shown. The shots are read to the nearest millimeter (tenth of a foot) and the distance (cut or fill) to the finished grade is written on the stake to the nearest millimeter (tenth of a foot).

Once the levels have been taken on a line of stakes, the elevation of the stakes can be figured and from that, the cut or fill to the finish grade of the roadway may be computed. The results of these computations must be checked before being put on the stakes. The Resident Engineer must spot check the stakes to ensure that the information pertaining to a particular stake is put on the correct one. See Subsection 3-160.40, Offset Staking of Centerline, for the prescribed method of marking stakes. To check for large errors in either the stake levels or the original cross-sections, the stake levels should be plotted on the cross-sections at the proper offset. If both the stake elevation and the cross-sections are accurate, the stake elevation plot will be 750 mm (30 inches) to 900 mm (35 inches) above the plotted ground surface.

3-170.30 Subgrade Stake Leveling

When it is time for the Contractor to fine grade the sub-grade, the Resident Engineer must re-run the centerline, from which the Contractor can offset the working stakes. It is the Contractor's responsibility to check the location, alignment, and elevations to assure that they are correct.

To re-run the centerline, the Contractor will set out working stakes and mark the station and offset on these stakes. They will spot check these stakes for conformity to the typical section and then establish finish grades on the sub-grade stakes, using the elevation as taken from the Plan Grade sheets.

If the actual finish grade cannot be placed on the stake, then the procedure is to reference the cut or fill distance to the actual finish grade. Care should be taken to balance foresights and backsights and shots should be kept within a distance of 60 meters (200 feet) of the transit or level. Before grades are run from each change of height of instrument (HI), the arithmetic should be checked to ensure that the proper grades are matched to the proper stake. After changing your HI, you should check back onto a stake that you have set a grade on with your last set up. Stakes should be firmly set and generally are offset .3 to .6 meters (1 foot to 2 feet) from the computed toe of the subgrade. In this way, the stakes will remain in position with a minimum of replacement throughout the subbase operations. It is very important to use the same reference to grade the stakes throughout the operation. As you come to a bench mark, levels should be checked and a variance of greater than 10 mm (.03 ft) should not be tolerated between bench marks that are known from previous work to be accurate.

3-180 CROSS-SECTIONING

3-180.10 General

Revised original, final, and borrow pit sections may be taken on conventional field level note paper. An example of cross-sectioning with this type of note paper can be found under Section 3-180.90, Borrow Pit Sections. Sections for special ditches, undercutting subgrade, slope stabilization, channel and structure excavation, and culverts, will normally be recorded in the proper Field Book (Field Book #2 - Drainage; Field Book #3 - Bridge; Field Book #6 - Excavation; Field Book #7 - Miscellaneous).

Roadway cross-sections are taken at 20 meter (50 foot) intervals along the centerline of the project on all full and half stations. A cross-section survey party will consist of a chief, who is usually the note keeper, a transit person, and two or three rod persons, depending upon terrain and conditions. Accuracy should be stressed at all times because an improperly read or recorded offset can cause problems at a later date. Cross-sections will be taken at ninety (90) degrees to all stations on the tangent between the PT and the PC and radically to the curve at all stations between the PC and PT on the curve. Right and left of base line or centerline is determined by standing on the line and facing forward in the direction of increasing stations. A rod reading an offset will be recorded for each break or change in terrain both right and left of centerline for a sufficient distance to ensure covering the area to be worked. On level terrain, the maximum distance between shots should be held to 10 meters (30 feet).

Survey cross-section notes are recorded by one of the following two methods:

1. As a fraction with the rod reading recorded as the numerator and the offset recorded as the denominator, with succeeding shots written across the page (this method is usually used in a Drainage Book).

2. In columns, with the offset and rod reading in separate columns and additional reading recorded down the page.

Examples:

(1)	0.975	1.400	1.585	2.710
	℄	3.1	6.1	7.6

(2)	℄	0.975
	Rt. 3.1	1.400
	6.1	1.585
	7.6	2.710

When the sectioning of a revised line is necessary, then the final sections must be taken at these same stations. When taking sections, check H.I.'s, right angles, and exercise care in taping and in the use of the hand level.

Make proper notations such as edge of stone-fill (ESF), old ground (OG) or anything that should be noted which would help clarify the situation to someone not familiar with the job. All survey notes must show the project name, number, personnel doing the work, and the date.

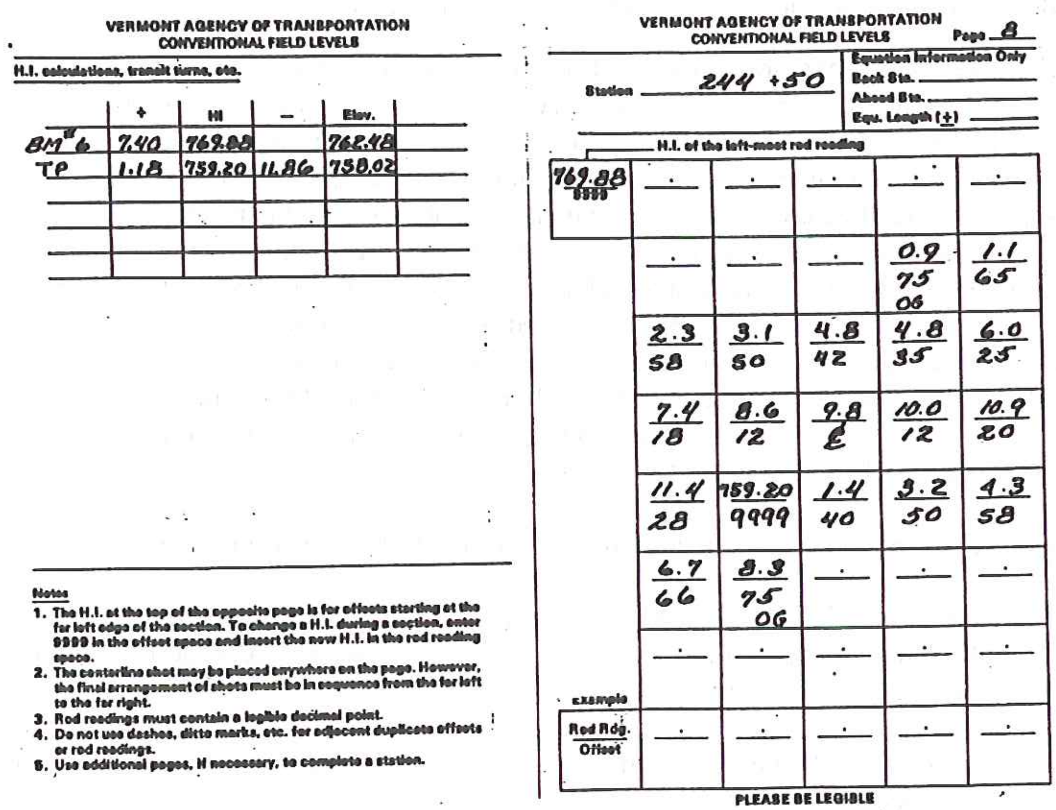


FIGURE 3-11: Conventional Field Level Notes

3-180.20 Preconstruction Centerline Cross-Sections

Any area of the project that has a revised centerline and shows equated stations on the cross-sections may require new original cross-sections before construction begins. Sections would be taken as explained in Subsection 3-180.10, General. Additional cross-sections may be necessary to adequately compute excavation in cut-to-fill transitions.

3-180.30 Cross-Section Extensions

It will be necessary to extend all original survey cross-sections that do not extend beyond the limits of construction. This is quite often determined by the presence of a dashed line shown on the cross-sections by the designers.

3-180.40 Stripped Ledge Cross-Sections

In all cases, ledge sections are required to verify the sub-surface ledge line shown on the plans and for computation of the final quantity of rock excavation and for the assignment of the rock over-breakage quantity. Additional cross-sections may be required when there are major changes in the ledge profile. In this case, the sections will be plotted on separate sheets, properly templated, and the quantity of rock excavation computed.

NOTE: When taking stripped ledge section, take all shots on ledge. "Ledge under" shots serve no purpose at all and can lead to mistakes being made if they are plotted up as ledge.

3-180.50 Drainage Pipe Cross-Sections

For each drainage pipe 1200 millimeters (48 inches) in diameter and under, a cross-section will be taken before work commences, along the proposed centerline of the pipe. This section will be recorded, as it is taken, in the drainage book in the particular section of the book set up for the pipe. This section will then be plotted, templated, and used to compute the quantity of trench excavation. It is also used to determine the correct location of the inlet and outlet, both horizontally and vertically. From this information the correct length of pipe can be determined. See Subsection 3-180.70, Structure Sections for sections covering pipes greater than 1200 millimeters (48 inches) in diameter.

3-180.60 Channel Sections

Channel sections will be taken according to standard survey procedure from a base line set up for the particular channel or, if parallel to the roadway, may be covered by an extension of roadway sections. Baselines for channel excavation should be tied to the roadway baseline. Channel excavation, when used in connection with a structure, will be for the inlet and outlet of the structure or a pipe greater than 1200 millimeters (48 inches) in span or diameter. The channel excavation will begin 300 millimeters (12 inches) beyond each end of the structure or pipe. It is recommended that new preliminary channel sections be taken at the time of construction staking and that final channel sections be taken as soon as work is completed on each channel location.

3-180.70 Structure Sections

For each drainage pipe or structure greater than 1200 millimeters (48 inches) in diameter, cross-sections must be taken at ninety degrees (90°) to the centerline of the pipe and to a distance of one-half (1/2) the diameter plus 3 meters (10 feet) each side of the centerline. The station interval of the sections will be 10 meters (30 feet) or less as required to cover the conditions. For bridges, the sections will have separate baselines for each pier and each abutment, with the baselines being parallel to the centerline of bearing at each location sectioned. Structure sections will be taken at all changes in direction of the structure excavation limits as shown in the following sketch.

