INSPECTOR'S HANDBOOK

CONSTRUCTION SURVEYING

IOWA STATE HIGHWAY COMMISSION

AMES, IOWA

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CONSTRUCTION SURVEYING

Paul Bingham
Clarence Pedersen

INTRODUCTION

This handbook is an inspector's aid. It was written by two inspectors to bring together all of the most-often-needed information involved in their work.

Much care has been taken to detail each phase of construction, with particular attention to the requirements and limitations of specifications. All applicable specification interpretations in Instructions to Resident Engineers have been included.

The beginning inspector should look to the handbook as a reference for standards of good practice. The Standard Specifications and Special Provisions should not, however, be overlooked as the basic sources of information on requirements and restrictions concerning workmanship and materials.

CONTENTS

Safety

For most of the safety rules, consult the safety manual distributed by the Iowa State Highway Commission and other booklets available in your office.

Some of the precautions to observe in survey are as follows:

When taking original cross sections where heavy grass or weed cover exists, it is best to wear a high-top shoe or boot to help support your ankles if there should happen to be hidden rocks or gullies. Never use a metal-face level rod when cross sectioning near electric power lines. While crossing in front of other men with the level rod extended to full length, take care not to swing the rod around and accidentally hit someone. Many times cross sectioning is done on a road open to traffic. In such a case always place warning signs. Even so, the motorist may not heed the signs, so be watchful at all times while on or near the highway.

When setting paving hubs the use of a sledge hammer is necessary, so make sure the handle is not loose or cracked. Always check where any other men are when starting a swing of the hammer to drive the hub. When the contractor has trucks moving in the area you are working in, causing a great deal of dust, request a watering down of the haul road as the dust makes it very dangerous and difficult to do accurate work.

Working around bridges being constructed presents some dangerous situations. You must wear a hard hat at all times. Whenever giving piling cut-off elevations or other elevations near the footing, have the contractor suspend overhead operations to minimize danger of anything falling. On such as a steel I-beam bridge, when splice grades are being given, the man with the rod will have to be out on the girders without any deck being in place. About the only advice here is for him to be careful not to step on any loose object and to walk carefully.

Whenever working at or near any construction, wear whatever safety equipment is called for in the safety manual. Always use care, especially around large machinery. Safety equipment helps but common sense is also needed.

Project Plans and Contract Documents

The resident construction office furnishes all the necessary plans, contracts and documents needed by the field forces to perform the various duties assigned to them on a project.

When the survey party receives the project plans and contracts, considerable checking must be done before the actual staking can be started. This checking is very important, and must be done by personnel familiar with plan reading and capable of figuring grades, curves, etc. The right of way shown on the road plan must be checked against the property owners contract to be sure that they are in agreement. If there is a discrepancy between the contract and the road plan, the road plan must be corrected so that it is in agreement with the contract. When the complete plan has been checked and any errors have been corrected, the right of way contracts should be placed in a binder book or folder. Contracts can be arranged either by stations or parcel numbers, whichever is more convenient. Make sure they are fastened securely.

Generally, the vertical curve profile grades have been figured and are found at the bottom of the road plan sheets. After carefully checking all verticals, the remaining profile grades can be figured, checked and written on the bottom of the plan. The profile grades are very important and will be used a number of times during the construction of the project, and careful checking is necessary to be sure that grades are correct. Details of vertical curves may be found under the section listed as curves.

All circular curves should be checked as to tangents, length, degree and stations. The station deflections of the curves will be figured before the centerline can be set, and correct curve information is essential. Curve information and deflection angles needed should be placed in a field book so they can be referred to at any time and will not have to be re-figured. All proposed cross road pipe and box culverts should be checked against the cross sections to be sure that the dimension given for their placement will match the final foreslope of the road. Also, elevations must be checked to be sure they are placed as to not interfere with the placement of the paving, and will drain the ditch as intended. Special ditch grades should be figured and checked and written on the plan.

A careful study and check of the plans is absolutely essential before actual staking is started. It is necessary to familiarize yourself with the details pertaining to the work that is to be done before you can satisfactorily complete the job. A common error is that some special detail or information was overlooked on the plan, because not enough time was taken to study the complete plan and note or mark special information that will be needed at a future time. A day-by-day check of the plans by the party chief in the area the survey party is working will help eliminate errors.

After all the checks are made, grades figured, and special information marked, the party chief should make sure that if any revisions have been made, they are placed on the plans at the correct locations. Plans and contracts should be with the survey party at all times, and a careful review of them will be helpful.

Land Monuments

In the first-settled portions of the United States, nearly all of the original land grants were of irregular shape, many of the boundaries following streams, trails and ridge lines. When these grants were divided into smaller tracts, the boundaries were still of irregular shape and it was thought sufficient if lands were described as bounded by natural or artificial features of the terrain.

As the country grew more land was developed, and property values increased, which made it necessary to lay out land in a more definite manner. It then became a general practice to determine the lengths and directions of the boundaries of land by measurements with a chain and compass, and to permanently fix the locations of corners by monuments. Although the terms corner and monument are generally used interchangeably, there is a distinction between them. The term "corner" is used to denote a point determined by surveying or other operation. The term "monument" should be used in speaking of the evidence of the location of that point – the corner. A monument may be destroyed and yet the location of the corner may still be known by measurements to trees, fence posts, large rocks, etc.

Each county is divided into townships, approximately six miles on a side, and the townships divided into sections, one mile square. Each corner of the section and each quarter corner of the section is generally referenced to some objects close by with measurements to them.

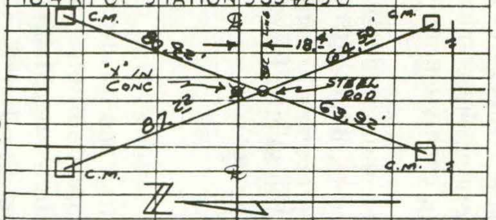
County courthouse records in the county engineer's office show locations of these land corners, and it is very important to keep these records up to date.

In the construction of highways, it is the responsibility of the resident construction engineer to replace section corners that will be destroyed by construction work. Generally the survey party is given this responsibility. The centerline of a highway does not necessarily follow the same line as the section line, but a section corner may appear somewhere within the limits of the right-of-way, and may be disturbed. It then becomes necessary to place reference points for these corners so they will be correctly replaced after construction is complete. When the corner is located off the concrete paving, an iron bar, iron pipe or some other permanent marker is placed in the ground at such depth that it will not be disturbed. When corners are to be replaced in concrete paving, a lead plug is drilled into the paving and the center of the corner is marked in the top of the plug.

The preliminary survey party will note all corners, recording the station and the distance from center of the highway (a very good reference). This information is shown on the road plan. Still other permanent reference points must be set to be certain they may be replaced. Concrete monuments crosstied and set firmly in the ground constitute one of the best methods for rural areas. This procedure is the same as the reference of control points of the highway centerline. Once a section corner is destroyed, and the reference point disturbed, it takes extra work and time to replace it, so it is to the survey party's advantage to reference the corners in such a way that they can be readily replaced. The more reference points set, the better the replacement will be.

SKETCH NO. 1

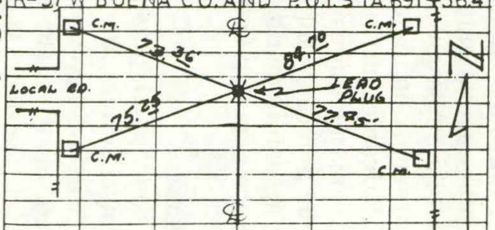
SO 1/4 COR SEC 24 MAPLE VALLEY TWP
T-90N R-38W BUENA VISTA COUNTY
18.4 RT OF STATION 535+290



SECTION CORNER INFORMATION

1 JULY 6, 1952 FOUND WOOD STAKE
2 JULY 6, 1952 REFER. COR. WITH CROSS TIED CONC. MONU. DIST. PLUMBED
3 OCT. 4, 1952 SET 1/4" STEEL ROD 12" BELOW GROUND (JOHN DOE)

NO. 1/4 COR. SEC. 17 HAYES TWP. T-90N
R-37W BUENA CO. AND P.O.T. STA. 691+36.4



1 JULY 13, 1952 FOUND IRON BAR
2 JULY 13 1952 REFER. COR. WITH CROSS-TIE CONC. MONU. DIST. PLUMBED.
3 OCT. 2, 1952 RESET COR. IN CONC. PAVEMENT WITH LEAD PLUG AND CHISELED CROSS (JOHN DOE)

In urban areas, where construction work will destroy corners, reference points are established in a different way than in rural areas. The crosstieing and the measurement may be the same, but the placement of concrete markers or hubs may not be possible. In this situation, chiseled "X's" in sidewalks, curbs, foundations and any other fixed structures are necessary. Correct measurement to these points is essential, and it is possible to replace corners by measurement alone. Marks on corners of concrete buildings, fire hydrants, etc., are also useful.

The reference points of each corner must be correctly recorded in a field book, and on final construction plans. The information should be clear and understandable and include date of reference, date of replacement, type of reference, type of marker used in replacement, measured distance to reference and whether plumbed, slope or flat chained, depth of replacement if underground, description of corner, (such as section number, range, tier and township) and any other useful data concerning the corner. All of this data should also be given to the county engineer, so he may keep his records up to date.

If the corner and reference points are destroyed, the resident construction engineer should be notified. He will choose the procedure for the replacement. Some methods of referencing points can be found in Sketch No. 1, showing the way corners can be placed in the book.

Bench Marks

A bench mark (B.M.) is a definite point of more or less permanent character, the elevation and location of which are known. Bench marks serve as points of reference for levels in a given locality. The elevations are established by differential leveling. Throughout the United States are permanent bench marks established by the U. S. Geological Survey and the United States Coast and Geodetic Survey. Similarly, bench marks have been established by various other federal, state and municipal agencies and by such private interests as railroads, water, and gas companies, so that the surveyor has not far to go before he can find some point of known elevation.

The Coast Survey bench marks consist of bronze plates set in stone or concrete and marked with the elevation above sea level. Those of the other agencies are of similar character. Other objects frequently used as bench marks are stones, pegs or pipes driven in the ground, nails or spikes in trees, pavements, telephone and power poles, painted or chiseled marks on curbs, sidewalks, foundations, culvert headwalls, bridge wings or abutments, and various other locations.

For any survey or construction work, levels are run from some initial bench mark of known or assumed elevation to scattered points in desirable locations for future reference. When the elevation of such points has been determined and their location has been recorded, the points become bench marks.

In highway construction, the preliminary survey party establishes bench marks at various locations along the route of the highway. These bench marks are generally located within the right-of-way lines or somewhere close so they will be convenient during the construction period.

During the construction period some of the bench marks that have been established within the right-of-way will be destroyed, such as those in trees that have been removed, in culverts and bridges that will be replaced, in telephone and power poles that have to be removed, in concrete foundations that will be destroyed and various other locations which will interfere with construction. It is the responsibility of the survey party to transfer, or to move this bench mark to a different suitable location, so that a known elevation will still be available in the general area. The survey party should first check the cross sections in the area where bench mark will be destroyed. The reason for this check is to determine the elevation of the road centerline after the project is completed.

After the final elevation has been noted, a suitable location for the transfer of the bench mark should be located, preferably one which can be used by setting the level on the road top. If there is a tree, concrete foundation, power pole, or some other object near this area and at a suitable location, the bench mark can be transferred to such a point.

After the location has been determined, an exact point of this location must be established. A spike driven in a tree or power pole, an "X" chiseled in concrete or something that is solid and can be easily found, will serve. At this point it is important to be sure that the level rod can be placed correctly on the bench that is established, and that there is sufficient space to readily move the rod and to extend it to its full length. If the B. M. is transferred into a tree or power pole, they may be leaning in such a way as to interfere with a correct placing of level rod.

After the transfer point has been established, it is then necessary to record in the bench mark transfer field book the number, elevation, location and description of the bench mark to be transferred and also the same information on the newly established bench mark. When this has been recorded, the new elevation can be established. If both the old and new bench marks are fairly close to each other, say 300' to 600' and the ground level is such that it is possible to level from one point to the other, then the level should be set somewhere half way between the two bench marks.

The level should be set in such a way that the leg points are firmly in the ground, and the level will not shake or move. The survey party instrumentman is responsible for the proper setting and leveling of the level, and care should be taken not to bump or disturb the level after it has been set. The rodman will then place the level rod on the bench mark to be transferred, and on a signal from the instrumentman, he will slowly move or rock the level rod back and forth in the direction of the instrument. The rocking of the rod gives the instrumentman a precise reading, which he records in the field book.

Then the rodman will place the level rod on the point the bench mark is to be transferred to, following the same procedure as on the old bench. The instrumentman records the rod readings in the book. Then, to be sure that no error has been made in the rod readings or the placement of the rod, the level should be picked up and moved to a new location and reset. The same procedure should be carried out once more to be sure the transferred elevation is correct.

If the bench mark transfer cannot be accomplished with one setting of the level, the level must be moved or turned as many times as necessary to complete the transfer. The general procedure is as follows: The rodman places the level rod on the bench to be transferred and the reading is taken by the instrumentman. The rodman then goes in the general direction of the new transfer B. M. location, and at some convenient spot within the range of the level telescope, about the same distance away from the level as the first reading. He then locates a stable object, or if none is available, he sets one such as a flat driven in the ground, and he marks a point on this stable object as a point to set the rod on. This point is called a turning point, or T. P.

A reading is taken on this point and recorded in the book, and the level is then moved and reset ahead of the turning point and in the general direction of the transfer location. This procedure is done as many times as necessary to be sure no errors were made during the first run. If an error is noted, then a third run is necessary. By this time the correct elevation should be established. If not, more runs are necessary.

The following sketch shows a page of a field book and the procedure generally used in keeping in bench mark transfers. In Sketch No. 1, as explained before, where a transfer can be made by one setting of the level, the reading is taken on the bench that is to be transferred (5.50). The reading 5.50 is the back sight and is added to the elevation of B. M. #1 which gives the height of the level (105.50). Then a reading 3.50 is taken on the new B.M., No. 1A, which is the foresight, and is subtracted from the height of level elevation which gives (102.00), the elevation of the newly transferred B.M.

No. 2 is the very same procedure except that more setups are needed, and turning points are necessary. Remember, the back sight is added to the elevation of the B.M. or turning point, which gives the height or elevation of the level, and the foresight is subtracted from the height of the instrument, which gives the elevation of the turning point or bench mark.