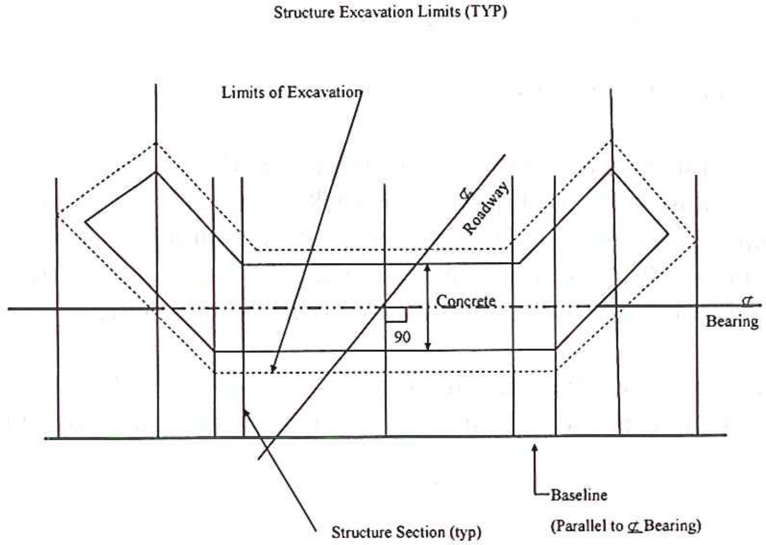


FIGURE 12: Structure Excavation Limits TYP

3-180.80 Gravel Pit Stripping Sections

For each gravel pit for which sections are to be taken, set up and tie in a baseline. Careful attention needs to be given to the setting up of this baseline so that it can either be preserved for the duration of the project or adequately tied in so that it can be reproduced at any time. It is also good practice to record a transit bearing for the baseline. See Subsection 203.13 Method of Measurement, Part (b) Borrow, of the Standard Specifications for Construction in regard to the area to be covered. Preliminary and final sections of the stripped area are necessary, as well as to put on the limits of the pit used, to satisfy Subsection 203.13(b) of the Standard Specifications for Construction.

3-180.90 Borrow Pit Sections

Introduction:
Figure 13 illustrates a typical borrow pit as well as methods on how to layout and cross-section a borrow pit.

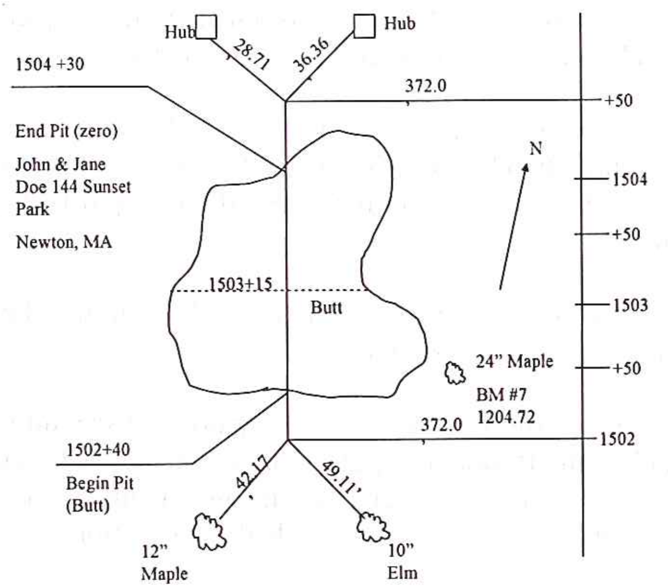


FIGURE 13: Illustration of a Borrow Pit

Field Work, Layout of Pit:

1. The borrow pit baseline should be one tangent and may be placed anywhere in the area. Both ends of the baseline must be securely tied in, well outside the construction limits. Pits that are located within 150 meters (500 feet) of the projects roadway centerline should be further tied to the roadway centerline.

2. The borrow pit baseline may be completely to the left or right of the pit or it may go through the pit. Therefore, it is possible and acceptable to have all offsets to the left or right of the baseline.

3. When the borrow pit is adjacent to the project roadway, the centerline tangent/sub tangent may be used as the baseline with stations extended to include the pit area.

4. Make a sketch of the pit on a blank sheet of field paper and place it after the cover sheet. The cover sheet will shown the name and location of the borrow pit, weather conditions, the names of the individuals on the survey crew and which instruments they were responsible for. Show all ties, approximate boundaries, beginning and ending stations, names and addresses of all owners, and an approximate north arrow.

5. Do not start the borrow pit at station 00+0. This will avoid negative stationing if the beginning needs to be extended (suggest starting at 10+000 or 20+000).

6. If possible, borrow pit elevations should be referenced to the established roadway bench line. Borrow pits outside the project area may have an assumed bench line. A minimum of two bench marks is required.

7. Original pit sections are normally taken at 10 meter (30 foot) station intervals (i.e. 10+000, 10+020, 10+040, 10+060, etc). However, in the case where the terrain is relatively flat and uniform, 20 meter (50 foot) station intervals are permitted.

8. Original odd stations may be taken, but if done, it must be a full width section. Do not take partial odd stations.

9. A final section must be taken for every original section within the excavation area, unless the Resident Engineer deletes an original section. It is possible to have extraneous original sections at the beginning or ending of the pit, but this is acceptable because they are outside the excavation area.

10. Original sections should not be taken until the pit is stripped. If for some reason original sections were taken before the pit is stripped, fill end areas will result. These fill end areas usually will be subtracted from the cut end areas to obtain the final payment area. This should be avoided. The deducted area will not usually equal the original stripped area.

11. Due to steep embankments or other reasons, the Resident Engineer may take slope levels instead of the conventional rod reading / offset levels.

12. The Resident Engineer may take original sections via conventional rod reading/offsets and final sections via slope levels or vice versa.

13. If possible, try not to mix slope levels with conventional levels for the same station. If deemed necessary, they will be accepted, but it is preferred that mixed levels for the same station be avoided. Different paper must be used for each method. (Conventional levels can be taken on slope level paper by using a vertical angle of zero).

14. If the original section needs to be extended, use the same original sheets for the station involved. If the extension is to the left of baseline, be careful how you indicate the new height of instrument (HI). Keep in mind; the HI at the top of the page is for the "left-most rod reading". Extensions to the right of baseline cause no problem since the new H.I. is placed in the next available box.

15. The stationing must be in ascending sequence.

16. Cross-sections must be perpendicular (90 degrees) to the baseline and not skewed. If a pit is wide enough, run parallel offset lines left and/or right of the baseline outside the anticipated excavation area, if possible. Set witnesses on each station along the offset line, flagging every other witness. Another possibility, set up the transit on every baseline station, then turn ninety degrees (90°), thus giving the rod-person exact direction.

17. Original and final sections may be taken using 3-D survey methods and then sections can be generated from the data.

<u>Field Work, Taking Field Levels</u>

1. Notes shall be taken on conventional level paper contained in either a loose-leaf or bound field book. This paper is commonly referred to as "engineer's field book paper" and can be obtained from Construction Headquarters.

2. Legibility is an absolute necessity.

3. All rod reading must contain a legible decimal point, even if it happens to be a whole number. For example, 5.0 must be the recorded rod reading of five.

4. Offsets are taken to the nearest centimeter (tenth of a foot).

5. Do not use ditto marks (") or dashes (-) when an offset or rod reading is the same as the previous shot.

6. If a rod reading is zero, enter as 0.0, do not leave blank or use a dash.

7. If it is necessary to change the H.I. within a station, enter the figure "9999" in the space allocated for offset and the proper H.I. in the space allocated for the rod reading.

   Example: $\frac{531.720}{9999}$

8. Be extremely careful if the HI change is to the left of baseline, since the HI at the top of the page is for the "left-most rod reading".

9. The baseline shot may be placed anywhere on the page. However, the final arrangement of shots must be in sequence, from the far left to the far right. If the baseline splits the pit, the usual procedure is:
   - Place the baseline shot somewhere in the middle of the page.
   - Take all the shots to the right.
   - Come back to the baseline and take all the shots to the left.

10. Distances between offsets should not exceed 10 meters (30 feet) except in flat areas, but they may be any distance from the baseline (i.e., 12, 19, 29, 33, 40.8, etc.)

11. On final sections, indicate the edge of the excavated pit (EP) and old ground (OG) shots. For best results, do not take old ground shots beyond the excavation limits because this causes slight slivers of cut or fill. Exception: if the original sections were taken before the pit was stripped, you must take shots to the old undisturbed ground because the pit strippings must be deducted from the cut areas.

12. HI calculations, transit turns, etc., may be recorded on the left-hand page.

13. The beginning and ending final stations must be denoted as "zero section" or "butt section". If the Resident Engineer desires a zero area to be used, it must be denoted as a "zero section". If an actual end area is desired, a final section must be taken and properly denoted as a "butt section". Obviously, an end area cannot be calculated unless there is an original and final section.

14. "Butt sections" in the middle of the pit are acceptable, but be sure to denote these very carefully. The "butt" may be within the original sections and/or the final section.

15. Estimated offsets and rod readings are not tolerated. Typical field note entries that must be determined are:
   - Level for another 20 meters (50 feet)
   - Continued up (or down) the same slope for 30 meters (100 feet)
   - Out 6 meters (20 feet), up 2 meters (6 feet)

16. Normally, the original cross-section for a given station will extend beyond the final section. If so, a perpendicular line is assumed from the extreme final shot to the original ground line. If the final section extends beyond the original section, a straight line is assumed from the furthest original shot to the furthest final shot. Therefore, it is important not to take extraneous final shots outside the excavated pit unless absolutely necessary.

17. Please do not prefix "non-plus" rod readings with a minus sign, since a rod reading is assumed to be negative unless prefixed by a plus (+) sign. The reason for this is: if a minus sign is keypunched, it is subtracted from the H.I., which means if you subtract a negative number from something, you are actually adding. (Example: 532.9 – (-5.2) is the same as 532.9 + 5.2.)

18. Topo descriptions should be limited to 10 characters and must be written legibly.

19. There cannot be a different topo description at the same offset for both original and final sections; however, there may be two descriptions at the same offset for the same terrain type.

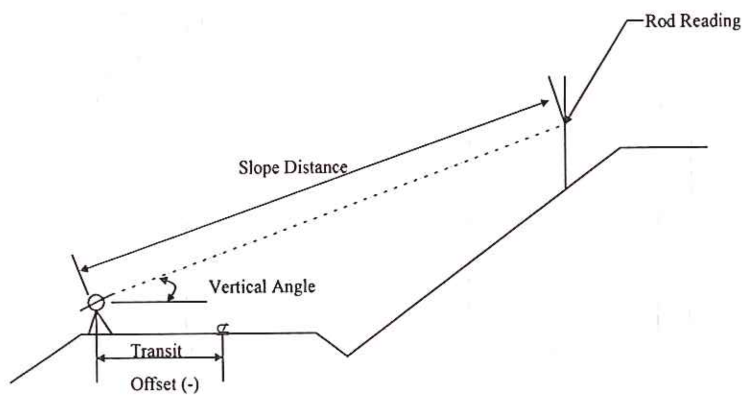


FIGURE 14: Typical Transit Setup

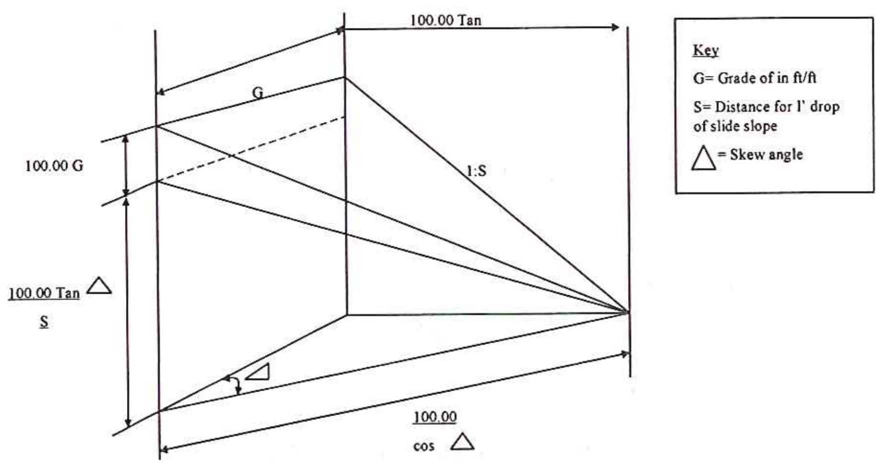
3-190 STRUCTURE SURVEY, STAKE OUT AND CONTROL

3-190.10 Culverts

The Resident Engineer should first locate, in the field, the inlet and outlet stations and offsets, as shown on the plans, to determine whether the pipe meets field conditions. Minor adjustments may be needed in pipe stationing and/or skew angle. Grade stakes are usually placed at proposed inlets and outlets. If, in the opinion of the Resident Engineer, the pipe should be moved a considerable distance or a new pipe should be added, he/she should present this information with drawings to his/her supervisor. Modifications in drainage systems may require changes in drainage rights, or new rights to be acquired, and possible amendments to the project's Storm Water Discharge Permit (Refer to the contract).

After the pipe location has been tentatively determined, stakes are placed beyond inlets and outlets along the proposed centerline of the pipe. Where inlets and outlets fall with Drop Inlets, the centerline of the Drop Inlet is staked parallel with the centerline of the road. Good judgment should be used in the placement of stakes so that they are not disturbed during the placing of the pipe.

The original cross-section along the proposed centerline of the pipe is taken and offset stakes are leveled (Subsection 3-190.40, Retaining Walls). Levels should appear in the drainage book. See Section V, Sample Field Book of this manual. This cross-section, the roadway template, and the pipe cross-section along the proposed centerline of the pipe are then plotted on cross-section paper. The correct method for determining the side slope ratio is shown in the preceding Figure (14). This method should only be used on tangent alignments. Where severe road grades occur in horizontal curves, a graphic solution must be used.



Slope of skewed line (ft/ft) = $\frac{\left(\frac{100.00 \tan \Delta}{S} + 100.00\,G\right) \cos \Delta}{100.00}$

$= \cos \Delta \left(\frac{\tan \Delta}{S} + G\right)$ (+ for upgrade, - for downgrade)

FIGURE 15: Computation for Side Slope on a Skewed Section

The correct pipe length and elevation having been found, the stake is ready to be marked. The front face of the stake should show the station, diameter, length, and type of pipe and whether the stake refers to the inlet or outlet of the pipe or the centerline of the drop inlet. One side of the stake must show the centerline or baseline offset and the distance to the end of the pipe. The opposite side should show the percent of grade of the pipe. It is advisable to discuss stake markings with the Contractor's Pipe Foremen and / or Drainage Foremen to establish a policy throughout the project.

3-190.20 Underdrain

Underdrain is normally staked at 20 meter (50 foot) intervals and at the beginning, ending, change of directions, and outlet points. It is advisable to confer with the Contractor on where to place the offset line to protect stakes.

3-190.30 Drop Inlets and Catch Basins

These items must be accurately laid out and proper elevations given. Offsets should be taken from the roadway centerline. Stakes are set in line with the back inside edge of drop inlets and back edge of grates for catch basins when curbing directs the water into drop inlets or catch basins. For typical pipe stakeout see the following figures.

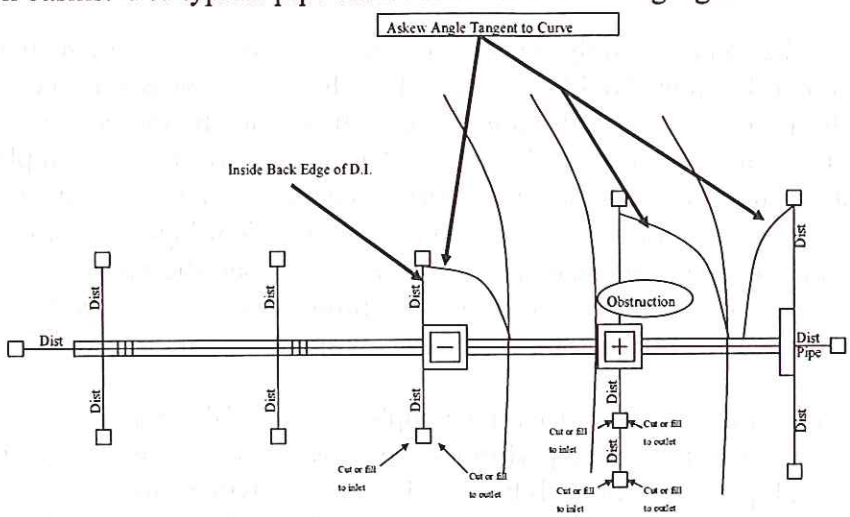


FIGURE 16: Typical Pipe Stake

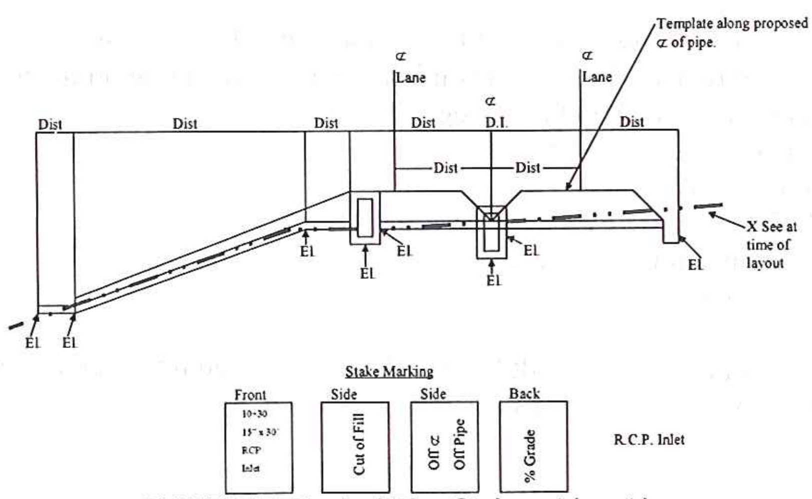


FIGURE 17: Typical Pipe Stakeout (cont.)

3-190.40 Retaining Walls

Retaining walls are usually placed in the outside ditch line of a roadway cut section. Control for the offset line should be placed so that the line may be easily reproduced. Offset stakes are usually placed on the shoulder slope at 20 meter (50 foot) intervals and at the beginning and ending points of the retaining wall. If the retaining wall occurs in vertical and/or horizontal curves, it may be more practical to use 10 meter (30 foot) intervals. Stakes should be marked with the station, offset, and cut. The plans normally locate the retaining wall from the centerline and the elevation from finish grade of the road.

3-190.50 Bridges

Bridges must be very carefully staked out and referenced. More than the minimum number of control points should be provided so that, if one or several control points are destroyed during construction, the bridge can still be quickly and accurately located and re-staked. On some bridge sites, it will not be possible to provide completely accurate reference stakes until the Contractor has performed some initial work, such as providing a working area in a river for a pier. In such a case, sufficient layout must be performed to allow the Contractor to build the working area; then when the point can be occupied, a more accurate layout should be performed. Throughout the construction, the reference stakes should be maintained and their accuracy improved whenever possible.

The layout of a bridge must start with a complete study of the plans and cross-sections to determine how the work will be performed. A separate book is used to record the layout information and quantities for each bridge. For bridges with spans greater than 30 meters (100 feet) in length, a total station should be used. Total stations are assigned to Resident Engineers based on the complexity of a project. VTrans Route Survey can also be contacted for bridge layout using their total station.

In the sketches that follow, several different methods of bridge layout are shown. These methods are merely one of several that might be used depending on the terrain around the structure and the complexity of the bridge.

1. Bridge Layout on Tangent
2. Bridge Layout on Curve
3. Bridge Layout for River Crossing
4. Determination of Inaccessible Distance
5. Triangulation

The accuracy of the more difficult layouts shall be checked by using VTrans total station equipment, or through the VTrans Route Survey Section.