SKETCH NO. 1

BM No.	BACK-SIGHT	HEIGHT INST.	FORE-SIGHT	ELEV	ELEV.	DESCRIPTION
③	B.S. +	H.I.	F.S. −		ELEV.	
BM#1A			3.78		120.82	STA. 27+30 RR SPK So. SIDE 30" ELM 88' LT.
T.P.	13.07		2.24			STA. 19+00 BALL OF R.O.W. RAIL 75' LT.
T.P.	12.62		4.35			STA. 16+80 TOP OF FLAT 20' RT.
BM#1	5.50				100.00	STA. 10+00 RR SPK So. SIDE 24" ELM 36' LT
②	B.S. +	H.I.	F.S. −	ELEV	ELEV.	
BM#1A			3.78	120.82	120.82	STA 27+30 RR SPK So. SIDE 30" ELM 88' LT
T.P.	13.07	124.60	2.24	111.53		STA. 19+00 BALL OF R.O.W. RAIL 75' LT
T.P.	12.62	113.77	4.35	101.15		STA. 16+80 TOP OF FLAT 20' RT.
BM#1	5.50	105.50			100.00	STA. 10+00 RR SPK So. SIDE 24" ELM 36' LT
①	B.S. +	H.I.	F.S. −	ELEV	ELEV.	
BM#1A			3.50	102.00	102.00	STA. 11+50 R.R. SPK No. SIDE 30" BOXELDER 85' RT
BM#1	5.50	105.50			100.00	STA. 10+00 R.R. SPK. So. SIDE 24" ELM 36' LT

In Example No. 3, the total of back sight readings = 31.19, the total of the foresight readings = 10.37. The total difference between the two totals = 20.82, which is added to BM #1 =100.00 + 20.82, which equals the elevation of BM 1A, 120.82.

Control Points

Preliminary surveys are made for the purpose of selecting the general route to be followed, and the fixing of the grades, alignment and other details of the selected route in order that the project may be constructed in accordance with a definite plan. The preliminary survey party sets or locates all control points on the project. Control points are points located on the centerline of the proposed highway and are generally an iron pin or bar buried underground so it will not be disturbed. These points are extremely important as they control the location of the centerline of the highway. These control points are abbreviated on the road plan, and some of the most common used are P.O.T., point on tangent, P.C., point of curve, P.I., point of intersection of two tangents, P.T., point of tangent, etc.

After the right-of-way has been staked it is necessary to preserve or be able to replace the control points after road construction is complete. It may be necessary to replace the control points several times during the construction period for the purpose of replacing the centerline.

So that these points can be replaced, the survey party is responsible for the setting of hub stakes or concrete monuments, known as reference points. Sometimes when there is not time enough to dig holes to set concrete markers, wood hubs are used, and markers are placed at a later date. Whenever possible it is the best procedure to set concrete monuments.

One of the ways to reference a control point is to first set two concrete markers approximately 30 to 45 degrees ahead and behind the point. These markers should be placed inside the right of way line approximately two to five feet, so they will not interfere with the fencing of the right of way. A hole is dug and the marker is securely tamped all around so it will not move, and about six to eight inches is exposed above ground. A fence post should be immediately placed fairly close to the marker so it can be readily seen, and will not be disturbed.

The transit is then set over the iron pin in the center of the marker, making sure the plumb bob is directly in its center. After transit is securely set, its scope is locked in line with the control point to be referenced, making sure the line of sight is in the center of the point. Markers are then set and properly tamped on the opposite side of the road inside the right-of-way line, making sure they are set directly in line with the opposite marker and control point. Care should be taken when setting fence posts on these markers so as not in any way to move them off the line they are set on.

A check of the cross sections should be made before control point reference points are set, to see that after the new grade is completed it still will be possible to see from one right-of-way line across the centerline to the opposite right-of-way line.

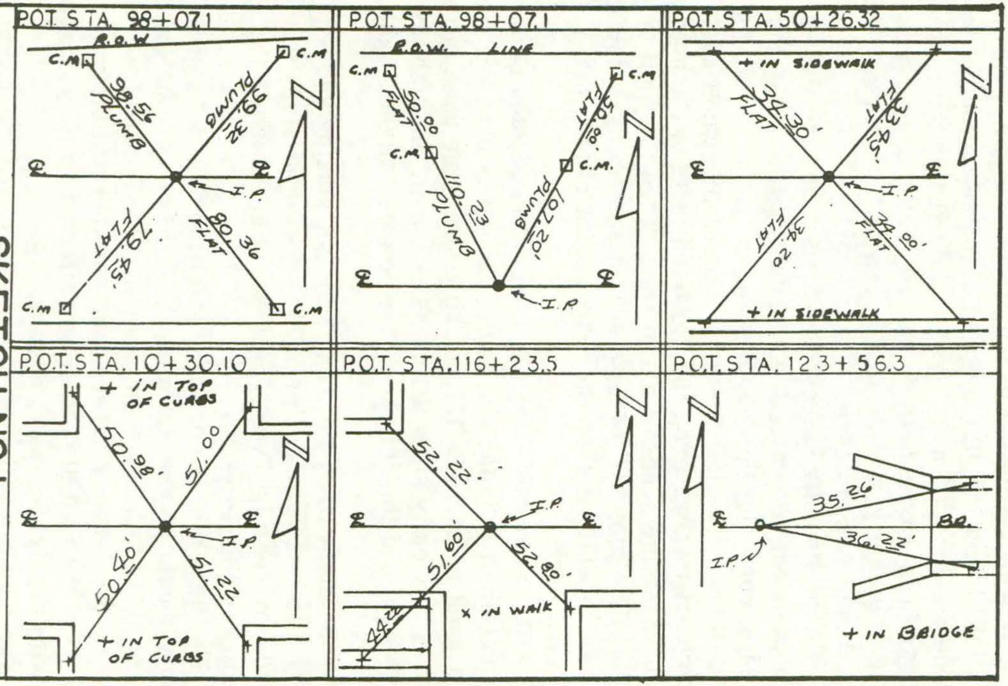
Sometimes a large fill is placed at this point and it is impossible to see from one line to the other. In such case it might be advisable to place temporary reference points doubled on just one side of the centerline, until after the grade is complete. In this situation the transit is placed over the control point, making sure it is directly over the point. The front hubs are driven flush with the ground and a tack placed in the top. The transit is then located on line with this tack and another hub is placed on the line behind the front hub, getting as much distance between the two hubs as can be obtained.

When all hubs are in place and double laths are placed across them, double flats with identification marking are placed on each side to form a protective cover over the hubs. Generally, the distances from the control point to the reference points are measured and recorded in the field book for future reference. In case reference points are too far from the centerline, the distances to them are not necessary.

In some cases, mostly in town and city work, the reference points may be a chiseled "X" in sidewalks, curbs, concrete foundations, etc. These are placed and measured in the same procedure as the concrete monuments.

Sketch No. 1 shows some typical crossties often used.

SKETCH NO. 1


P.O.T. STA. 98+07.1
R.O.W.
C.M
98.56 PLUMB
99.32 PLUMB
I.P.
79.45' FLAT
80.36 FLAT
P.O.T. STA. 98+07.1
R.O.W. LINE
50.00 FLAT
110.23 PLUMB
107.20' PLUMB
P.O.T. STA. 50+26.32
+ IN SIDEWALK
34.30' FLAT
33.45' FLAT
34.20' FLAT
34.00' FLAT
P.O.T. STA. 10+30.10
+ IN TOP OF CURBS
50.98'
51.00
50.40'
51.22
P.O.T. STA. 116+23.5
52.22'
51.60
52.80'
44.22
X IN WALK
P.O.T. STA. 123+56.3
35.26'
36.22'
BR.
+ IN BRIDGE

Right–of–Way

After the centerline of the proposed highway has been established, and the drainage and drainage structures have been determined, the next step is to determine the right-of-way. Right-of-way is defined as: right of passage, as over another's property; a route that is lawful to use; land over which a public road passes.

The preliminary survey, the design, and the right-of-way department determine the amount of right-of-way that is needed to construct the proposed highway. When this has been determined, right-of-way purchasing personnel contact the property owners along the proposed route of the highway and purchase the needed right of way. When the right of way buyer and the property owner reach an agreement, a contract is drawn up which establishes the amount of land that is purchased.

After the right-of-way has been acquired, and before construction of the road can begin, the newly acquired right-of-way must be staked. This staking should be done in such a way as to clearly show the property owner, the highway commission, and the contractor the new established right-of-way line.