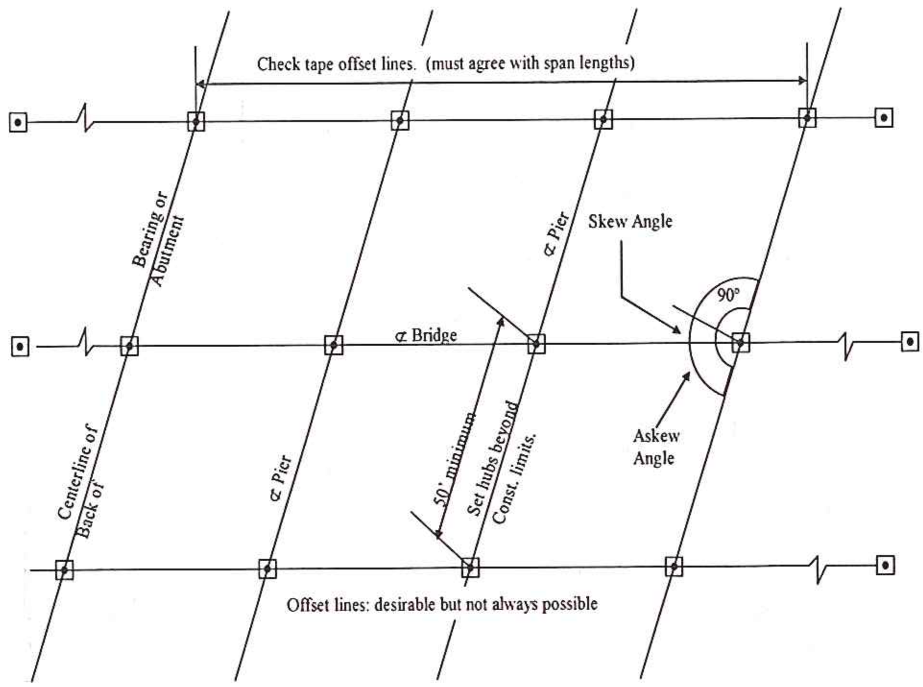


FIGURE 17: Typical Layout on a Tangent

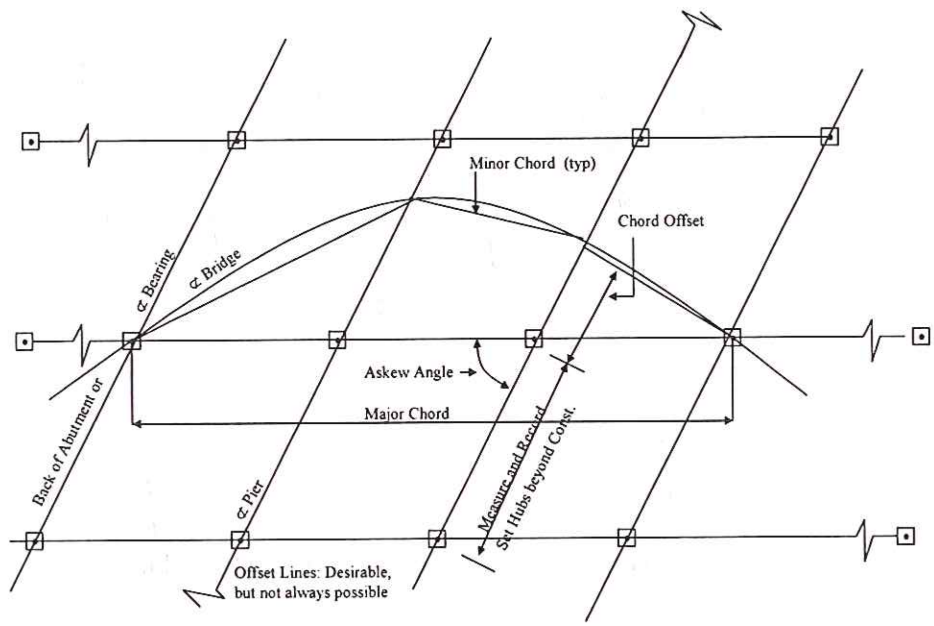


FIGURE 18: Typical Bridge Layout on a Curve

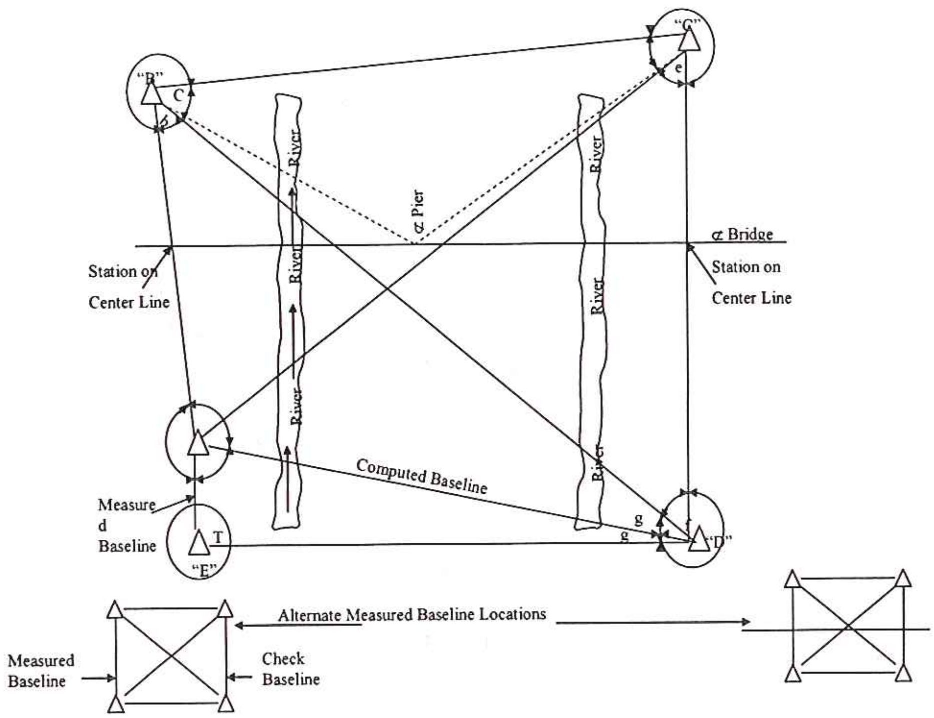


FIGURE 19: Typical Bridge Layout for a River Crossing

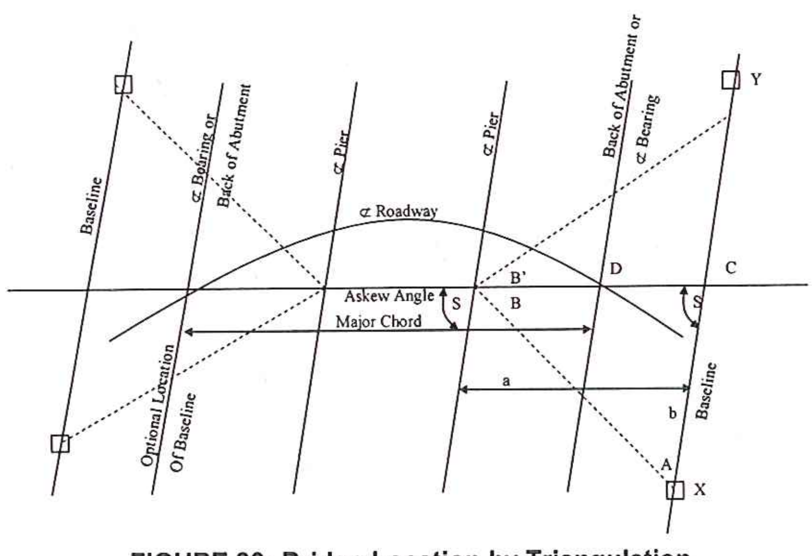


FIGURE 20: Bridge Location by Triangulation

3-190.60 Concrete Box Culvert

The Resident Engineer may choose to perform the initial layout of a concrete box culvert using either a very elaborate setup or a simpler centerline control method. The centerline control method provides basic information at the onset of the project for the Contractor, with additional layout performed when the Contractor has reached a point where they may need additional control for further work. Each method has its advantages. By initially making a complete layout with line and grade control, the Resident Engineer has fulfilled the obligation of line and grade. However, much of this will be wasted effort as it is often impossible to improve the area without a subsequent loss of control. To ensure that everything is built as the plans intend it to be, the Resident Engineer must do additional stake out as construction progresses. In most cases, it would seem more logical to do the minimum for initial layout and provide the control as it is required by construction.

The following sketch shows a typical concrete box culvert stake out:

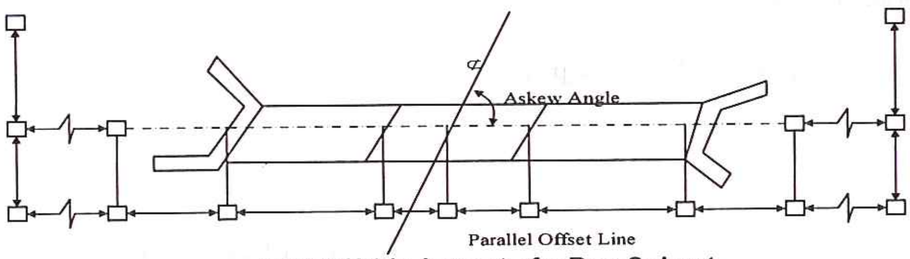


FIGURE 21: Layout of a Box Culvert

3-190.70 Bridge Beam Profiles

It is necessary to profile the top of the erected steel beams to assure a good riding finished road surface. Any irregularities in bridge seats, camber of beams, or dead load deflection will be taken care of by this process.

Label the notes with project name, project number, contract number, station, and structure name or number. Draw a sketch of the beam layout as on the project plans or steel plans, identifying the beam numbers, abutments and piers, direction of station, stream flow, etc.