The survey party is responsible for staking and establishing this right-of-way line, and very careful study of the right-of-way contract is essential so as to establish the right-of-way line correctly.

The right-of-way contract centerline distances and stations should be checked with the right-of-way shown on the road plans to be sure that they are in agreement. If there is a discrepancy between the contract and the road plans, then the road plan must be corrected so it is in agreement with the right-of-way contract.

The contract will show the stations, and the distance from the centerline to the new right-of-way line to be established. The new line may be the same distance from centerline across a piece of property, or it may change at various stations, depending on the amount of land required for construction. Where the distance from centerline to the right-way line changes, it is known as a break point, or a change in right-of-way. This point is located on the centerline of the road by chaining from a known point, and a transit is set over the point and a right angle (90^{o}) is turned from the centerline. After the angle is turned, the correct distance from the centerline is measured with a steel chain and an iron rail (right-of-way rail) is driven so that the flat side of the rail, or the flange, is at the correct distance. This rail will be a permanent marker and should be driven so that approximately 12" will be exposed above the ground. A steel fence post should be placed adjacent to the rail as a warning to equipment operators. Both rail and fence post should be painted so they are clearly visible.

After the break points in the right-of-way have been established, stations or any other points that are necessary should be established between them. This is done by setting the transit on one point, sighting on the next point and driving wood hubs 100' apart, or less if needed, between points. If it is not possible to sight from one point to another, then it is necessary to set a permanent marker between points on the same line of sight. Permanent points and all stations between them should be identified by placing identification flats adjacent with station numbers and the distance from centerline written clearly on them with lumber crayon.

When the right-of-way line crosses a fence line, other than the line between property owners, a hub should be placed as near as possible to this fence so the property owner may place a corner post in the correct place. A permanent marker should be placed on the right-of-way line where it crosses a line between differently owned parcels. This marker is not intended to establish the property line between the two owners. It is only intended to show where the right-of-way crosses that line. The establishment of property lines outside of the State's right-of-way is not the responsibility of the survey party.

Correct and careful measurement is very essential in the staking of right-of-way, to be certain that permanent markers and intermediate points are placed at the correct distance from the centerline. These markers make it possible for the property owner or the highway commission to reestablish the right-of-way line at any time.

If the centerline is on a curve and the right-of-way is to be staked from the curve, right angles from the curve must be turned out. This procedure is explained in articles pertaining to circular curves.

Shown in Sketch No. 1 is the right-of-way on each side of the road. Right-of-way rails are driven at each break point and a steel post driven beside each one for protection. Both rail and post should be painted. Hub between break points, using a transit, and place a flat near each hub showing station and distance from the centerline. Distances from the centerline to a variable right-of-way can be figured as follows:

Take the total distance along the centerline between right-of-way break points and divide into the difference of distance from centerline of the two points, which gives the amount the right-of-way moves in or out per foot. Take distance times the amount per 100'.

Example:

In Sketch No.1, right-of-way on the left side from Station 0+00 to 4+00 is 100' to 200'

400' = distance
100' = difference between break points

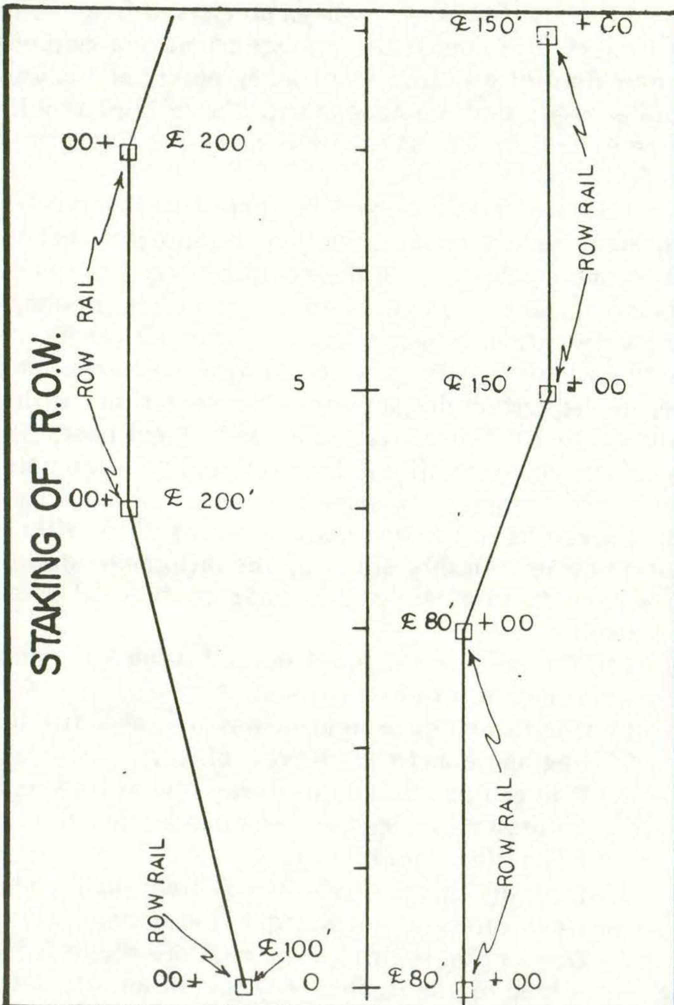
$$\frac{100'}{400'} = .25 \text{ per foot}$$

.25 times 100 = 25' per 100'

Station 1+00 right of way will be 125' from centerline
Station 2+00 right of way will be 150' from centerline
Station 3+00 right of way will be 175' from centerline

On right side Station 3+00 is 80' and Station 5+00 is 150', difference between 80' and 150' = 70'. $\frac{70}{2} = 35'$.

Right of way distance at Station 4+00 is 80' plus 35' = 115'.


STAKING OF R.O.W.
ROW RAIL
ROW RAIL
ROW RAIL
ROW RAIL
00+ ℄ 200'
00+ ℄ 200'
00+ ℄100'
0
5
℄80' +00
℄80' +00
℄150' +00
℄150' +C0

SKETCH NO.1

Right-of-Way Markers

After right-of-way has been purchased from the property owners it is necessary to place permanent markers on the new right-of-way line at all break points and any intermediate points that are necessary. The right-of-way line can be established at any time by running a line between markers.

4.5' iron rails are used as right-of-way markers in rural areas, and are placed so they are in agreement, as to station and distance, with the contract. Rails are set using a transit for angles and a chain for the correct distance, being very careful that the correct distance from the centerline is measured. Rails are driven with the flange, or flat side, at the correct distance from the centerline, with approximately 8 to 10" left above the ground. Steel posts are driven next to each rail and both rail and post are painted to be clearly visible. In some cases the rail may come in such a place as to be dangerous or a hindrance to the property owner. In this situation the rail can be driven below ground and a note of this made on the final plan and field book.

Rails should be set in all the following locations when such situations occur on the project:

1. One rail on each right-of-way line opposite the beginning and end of every curve.
2. One rail on each right-of-way line at intermediate points on long curves, when necessary to clearly define the right-of-way.
3. One rail on each right-of-way line when such lines intersect government land lines.
4. One rail on each right-of-way line where it is joined by the right-of-way line of an intersecting road or railway.
5. One rail at each angle in any right-of-way line.
6. Two rails at each offset in any right-of-way line.

A

All permanent markers should be listed in the reference field book noting station distance from the centerline, right or left of centerline, and any other information that may be useful in the future. All right-of-way markers are listed on final construction plans at their correct location. A convenient way of recording permanent markers is to have one field book arranged especially for permanent references. This book should contain all ties, records, and references for all land corners, centerline points, right-of-way markers and final bench marks for the entire project. A list of permanent markers should be filed with the maintenance engineer who is to maintain the project on completion.

Borrow Areas

Where more fill material is needed than can be acquired from within the new established right-of-way line, it is necessary to find an area outside the right-of-way line where this material can be acquired. This area is generally a knoll or hill which soil tests show to be satisfactory for road construction. This land is not purchased by the Highway Commission. The property owner is paid a price for the material that is taken from it, usually so much per acre, and it is defined as a borrow area.

While staking the permanent right-of-way line, the survey party should check carefully the right-of-way contracts to see if a borrow area is included in the contract. If a borrow area is noted in the contract, then a hub stake can be set on the right-of-way, at the beginning and end of the borrow, if it is adjacent to the right-of-way. If the borrow area is at right angles to the right-of-way line, set the transit on the hubs at the beginning and end of the borrow, turn right angle and measure distance to back side of borrow. When measuring from the right of way line, extreme care should be used so that the correct distance is measured. Distance to the back side of the borrow is from the centerline of the road – not from right-of-way.

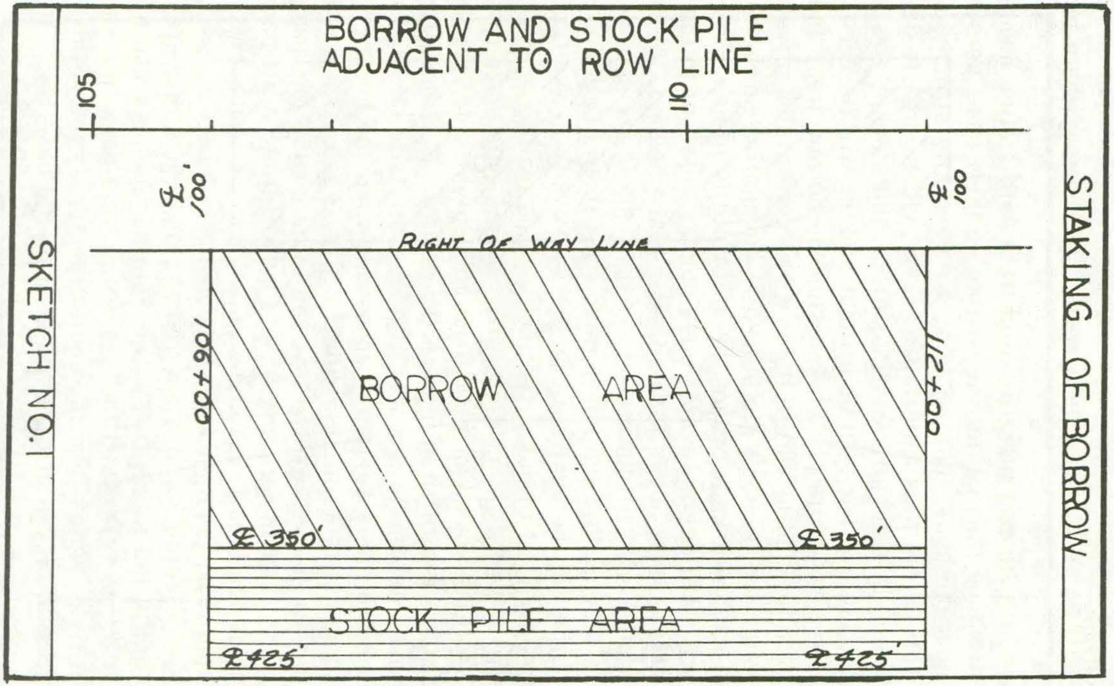
After the beginning and end of the borrow has been established it is necessary to set hubs between, then on stations or any other points that are needed. At this time some thought should be given to how this area is to be cross sectioned, so that if extra hub stakes are needed to help in the cross sectioning they can be placed at this time. This stake line on the back side of the borrow is important to the property owner, the Highway Commission and the road contractor. If the property owner plans on placing a temporary fence he will know where to place it. The road contractor will be able to see the limits of the borrow where his work will be done.

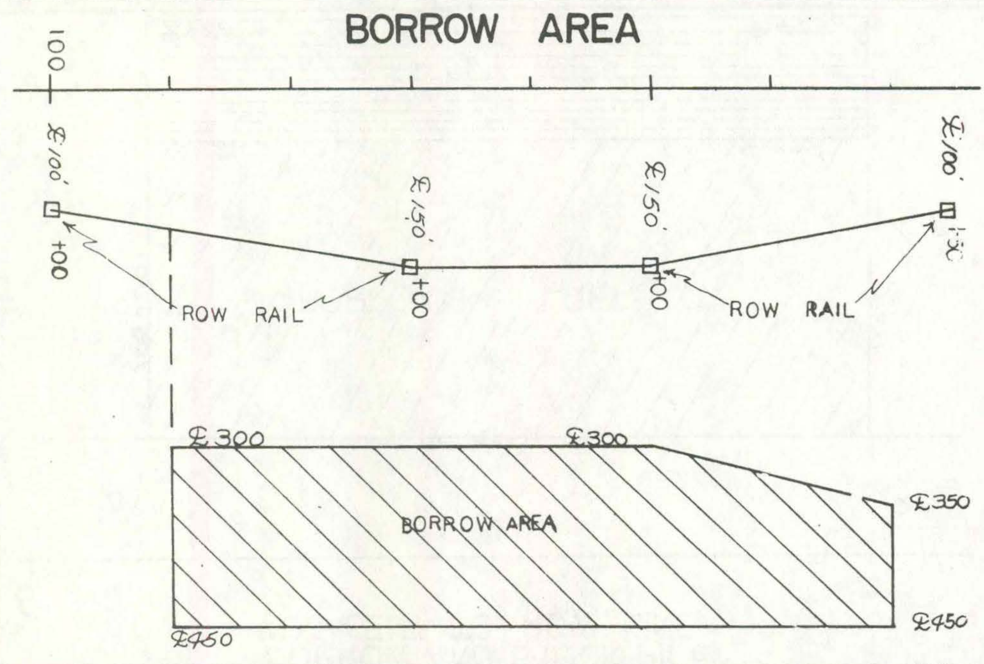
Lath and identification flats with station numbers and distance from centerline written on them shall be placed near the hubs. Borrow areas are generally stripped of top soil before road material is taken, and an area is designated where to stockpile this topsoil. If the stockpile is within the borrow limits no additional staking will be necessary. If the stockpile is to be outside the borrow area, and is to be furnished by the Highway Commission, the survey party will have to stake the stockpile boundaries so the road contractor will know where the stockpile is to be.

If the borrow area does not lay adjacent to the right-of-way line, but is located some place beyond, the borrow limits will still be staked, to show the exact borrow area. In staking this type of borrow, care should be taken to establish the control or break points, so in case they are knocked out or destroyed they can be readily replaced at the same location. Generally, on this type of borrow, cross sections are taken from some convenient side, or a base line is established through the borrow. It is important that this line can be replaced if necessary, so that final measurement or cross sections can be taken. If the borrow area is to be cut to a pre-determined depth, then elevations taken on borrow hub stakes can be used to determine the amount of cut

The survey party should make sure that all borrow boundaries are clearly marked so the road contractor does not encroach on land not intended for that purpose.