The Project Manager in the Structures Section can provide a beam profile spreadsheet to assist you in determining the proper depth of concrete over the beams. The finish grades at 1.5 meter (5 foot) intervals (or other intervals shown on the beam profile spreadsheet) over the beams are determined before taking the beam profiles. The profiles should be taken at the same intervals as shown on the beam profile spreadsheet. The following procedure should be followed to minimize the work involved.

For Simple Span Bridges:

Label the centerline of bearing of beam #1 (beam on left in direction of stationing) span #1 as 0+000. Take rod readings at intervals of 1.5 meters (5 foot) (or other specified intervals). Distances are to be recorded as 0+000, 0+001.5, 0+003, 0+004.5, etc., to centerline of bearing at opposite end of beam. Repeat procedure for all beams and all spans, always starting at 0+000 on all beams.

For Continuous Span Bridges:

Use the same procedure, except start at the centerline of bearing at the beginning of the span and continue the rod readings at the intervals shown on the spreadsheet to the centerline of bearing at the end of each continuous run of steel girder.

If a beam has a top cover plate, note the locations where the rod is set on top of this cover plate. Take all measurements along the top of the steel beams with a steel tape. A sample page of notes follows:

Typical Page of Notes for Simple Span:

HI 156.283

Beam #1	Rod	Elevation of Top Beam
0+000 = ⊄ of Bearing	0.341	155.942
0+001.5	0.357	155.926
0+003	0.396	155.887
0+004.5	0.418	155.865
0+006 etc.	0.433	155.85
0+018	0.524	155.759
0+018.54 =⊄ of Bearing	0.530	155.753

Beam #2		
0+000 =⊄ of Bearing	0.533	155.75
0+001.5	0.549	155.734
0+003	0.573	155.71
0+004.5	0.606	155.677
0+018.54 = ⊄ of Bearing	0.710	155.573

Beam #3		
0+000 = ⊄ of Bearing	0.713	155.57
0+001.5	0.722	155.561
0+003	0.738	155.545
0+004.5	0.765	155.518
0+018	0.829	155.454
0+018.54 = ⊄ of Bearing	0.835	155.448

Compute the depth of concrete required at each profile point as follows:

In all cases, the field computation will involve only the subtraction of the elevation of the beam from the theoretical screed elevation. The screed elevations will be furnished on the beam profile spreadsheets to the Resident Engineer by the Project Manager in the Structures Section.

Take the beam profiles as indicated above. Reduce the notes and list the elevations on the beam profile spreadsheets where indicated. Complete the computations.

The notes on the beam profile spreadsheet will be the minimum depth of concrete required over the beam. Where the field computations indicate that any concrete depth is less than the minimum, all the computed depths should be increased by the amount necessary to bring the depth up to the specified minimum and the finished grade of the bridge raised a like amount.

Where there is any doubt as to the method or results of the computation, please forward the information to the Structures Section for checking.

<u>3-190.80 Bridge and Underpass Clearance</u>

Bridge clearances must be a matter of public record as soon as any change occurs. In order to ensure this practice is performed and standardize the methods used in recording, the measurements must be taken according to diagrams shown further on in this Section.

Upon completion of any new structure, the Resident Engineer will measure and confirm the proper clearances have been maintained and report these to the VTrans Bridge Management & Inspection Engineer as final clearances in lieu of the original ones sent when the restriction first occurred.

In the case of paving project under an existing structure vertical clearance measurements will be taken before and after paving is completed.

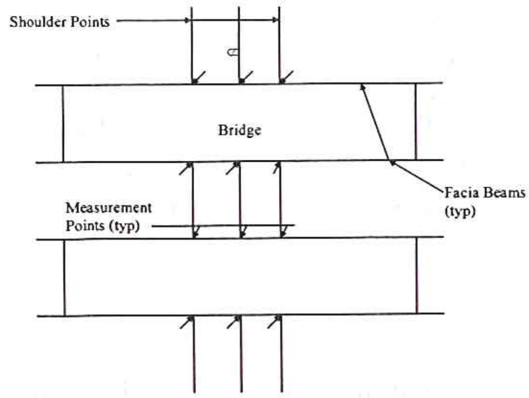


FIGURE 22: Bridge Underpass for Projects under existing structure(s)

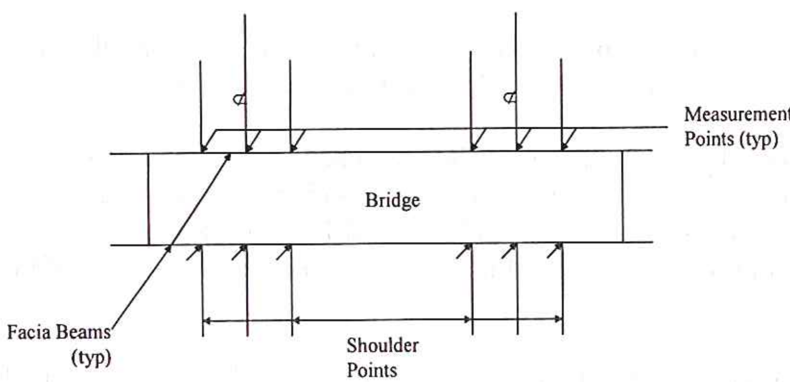


FIGURE 23: Bridge and underpass Clearance for Projects over an existing road

3-200 MISCELLANEOUS

3-200.10 Slope Taping

This method is used on steep slopes to obtain a horizontal measurement. When slope taping is used and executed with care, the results can be accurate and save time. The following method should be used:

1. Occupy the first point with the transit.

2. Establish the point to which the distance is needed.

3. Hold the zero end of the tape at the telescope axis. Using the middle cross-hair, sight on the point to which you are measuring. If this point cannot be seen, then sight on the point of the tape which is plumb over the offset point (use the plumb bob). Read the vertical angle on which the scope is positioned and measure the slope distance from the transit to the point.

4. The Cosine of this angle multiplied by the slope distance will result in the horizontal distance between the two (2) points in the ground.

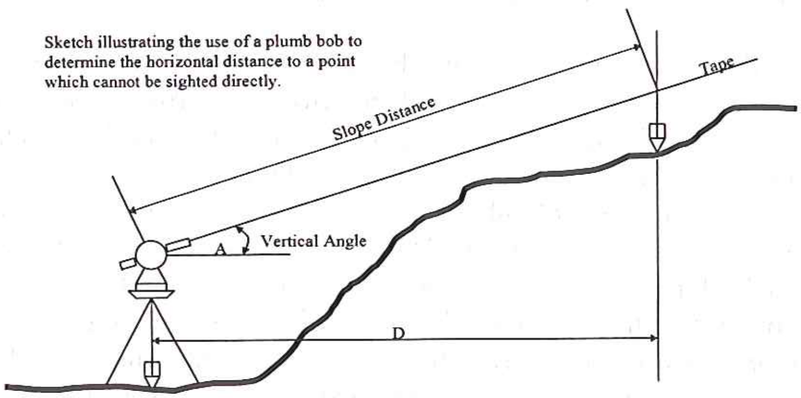


FIGURE 24: Example of Slope Taping
(Horizontal Distance (D) = Cosine Angle A x Slope Distance)

3-200.20 Slope Stakes

Following are procedures whereby slope stakes may be set or checked for accuracy.

Checking Grade Stakes in Cuts & Fills

From time to time the Resident Engineer may call upon one of his or her assistants to accurately check a cut or fill slope. There are many methods by which this can be accomplished. The following two examples depict such methods (Note: English units used.)

Offset stakes are referenced to the center line. On each stake is written the following information:

- The station the stake represents.
- The offset distance from the stake to the center line.
- The vertical difference in elevation from the top of the stake to the center line finish grade. (Expressed as either cut or fill to the hundredth of a foot)
- The offset distance from the stake to a base line if one exists.

Computations for slope staking in cut areas are based on the distance from the top of cut A (where the side slope intersects old ground (OG)) to a point parallel to the edge of subgrade on the neat line B or to the back of ditch C.

To exemplify this procedure we will use points A and B.

The exact offset for the top of cut A is found by trial and error. For the first trial the distance is scaled from the stake to the top of cut from the cross-sections. (For this example the scaled distance is 5.0'.) Using a hand level and a six-foot rule, the OG elevation is found to be 0.88' below the top of the stake. Point A now has an offset value of 102' off and C-27.12'. The edge of subgrade is 3.34' below the center line elevation. To the subgrade point offset, we add 9.0'. An 18" ditch requires 6' on a 1-4 slope and an additional 3' on a 1-2 slope to obtain a point at the same elevation with the edge of subgrade. Point B now has a fill value of 3.34' and an off value of 40.75' (31.75' + 9.00'.) If point A were chosen correctly, the horizontal distance between points A and B should be twice the vertical difference between the same two points. (Rate of closure of a 1-2 slope.)

102.00' – 40.74' = 61.25'
27.12' + 3.34' = 30.46' x 2 = 60.92'

For all practical purposes, point A has been staked accurately enough.