Sketch No. 1 shows borrow and stock pile areas adjacent to the right-of-way line. Borrow sections can be taken at right angles from the centerline, or a base line can be run at right angles from the centerline across the borrow, and sections taken at right angles from the base line. If base line sections are taken, a drawing of the borrow and all the information conce ning how sections were taken must be placed in the cross section book, so the base line can be replaced after the contractor is done with the borrow. The drawing should be in detail so that someone not familiar with the original sections can readily replace the base line and take final sections in the same way the original cross


BORROW AND STOCK PILE
ADJACENT TO ROW LINE
105
110
℄ 100'
℄ 100'
RIGHT OF WAY LINE
106+00
112+00
BORROW AREA
℄ 350'
℄ 350'
STOCK PILE AREA
℄ 425'
℄ 425'
SKETCH NO. 1
STAKING OF BORROW


BORROW AREA
100
℄ 100'
+00
℄ 150'
+00
℄ 150'
+00
℄ 100'
ROW RAIL
ROW RAIL
℄ 300
℄ 300
℄ 350
BORROW AREA
℄ 450
℄ 450

SKETCH NO. 2

sections were taken. Also, after work in the borrow area is complete, the survey party will have to stake the fence line for the property owner. In Sketch No. 1 stakes will be set from Station 106+00 to Station 113+00 100′ from the centerline.

Sketch No. 2 shows borrow some distance from the centerline. This type of borrow requires stakes on all sides so the contractor can see where his work will be. Cross sections of the borrow would generally be taken by using the backside of the borrow as a base line, and taking sections to the north. A detailed drawing of the borrow area must be placed in the cross section book to show how original sections were taken.

All borrow areas may not be as simple to lay out as shown on the two sketches. Some areas will take considerable planning and staking to lay out the boundaries and base line to insure correct cross sectioning. Regardless of what type of borrow is to be staked, a detail drawing showing complete information is extremely important.

Cross Sectioning, Original and Final

After the right-of-way and borrow areas have been staked and before construction work can be started, it is necessary to record the actual lay of the ground or the elevation of the land before it is disturbed. This is known as cross sectioning, which is done before construction and after construction is complete, and better known as original (or preliminary) cross sections, and final cross sections. The purpose of taking cross sections is to be able to reproduce, from the cross section notes taken in the field, the actual lay of the ground on paper. From the cross sections, earth quantities, drainage lines, area cuts and fills and various other quantities can be calculated. The amount of material the contractor has cut and filled is determined by the original and final cross sections taken by the survey party and it is very important that the sections are taken correctly.

Cross sections should be taken at every 100′ station and at any intermediate point where the slope of the ground changes abruptly, to obtain sections which truly represent the ground surface. Ground elevations are taken at the centerline and at all points right and left where the lay of the ground breaks or changes, and the distances to these elevations are measured.

Cross sections are taken at right angles to the centerline right and left to the right-of-way line, and in case of a borrow area which is adjacent to the right-of-way line, cross sections will extend to the back of the borrow area. Borrow cross sections can be taken separately if it is more convenient to do so. Cross sections should cover all side ditches, roads, creek and river banks, drainage areas, and other places that will affect the earth quantities. Care should be taken in making sure all shots are at right angles to the baseline and that all ground changes are shown. There is a tendency to take too few cross sections, particularly in rough country where rapid changes in the profile occur.

The level instrument is placed to read the level rod from one right-of-way line to the other, and as far ahead as possible. One rodman will call out the distance from centerline at each place the other rodman places the rod, and the notekeeper will record readings, distances and stations in the field book. The rodman on the centerline will keep the man taking the shots on a line at right angles to the centerline. Generally there is a right-of-way stake on each station which will be a guide for right angles, but where no stake is available, it is necessary to set a lath or range pole on each side of the centerline at right angles so shots will be taken correctly.

The rod readings and distances are observed to tenths of feet, except when reading a bench mark or a turning point, when the rod is read to hundredths. When measuring the distance to a shot, care should be taken to keep the tape or chain fairly straight so the distance will be correct. When steep slopes are encountered, it is necessary for the one doing the measuring to move to a measured point on the slope and call the distance from that point, remembering to add the distance to point to the distance on the tape.

Sketch No. 1 shows the location of shots and distances from the centerline with a level instrument placed to see all shots taken.

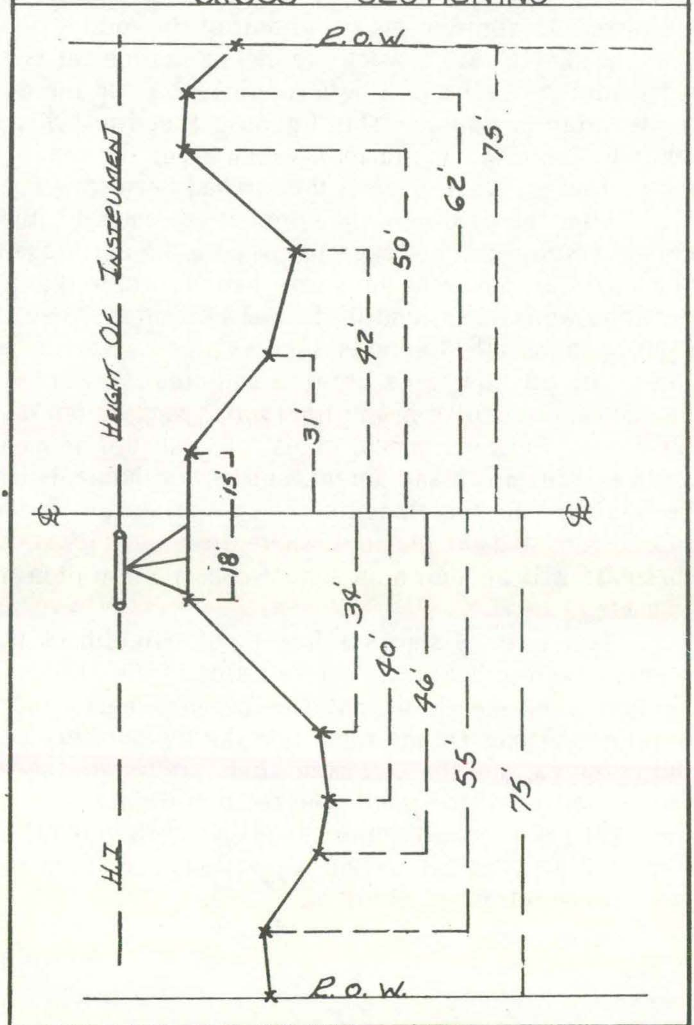
In rough or hilly terrain it may not be possible to see the level rod at all points where elevations are needed. One way to remedy this situation is to set up another instrument at a place below the first instrument and where the top instrument is sighting near the top of the rod, and the bottom instrument is sighting the lower part of the rod.

In Sketch No. 2, when the bottom instrument is set, a rod reading is taken with both instruments, and the difference in elevation is figured. This figure is added to every reading taken by the lower instrument, which gives the reading the top instrument would read if the rod had been long enough.

After the grading on the project is complete, the final cross sections can be taken to compute the earth quantities. The finals are taken at the same stations where the original sections were taken, and in the same manner. When taking final sections all structures such as pipe culvert, flow lines, culvert flow lines, intakes and other flow lines should be shot and recorded in the final cross section book. Also all drives, field entrances, dikes, etc., should be measured, as to length, width and height, so that earth quantities can be figured. The length and size of all driveway pipe should be recorded and the stations where drives are located. All this data will be shown on a final construction plan when it is made.

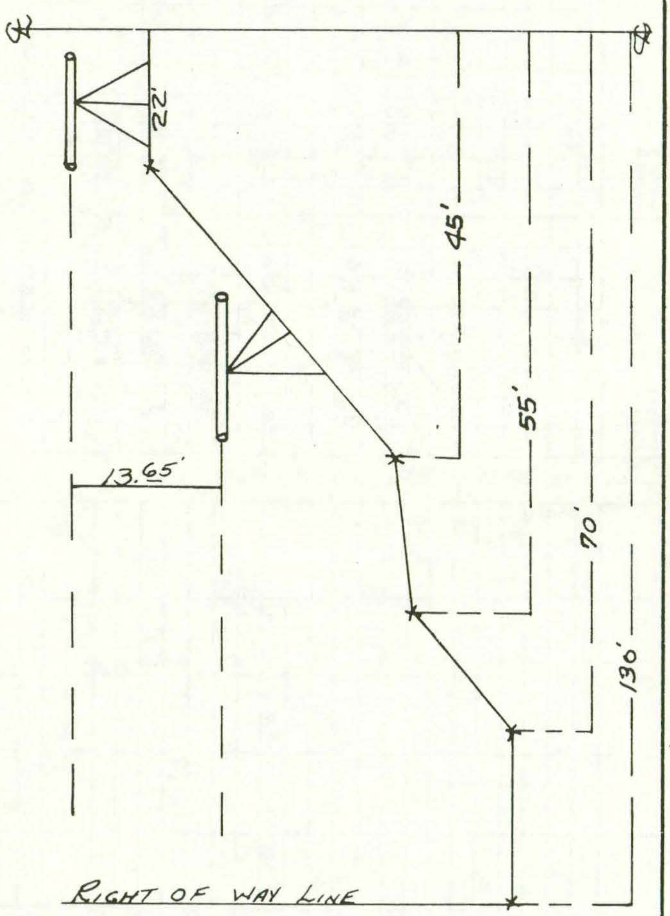
Sketch No. 3 shows a drawing of a field book page in a cross section book. On the left side is the station of the section taken, height of instrument, bench marks and turning point elevation. On the right side the top numbers are the rod readings, and the bottom numbers are the distance from the centerline of the road. The red line down the center of the right page indicates the centerline of the road. Make sure that a sufficient amount of sections are taken so the final computations are correct.

CROSS SECTIONING



SKETCH NO. 1

CROSS SECTIONING



SKETCH NO. 2

SKETCH NO. 3

CROSS SECTIONING

						SURVEY PARTY / DATE WEATHER
103+50						2.5/150 3.0/150
103+50						3.8/100 4.2/70 5.7/50 7.6/48 5.7/37 4.7/50 3.8/100 3.6/150
103+50						9.6/32 8.4/25 5.8/19 4.6/9 4.4/— 4.5/9 5.3/16 7.6/21 7.1/30
T.P.	2.36	1197.37	8.94	1195.01		STA 103+00 BALL OF R.O.W. RAIL (31') RT
103+00						8.9/200 9.2/150
103+00						9.3/100 9.2/60 7.3/42 8.5/35 9.7/32 9.7/50 9.5/100 9.0/150
103+00						10.5/30 10.3/22 5.5/13 5.6/9 5.4/— 5.6/9 6.0/13 10.9/25 10.4/30
BM #4	2.45	1203.95 H.I.			1201.50	STA. 102+33-RR SPK SO. SIDE 24" ELM 200' LT

Circular Curves

In relatively level country, long tangents should be connected with long sweeping curves. Sudden changes in alignment should be avoided as much as possible. The alignment, then, may be considered as made up of tangents and circular curves.

Circular curves may be described by giving either the radius or the "degree of curve". In highway design, the degree of curve is defined as the central angle subtended by an arc of 100'. This is known as "arc definition". See Sketch No. 1.

Circular curves are classified as simple, compound, and reverse. If the simple curve can be understood clearly, then no trouble should be encountered with the others. The following paragraphs will deal with simple curves.

The centerline of a road consists generally of a series of straight lines and curves. The straight lines are called tangents and a simple curve is a circular arc joining two tangents. Sketch No. 2 shows such a curve with its related parts or functions.

P.C. = Point of Curve
T = Tangent of Curve
P.I. = Point of Intersection of Tangents
Δ = Central angle, controlling angle
E = External - Distance from PI to Curve
D = Degree of Curve
R = Radius of Curve

Following are some formulas and examples which are helpful in figuring curve lengths, tangents, radii, degrees, and externals.

1) For degree of curve with known or fixed tangent:

$$\text{Degree of curve} = \frac{\text{Tan}\ \frac{\Delta}{2} \times 5729.6}{\text{Fixed Tangent}}$$

Example problem with = 36°41'
and with a fixed tangent = 633.27'
Tangent $\Delta/2$ = 0.33152)

$$(0.33152)(5729.6) = 1899.6$$

$$\frac{1899.6}{633.27} = 3^\circ \text{ (Degree of Curve)}$$

2) Radius: A one degree curve is defined as a curve having such a radius that 100′ of arc will subtend a one degree central angle. There are 360 degrees of central angle for a complete circle. The circumference of a circle is expressed by the formula — $2\pi R$ (PI or $\pi = 3.14159$). Therefore the radius of a one degree curve is determined by the formula:

$$2\pi R = 360 \times 100 \qquad R = \frac{36{,}000}{2\pi} = \frac{36{,}000}{2(3.14159)} = 5729.6 \text{ feet}$$

Radius of 1° curve = 5,730′ (practically)
Radius of 2° curve =

$$2\pi R = \frac{360}{2} \times 100$$

$$R = \frac{18000}{2\pi}$$

$$R = \frac{18000}{6.28318} = 2864.79$$

Radius of 2° curve is ½ of 5729.6
Radius of 3° curve is 1/3 of 5729.6
Radius of 4° curve is 1/4 of 5729.6
The formula for the radius of any degree of curve is therefore:

$$R = \frac{5729.6}{D}$$

3) The degree of curvature for any specified radius is therefore:

$$D = \frac{5730}{\text{Radius}} \quad \text{Example} \quad D = \frac{5730}{1910} = 3^\circ$$

4) Length of curve:

$$L = 100 \times \frac{\Delta}{D} = \frac{\text{central angle} \times 100}{\text{degree curve}}$$

Example: $\Delta = 36^\circ 41'$ $D = 3^\circ 00'$

$$L = \frac{36.6833 \times 100}{3} = 1222.78' \text{ length}$$

5) Deflection per foot is equal to 1/2 the degree of curve divided by 100 $\left(\frac{D/2}{100} = d\right)$

Example: $\Delta = 36^\circ 41'$ (D) $= 3^\circ$

$D/2 - 90'$ (minutes)

$d = \frac{90}{100} = 0.9'$ per ft.

or

$d = \frac{3 \times 60'}{2} \div 100' = .90'/\text{ft.}$

Example: $\Delta = 0^\circ\ 47'$ $D = 0^\circ\ 07'\ 50''$

$\frac{7.83333}{2} = 3.91666'$

$d = \frac{3.91666}{100} = .03916'$ per ft.

(You will note that we converted 50″ to hundredths of a minute 50″ = 0.83333 minutes)

The deflection per foot may also be obtained by multiplying the degree of curves by .3

$$d = \frac{(D)\,(60)}{(2)(100)} = 0.3\,D$$

Example: $3^\circ \times .3 - .9$ per ft.

$4^\circ \times .3 - 1.3$ per ft.

$3^\circ\ 30' - 3.500$

x.3

1,0500 or 1.05′ per ft.

The deflection per foot is also 1/2 of the central angle divided by the length of the curve. $\frac{\frac{\Delta}{2}}{L}$

Example: $\Delta = 0^\circ 47'$ $D = 0^\circ 07'\ 50''$ $L = 600'$

$$d = \frac{\frac{47'}{2}}{600} = \frac{23.5}{600} = 0.03916' \text{ per ft.}$$

Calculation of deflections of a simple curve is shown in the example below:

Δ = 40° 45′ – 30″ Rt.	P. C. Sta.	105+42.31
D = 7° 30′	P. I. Sta.	108+26.12
T = 283.81′	P. T. Sta.	110+85.75
L = 543.44′		
E = 51.01′		
R = 764.00′	½ Δ =	20° – 22′ – 45″

PC 105+42.31 = 0° – 00′–00″
106+00 = 2°–09′– 48
107+00 = 5°–54′ – 48″
108+00 = 9°–39′ – 48″
109+00 = 13° – 24′ – 48″
110+00 = 17° – 09′–48″
P.T. 110+85.75 = 20° –22′–45″

First it is necessary to figure the deflection per foot. Change the degree of curve into minutes, divide by 2 and divide answer by 100.