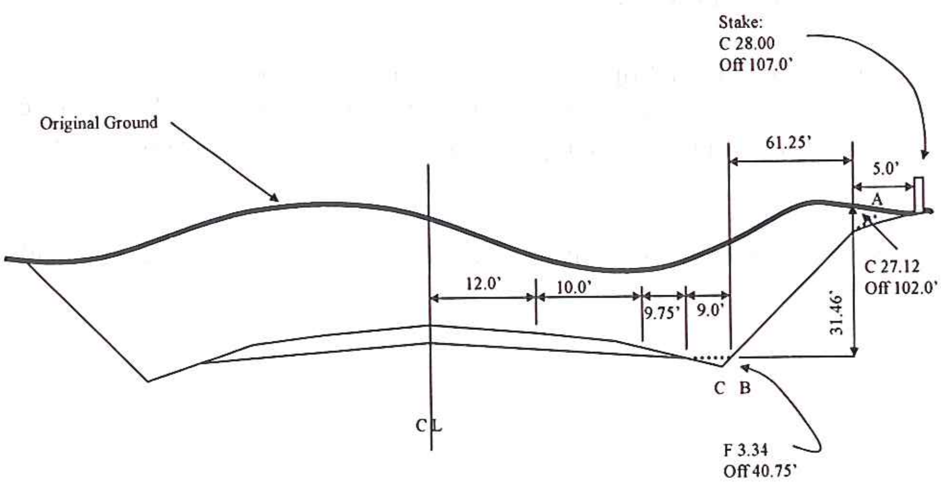


FIGURE 25: Illustration of checking grade stakes

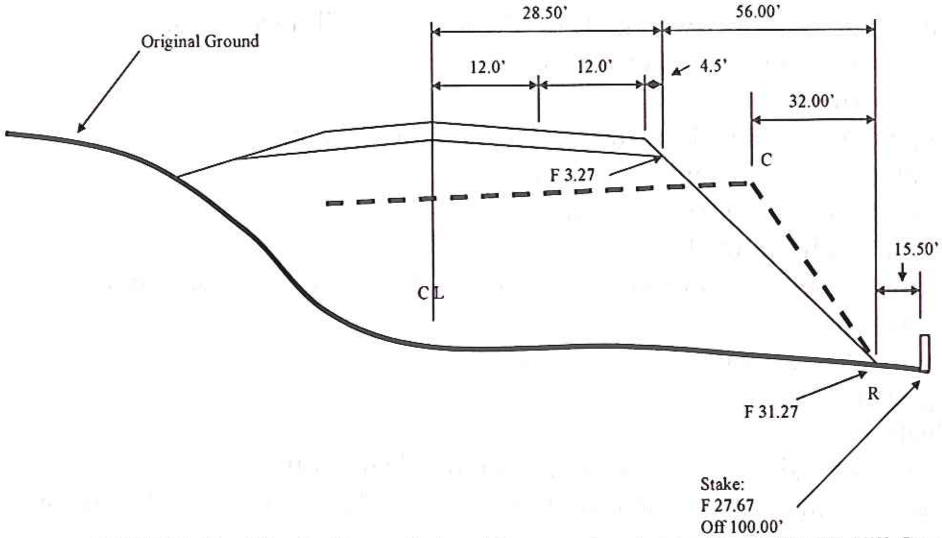


FIGURE 26: Illustration of checking grade stakes in an Earth Fill Section

Earth Fills

The same procedure for establishing the top of cut is followed when establishing the toe of fill. Briefly: Point A, from the cross-sections, is guessed at being 15.50' on the inside of the hub. Using a hand level and a six foot rule, it is found that point A is 3.60' below the hub, resulting in a fill at point A of 31.27'.

28.50' + 15.50' – 100.00' = 56.00'
27.67' – 3.27' + 3.60' = 28.00'

Point A is correct because a horizontal distance of 56.00' on a 1-2 slope requires a 28.00' rise in elevation.

During the construction of the embankment it may be desired to spot check the accuracy of the slope stakes. In the above example, point C represents such a spot check. Again using a hand level and a six foot rule and starting at point A, it is determined that the difference in elevation between point A and point C is 21.00'. If point C is correct, the horizontal distance should be 42.00'. On measuring the distance from points A to C, it is discovered the distance to be 32.00'. This indicates the embankment slope must be flattened in such a way that point C is moved horizontally a distance of 10.00' closer to the centerline.

3-200.30 Location of Water Pipe Sleeve and/or Water Line

Water pipe sleeves and water lines that pertain to the project should be referenced to the roadway centerline and surrounding trees or structures. The sketches of water pipes and sleeves should include the following information:

1. Vermont Agency of Transportation (VTrans).
2. Full name of property owner(s) and complete mailing address.
3. Full name of project and number.
4. North arrow.
5. Type of material and size of sleeve pipe and/or water pipe.
6. Centerline and stationing on road.
7. Arrows indicating nearest town.
8. Ties at each end of sleeve.
9. Name on buildings or structures, such as: barn, porch, house or bridge abutments.
10. Name of trees, such as: elm, ash, maple.
11. Type of culvert.
12. Scale.
13. Name of Resident Engineer, date and initials of plotter.
14. Anything important which would help the land owner(s) to find these sleeves.

Separate sketches should be drawn for each installation. The sketch should be submitted with the project records to the Finals Engineer who will send copies to the property owners, District Transportation Administrator, Town Clerk, and one copy will be retained with the permanent project records and/or record plans.

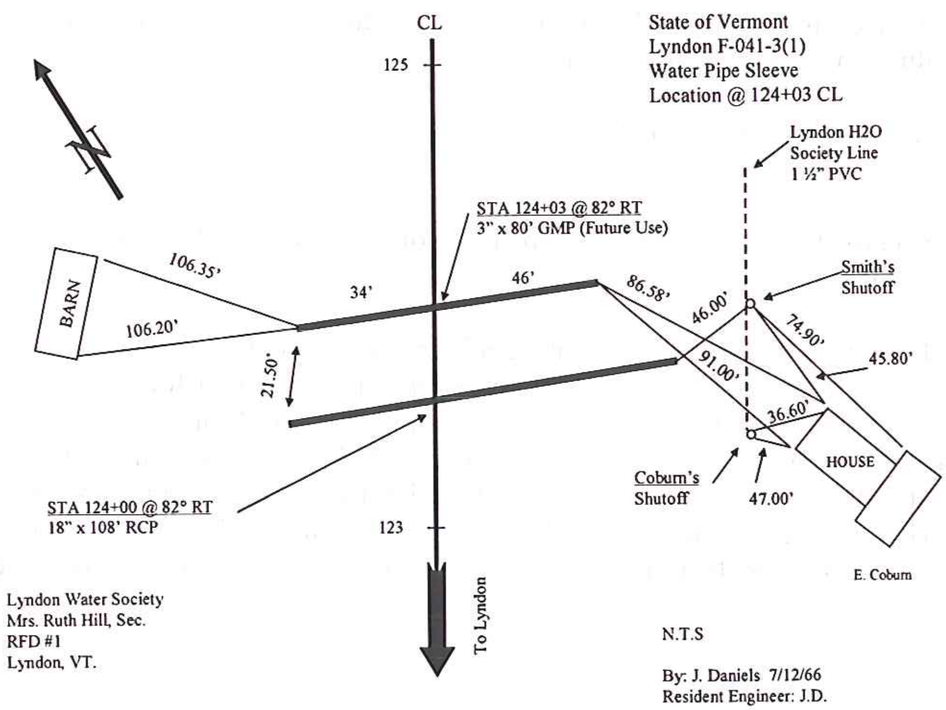


FIGURE 27: Location of Water Pipe Sleeve

3-210 CURVE INFORMATION

3-210.10 Horizontal Curves

Simple Curves: The radius can be used to define a curve in lieu of the degree of curve definition to describe horizontal curves.

For projects designed or constructed in English units of measure, the arc definition of degree of curve is primarily used. The arc definition is defined as the change of direction of the central angle per an arc length of 100 feet (30.5 meters). The relationship between the degree of curve and the radius in feet is stated by the following equation:

$$R = \frac{5729.58}{D}$$

Some of the various definitions and relationships of a simple curve are given below:

(Δ) = Deflection Angle

Tangent distance (T) = $R(\tan \Delta/2)$

External distance (E) = $R(\sec \Delta/2 - 1) = R(\text{Exsec } \Delta/2) = T(\sin \Delta/2) - M$

Middle Ordinate (M) = $R(1 - \cos \Delta/2) = R(\text{Vers } \Delta/2) = R - R(\cos \Delta/2)$

Long Chord (L.C.) = $2R(\sin \Delta/2) = 2T(\cos \Delta/2)$

Length of Curve (L) = $\frac{\Delta(100)}{D} = \frac{\Delta 2°R}{360°} = \frac{\Delta R}{57.2958}$

The deflection angle (Δ) is measured in decimal degrees. For English units, D is measured in decimal degrees and R is in feet.

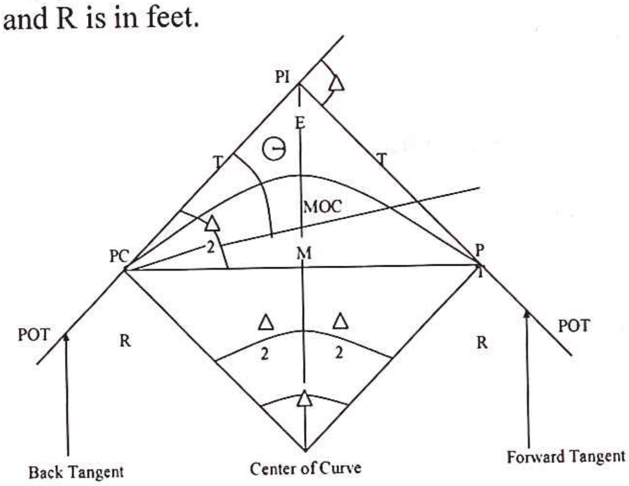


FIGURE 28: Simple Circular Curve

CALCULATIONS FOR A HORIZONTAL CIRCULAR CURVE

Given:
P.I. Sta. 107+67.90 $\Delta = 11^\circ\ 00'\ 00''$ $D = 2^\circ\ 30'\ 00''$

Calculate the Radius
R = 5729.58/D
R = 5729.58/2° 30' 00"
R = 2291.83'

Tangent Distance
T = R(Tan Δ/2)
T = 2291.83(Tan 11° 00' 00"/2)
T = 220.68'

Length of Curve
L = 100 (Δ/D)
L = 100 (11° 00' 00"/ 2° 30' 00")
L = 440.00'

External Distance
E = T(Tan Δ/4)
E = 220.68(Tan 11° 00' 00"/4)
E = 10.60'

CALCULATE P.C. AND P.T. STATIONS

P.C. Station
P.C. = P.I. Station – Tangent Distance
P.C. = 107+67.90 – 220.68
P.C. = 105+47.22
P.T. Station
P.T. = 105+47.22 + 440.00
P.T. = 109+87.22

CALCULATE DEFLECTION ANGLES

Deflection for 100' of Arc
100' Arc = D/2
100' Arc = 2° 30' 00"/2
100' Arc = 1° 15' 00"

Deflection for 50' of Arc
50' Arc = D/4
50' Arc =2° 30' 00"/4
50' Arc =0° 37' 30"

Deflection for 25' of Arc
25' Arc = D/8
25' Arc =2° 30' 00"/8
25' Arc = 0° 18' 45"

Deflection for 1' of Arc
1' Arc = D/200
1' Arc = 2° 30' 00"/200
1' Arc = 0° 00' 45"

<u>CALCULATE CHORD LENGTHS</u>

Chord Length for 100' of Arc
100' Arc = (2)(R)(Sin of Deflection Angle) Deflection Angle = D/2
100' Arc = (2)(2291.83)(Sin 1° 15' 00")
100' Arc = 99.99'

Chord Length for 50' of Arc
50' Arc = (2)(R)(Sin of Deflection Angle) Deflection Angle = D/2
50' Arc = (2)(291.83)(Sin 0° 37' 30")
50' Arc = 50.00'

<u>CALCULATE THE DEFLECTION FOR THE FIRST STATION FROM THE P.C. OR ANY ODD STATION ALONG THE CURVE</u>

1. Take the distance from the last point with a known deflection to the station you are calculating.

2. Multiply this distance by the deflection of a 1' Arc (D/200), this will give you the deflection between these two points.

<u>Example: Find the deflection angle for Sta. 108+55.</u>

(108+55 - 105+47.22) = 307.78'

307.78'(0° 00' 45") = (3° 50' 50") Note: Use decimal degrees for this calculation.

EXAMPLE OF A FIELD BOOK SETUP FOR A HORIZONTAL CURVE

Deflections For Curve #1

Sta.	Distance	Chord Distance	Deflection Angle	Total Deflection	
105+00					
+47.22	0	0	0	0	P.C.
+50	2.78'	2.78'	0° 02' 05"	0° 02' 05"	
106+00	50.0	50.00	0° 37' 30"	0° 39' 35"	
+50	50.0	50.00	0° 37' 30"	1° 17' 05"	
107+00	50.0	50.00	0° 37' 30"	1° 54' 35"	
+50	50.0	50.00	0° 37' 30"	2° 32' 05"	
108+00	50.0	50.00	0° 37' 30"	3° 09' 35"	
+50	50.0	50.00	0° 37' 30"	3° 47' 05"	
109+00	50.0	50.00	0° 37' 30"	4° 24' 35"	
+50	50.0	50.00	0° 37' 30"	5° 02' 05"	
+87.22	37.22	37.22	0° 27' 55"	5° 30' 00"	P.T.

Checked by: <u>(Initials) (Date)</u>   Calculated by: <u>(Initials) (Date)</u>

Δ = 11° 00' 00"   D = 2° 30' 00"
P.C. Marked by P.K. Nail

Deflection Angles

100' of Arc = D/2 = 2° 30' 00"

= 1° 15' 00"

50' of Arc = D/4 = 2° 30' 00"/4

= 0° 37' 30"

1' of Arc = D/200 = 2° 30' 00"/200

= 0° 00' 45"

Chord Lengths

100' of Arc = (2)(R)(Sin of Deflection Angle)

= (2)(2291.83)(Sin 1° 15' 00")

= 99.99'

50' of Arc = (2)(R)(Sin of Deflection Angle)

= (2)(2291.83)(Sin 0° 37' 00")

= 50.00'

P.T. (Note: Total Deflection should equal Δ/2)

Other Types of Horizontal Curves: In addition to simple curves; compound curves, reverse curves, and vertical curves are also used in highway work.

Compound curves are a combination of two or more simple curves and their use should be avoided where a simple curve can be used. However, due to either right-of-way problems or topographic considerations, a compound curve may occasionally be necessary. The curve must not be compounded at a ratio greater than 2:1. If the adjacent curves differ by more than 2°-00', a transition curve should be used.

A reverse curve is a combination of two simple curves of opposite curvature with a common tangent. A tangent adequate in length to provide the super elevation transition required by the Design Policies should be provided between the curves. If the reverse curves do not contain any super elevations, a tangent between the curves is not required.

A "broken-back" curve is a term used to denote two curves in the same direction separated by a short tangent or by a flat curve whose radius is greater than twice the radius of either of the two initial curves. This layout is particularly objectionable on highways and should be avoided by using one simple curve or a compound curve if necessary.

In the past, there was a period when transition or spiral curves were extensively used in connection with pavement widening along curves. As the curves became flatter and the pavement wider, it became unnecessary to widen at curves in this manner. It remains, however, that vehicular paths entering and leaving circular curves follow a spiral curve. For this reason, or for the reason of "fitting" an alignment into a problem area, transition curves may occasionally be used.

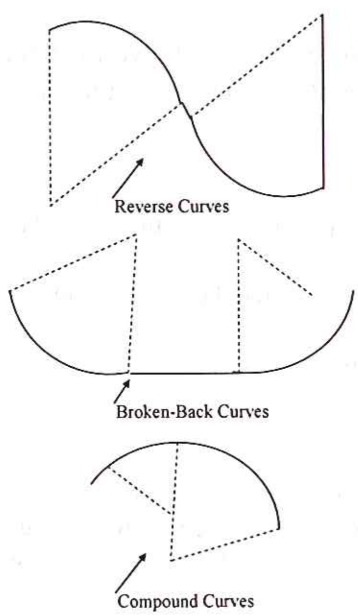


FIGURE 29: Illustration of Curve Types

3-210.20 Vertical Curves

Vertical curves are used to transfer a smooth change from one slope to another along an alignment to account for the change in terrain.

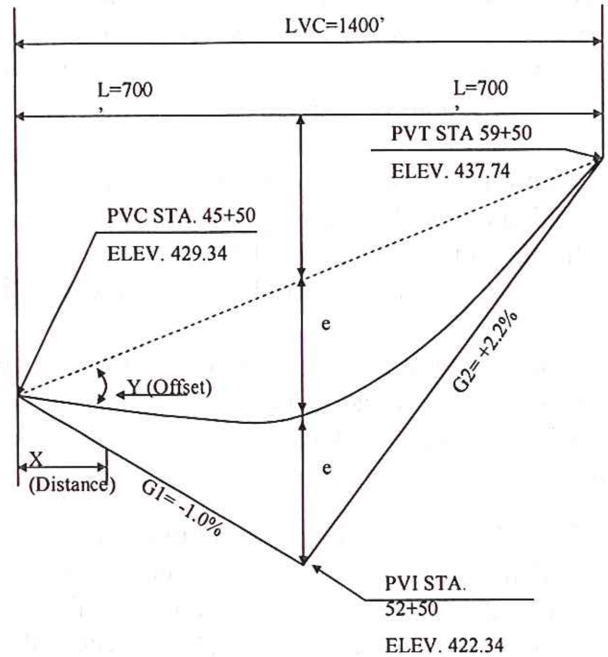


FIGURE 30: Illustration of a Vertical Curve

CALCULATIONS FOR VERTICAL CURVE

Listed below are several definitions of the elements of a vertical curve and a set of sample field notes that have been prepared for field use to stake out a vertical curve.

Definitions:

PVC: "Point of vertical curve". Station on centerline where the vertical curve starts.

PVI: "Point of vertical intersection". Station at which the two tangent grade lines intersect.

PVT: "Point of vertical tangency". Station on centerline where the vertical curve ends.

LVC: Length of vertical curve.

OFFSET: The vertical distance from the tangent grade line to the vertical curve. A mathematical constant whose value is determined by the grades of the two intersecting tangents and the length of the vertical curve. Equation: Grade #2(%) – Grade#1 (%) x (LVC) (Stations)/8 (Constant) = (G2-G1)(LVC/100)/8

CL ELEV: = Tangent Elevation $\pm$ offset. Highpoint/low point locations. Distance from PVC = G1 x (Stations)/G2 –G1

EXAMPLE FIELD NOTES FOR A VERTICAL CURVE

Tangent Station	(X) Distance	Elevation	(Y) offset	Elevation on Curve
45+50	--	--	--	429.34
46+00	50.00	428.84	0.03	428.87
47+00	150.00	427.84	0.26	428.10
48+00	250.00	426.84	0.71	427.55
49+00	350.00	425.84	1.40	427.24
49+50	400.00	425.34	1.83	427.17
50+00	450.00	424.84	2.31	427.15
50+50	500.00	424.34	2.86	427.20
51+00	550.00	423.84	3.46	427.30
52+00	650.00	422.84	4.83	427.67
52+50	700.00	422.34	5.60	427.94
53+00	650.00	423.44	4.83	428.27
54+00	550.00	425.64	3.46	429.10
55+00	450.00	427.84	2.31	430.15
56+00	350.00	430.04	1.40	431.44
57+00	250.00	432.24	0.71	432.95
58+00	150.00	434.44	0.26	434.70
59+00	50.00	436.64	0.03	436.67
59+50	--	437.74	--	437.74

e = (G2-G1) LVC/8 = (2.2-(-1.0))14/8 = 3.2(14)/8 = 5.60 Vertical offset at VPI.

Y-Offset @

46+00 & 59+00 = (50/700)2(5.60) = 0.03
47+00 & 58+00 = (150/700)2(5.60) = 0.26
48+00 & 57+00 = (250/700)2(5.60) = 0.71 Y = e(X/L)2
49+00 & 56+00 = (350/700)2(5.60) = 1.40
49+50 = (400/700)2(5.60) = 1.83
50+00 & 55+00 = (450/700)2(5.60) = 2.31
50+50 = (500/700)2(5.60) = 2.86
51+00 & 54+00 = (550/700)2(5.60) = 3.46
52+00 & 53+00 = (650/700)2(5.60) = 4.83
52+50 = (700/700)2(5.60) = 5.60

When using this method, the elevation difference is calculated from both the tangent gradients at specified distances from the PVC and PVT and then applied to the tangent elevations determined for the two gradients. The value of (e) is the offset at the VPI and each individual station's offset value is determined as a percentage of the external at the VPI. The vertical offsets from a tangent to a parabola are proportional to the squares of the distances from the point of tangency.

STATION AND ELEVATION OF LOW POINT OF VERTICAL CURVE

X (In Station from VPC) = $G_1L/(G_2-G_1)$ = 1.0(14)/(2.2-(-1.0)) = 1.0(14)/3.2 = 4.375 Sta. or 437.50'.
Station of Low Point = 45+50 + (4+37.5) = 49+87.50
X-Distance = 437.50 Tangent Elev. = 429.34 – 437.50(0.01) = 424.96'
Y-Offset $(437.50/700)^2(5.60) = 2.19'$
Elevation of Low Point = 424.96 + 2.19 = 427.15'

ALTERNATE METHOD OF CALCULATING CURVE ELEVATIONS

An alternative method of calculating the elevations of a vertical curve is as follows: calculate the value of (a) using the following formula: The tangent elevations are computed using the elevation of the PVC and the slope of the forward tangent. An elevation is computed for each station needed. Then compute the offsets from the forward tangent to the curve. The offset equals aX2. Apply the offset values to the tangent elevation to obtain the curve elevation.

$a = 100(G_2-G_1)/2L = 100(2.2-(-1.0))/2*1400 = 0.114$
$2a = 0.228$

Station	Tangent Elev.	Offsets from AV=aX^2	Curve.	Check 1st Diff.	2nd Diff El. =G_1X
45+50	429.34		429.34		
46+00	428.84	$-.114*0.50^2=0.03$	428.87		
47+00	427.84	$-.114*1.5^2=0.256$	428.10	-0.77	
48+00	426.84	$-.114*2.5^2=0.71$	427.55	-0.55	0.22
49+00	425.84	$-.114*3.5^2=1.40$	427.24	-0.31	0.24
49+50	425.34	$-.114*4.0^2=1.83$	427.17		
50+00	424.84	$-.114*4.5^2=2.31$	427.15	-0.09	0.22
50+50	424.34	$-.114*5.0^2=2.86$	427.20		
51+00	423.84	$-.114*5.5^2=3.46$	427.30	+0.15	0.24
52+00	422.84	$-.114*6.5^2=4.83$	427.67	+0.37	0.22
52+50	422.34	$-.114*7.0^2=5.60$	427.94		
53+00	421.84	$-.114*7.5^2=6.43$	428.27	+0.60	0.23
54+00	420.84	$-.114*8.5^2=8.26$	429.10	+0.83	0.23
55+00	419.84	$-.114*9.5^2=10.31$	430.15	+1.05	0.23
56+00	418.84	$-.114*10.5^2=12.60$	431.44	+1.29	0.24
57+00	417.84	$-.114*11.5^2=15.11$	432.95	+1.51	0.22
58+00	416.84	$-.114*12.5^2=17.86$	434.70	+1.75	0.24
59+00	415.84	$-.114*13.50^2=20.83$	436.67	+1.97	0.22
59+50	415.34	$-.114*14.00^2=22.40$	437.74		

One method of checking your calculations is to calculate the first and second differences of the curve elevation between the full stations. The second difference should be the same and is equal to 2a, which is the percent of constant change in slope per station.

3-220 FINAL MEASUREMENTS

Final measurements for pay quantities should be made concurrently with construction operations where feasible. This procedure results in greater accuracy and reliability. Naturally, some items can only be checked after construction is completed.

3-220.10 Items Measured During Construction

The following items are examples of those that should be measured immediately after constructed:

- removal items
- undercuts
- storm sewers
- conduit
- buried cable
- clearing and grubbing

3-220.20 Items Measured after Construction

All measurements for final payment must conform to the requirements of the latest edition of the VTrans Standard Specifications for Construction and supplements thereto or for the edition specified in your contract:

- fencing
- guard rail
- turf establishment
- structure length
- curb and gutter
- sidewalks
- bridge approach panels

3-220.30 Final Cross-Sections

Final cross-sections are used for the computation of final pay quantities. Each final cross-section should be taken at the same station where the original section was taken. This eliminates any need for interpolation of an original at the new station.

3-220.40 Structures

Project field staff or a survey crew should measure drainage structures (catch basins, manholes, etc.) at the time of installation. Documentation of final elevations and locations will be required.

3-220.50 Final Plans

The original plan sheets must be corrected to show any changes and additions made during construction. All corrections or changes shall be noted on the plan sheets. No original details should ever be removed from the plan sheets. The following list provides some of the information that must be checked, corrected and added to the original plan sheets:

- Horizontal and vertical control
- Location, dimensions, and elevations of drainage structures. Each of these should be field checked.
- Changes in typical sections
- Horizontal alignment (including curve changes and control point ties)
- Profile grade
- All underground units (cables, conduits, pipe, etc.)

3-230 MONUMENTATION

The Resident Engineer, working with the VTrans Route Survey Section, should be in charge of as much of the post construction monumentation as possible.

3-230.10 Final Alignment

Every effort should be made to install monumentation along the final alignment prior to the project being accepted. All PI's shall be monumented, or if inaccessible the adjoining tangents shall be monumented. PC's and PT's should be monumented.

3-230.20 Right-of-Way

The Right-of-Way (ROW) should be monumented and marked prior to construction and maintained throughout the duration of the contract. However, if the ROW must be re-monumented, it should be done under the supervision of a professional Land Surveyor (LS) licensed in the State of Vermont and must possess a valid LS number. The Resident Engineer shall contact the VTrans Route Survey Section to set the ROW bounds, unless stated otherwise in the contract for your specific project. If consultant supplied surveying crews set the ROW bounds they shall have a valid Vermont LS number. The Consultant shall provide documentation to the Resident Engineer showing the bounds that have been set, as well as any bounds that have not been set. Once this documentation (station, offset, and coordinates) is provided, the Resident Engineer shall send a copy to both the Chief of Plans & Titles and the Chief of Survey. If the VTrans Route Survey Section sets the bounds, they will notify the Resident Engineer as to which bounds were set and will also prepare the documentation for presentation via the Resident Engineer to the Chief of Plans & Titles and Chief of Survey.

3-230.30 Federal or State Agency Survey Monuments

When a Federal or VTrans survey monument is to be destroyed, the VTrans Route Survey Section in Montpelier shall to be notified so that the marker may be accurately transferred. The complete identification of stamped information on the marker should be given when reporting this information. The elevation of the marker should be transferred by the Resident Engineer to a stable and secure temporary bench mark until the new tablet can be set. This will provide a reference, in the case of a temporary bench mark, in the event that there is a delay in moving the marker or if the marker is accidentally damaged.

3-230.40 Property Line Fence and Boundary Markers

The Resident Engineer assumes the responsibility for the control of the "Property Line Fence". Much of the fence layout can be done from the construction stakes. When the fence is not parallel to the centerline of the roadway with changes in offset marked by boundary markers. The Resident Engineer shall stake the right-of-way taking line first, positioning the boundaries as per plan. If a "Boundary Marker" is positioned as a corner and obviously is not on the accepted line (dividing property), make no attempt to reposition it. All boundary markers shall be positioned at the exact station and offset that is given on the right-of-way plans. Property line fence, generally speaking, goes from boundary marker to boundary marker. When staking bounds, the Resident Engineer shall accurately locate the position of the boundary marker by positioning a stake with a survey tack in the top of it. From this, the Contractor will tie off the control, locate the bound and position it according to the ties used. A spot check should be made by the Resident Engineer on the accuracy of the location used by the Subcontractor. Boundary markers are only required when the taking line changes direction, i.e. the offset distance changes.

When the fence is on a tangent and you can see from one boundary to the other, merely locate the exact position of the boundaries. From that, the fence installer can take care of its needs by intermediate alignment stakes in order to control the location.

When the fence is not parallel to the roadway centerline, then the Resident Engineer must use intermediate alignment control in order for the fence Subcontractor to properly position the fence.

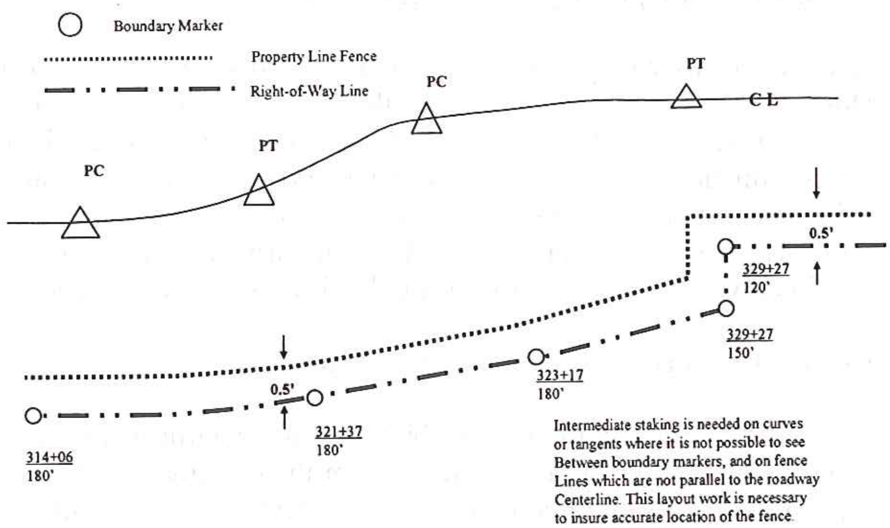


FIGURE 31: Property Line Fence and Boundary Markers

3-230.30 Bench Marks

During the course of construction, the status of the original bench marks and any temporary bench marks may change; as many are accidentally destroyed and will need to be reestablished. At the end of the project, a bench mark list should be made tabulating all remaining bench marks and temporary bench marks.

3-230.40 Traverse Stations

On projects employing the Vermont State Plane Coordinate System, efforts should be made to perpetuate the control stations after completing construction. All remaining control stations should be shown on the final plan sheets.