60 minutes in degree
x7 degree
420 minutes
+30 minutes
450

$\frac{450}{2}$ minutes 225′

$\frac{225'}{100}$ = 2.25′ deflection/ft.

For 100′, the deflection is:

2.25 x 100 = 225.00′ $\frac{225.00'}{60}$ = 3° – 45′

From P.C. 105+42.31 to 106+00 = 57.69′

57.69 x 2.25′ = 129.8025

$\frac{129.8025}{60}$ = 2°– 09′ – 48″ deflection from P. C. to Sta. 106+00.

Deflection		Station
2° – 09′ – 48″	=	106+00
3° – 45′ per 100′		
5° 54′ 48″	=	107+00
3° 45 per 100		
8° 99′ 48″		
60		
9° 39′ 48″	=	108+00
3° – 45′		
12° 84′ 48″		
60		
13° 24′ 48″	=	109+00
3° 45′		
16° 69′ 48″		
60		
17° 09′ 48″	=	110+00
3° 12′ 57″ for		85.75′
20° 21′ 105″		
60 –		
20° 22′ 45″	=	110+85.75 P.T.

6) To run a curve on an offset the deflections per foot will remain the same, but the chord length between hub points on the curve will be reduced or increased, depending on whether the offset curve is inside or outside the plan curve.

The increased or decreased chord length is found as follows:

For inside curves,

$$\frac{\text{Radius of curve} - \text{offset}}{\text{Radius of curve}} \times \text{plan-curve chord}$$

For outside curves,

$$\frac{\text{Radius of curve offset}}{\text{Radius of curve}} \times \text{plan-curve chord}$$

For short distances on flat curves, such as used in staking hubs for paving (25' intervals), the centerline distance and chord length are considered equal.

7) For right angles from a point on a curve, if backsight is to the P.C. of a curve, set on point to be turned, set vernier at 0°-00', sight P.C. and turn 90° plus the deflection of point transit is set on, to the outside of curve.
8) For right angles from a point on curve, if backsight is to a station on the curve, take deflection of point to be turned, add 90° to it, then minus the deflection of the point backsighted which gives amount to turn for outside of curve.
9) To move transit to station on the curve and continue running curve, set transit on turn point, set vernier on degrees and minutes of point backsighted, plunge scope and turn defection of next point ahead of turn. Sighting of the P.C. (0° 00') is the best method.

Vertical Curves

On highways, in order that there may not be abrupt change in the vertical direction of moving vehicles, adjacent segments of differeng gradient are connected by a curve in a vertical plane, called a vertical curve. Usually the vertical curve is the arc of a parabola. This form is well adapted to gradual change in direction, and elevations along the curve can readily be computed. Usually the length of the vertical curve is an even number of stations or a convenient whole number in feet. The station and plus of the P.I. and elevations of stations along the uniform grade line are determined from the profile grade.

Refer to the vertical curve shown on Sketch No. 3. On a road, a +0.8 percent grade meets a –0.4 percent grade at Station 90+00 and at an elevation of 100.00. It is desired to establish a vertical curve connecting the two grades. In this particular case we will use a 600 foot vertical curve to connect the two adjacent segments. The tangent length on either side of the P.I. is 600 divided by 2 or 300 feet. The Station A is, therefore, 90+00 minus 300 = 87+00 and Station C is 90+00 plus 300 = 93+00. The elevation of A is 100.00 – (3 x 0.80%) = 97.60, and the elevation of C is 100.00 – (3 x 0.40%) = 98.80.

The elevation of mid-point D of the long chord AC is the mean of elevation A and C: ½ (97.60+98.80)=98.20′.

The mid-point E of the vertical curve is midway between D and (PI) B: ½ (98.20 + 100.00) = 99.10.

The offset from the P.I. to the curve is 100.00 – 99.10 = 0.90′ by using the formula:

$$\frac{(\text{Distance})^2}{(\tfrac{1}{2}\ \text{Vertical Curve})^2} \times \text{offset} = \text{Tangent Offset}$$

The tangent offset at Stations 89+00 and 91+00 is:

$$\frac{2^2}{3^2} \times 0.90 = 0.40'$$

The tangent offset for Stations 88 00 and 92 00 is:

$$\frac{1^2}{3^2} \times 0.90 \quad 0.10'$$

The elevations of points on curve are then determined as shown in the following tabulation:

Station	87+00A	88+00	89+00	90+00	91+00	92+00	93+00=C
Tang.Elev.	97.60	98.40	99.20	100.00	99.60	99.20	98.80
Tang. Offset	0.00	0.10	0.40	0.90	0.40	0.10	0.00
Elevation of Curve	97.60	98.30	98.80	99.10	99.20	99.10	98.80

One check that can be made is: The beginning curve elevation, plus the end curve elevation, plus twice the P I elevation divided by 4 equals centerline of curve elevation at the P.I. station.

Sketch No. 3:

Beginning curve	=	97.60
Ending curve	=	98.80
P.I. X 2	=	200.00
		396.40

$$4 \overline{)396.40} = 99.10 \text{ centerline elevation}$$

The offset from the PI to the curve is called the M.O., or middle ordinate. It can be found by multiplying the algebraic sum of the grade percentages by the length of curve in stations and dividing by 8. Thus:

$$\frac{.8 - (-.4)}{8} \times 6 = 0.9'$$

Spirals

On highway curves (except very flat curves) the roadway is superelevated, that is, one side is higher than centerline, while the other is lower than the centerline. Since the superelevation should be gradually attained at the beginning and reduced at the end, spiral curves at each end serve the purpose of providing the gradual change. For a detailed explanation and calculation of spirals and transitions, see the book titled, Transition Curves for Highways, by Joseph Barnett.

Following is an example of figuring deflections for even stations on a spiral curve:

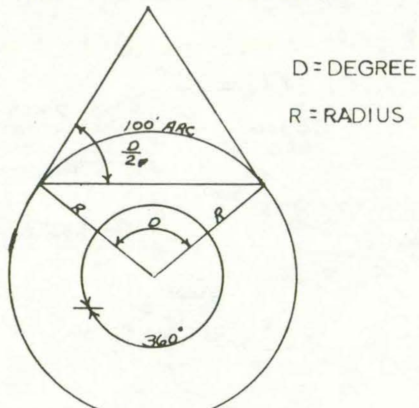
L^2 = Distance from TS or ST to station or plus squared.
L^2s = Length of spiral squared.
Øs = Intersection angle.

Formula: $\frac{L^2}{Ls^2} \times \frac{Øs}{3} =$ Deflection

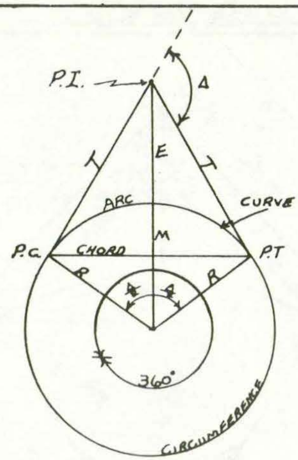
Example: Length of spiral = 200 ft.
Øs = 5°

T.S. Station 991+54.1 wanted deflection for 992+00:
Distance from T.S. to 992+00 = 45.9'. 5° converted to minutes equals 60' x 5° or 300 minutes.

ARC DEFINITION

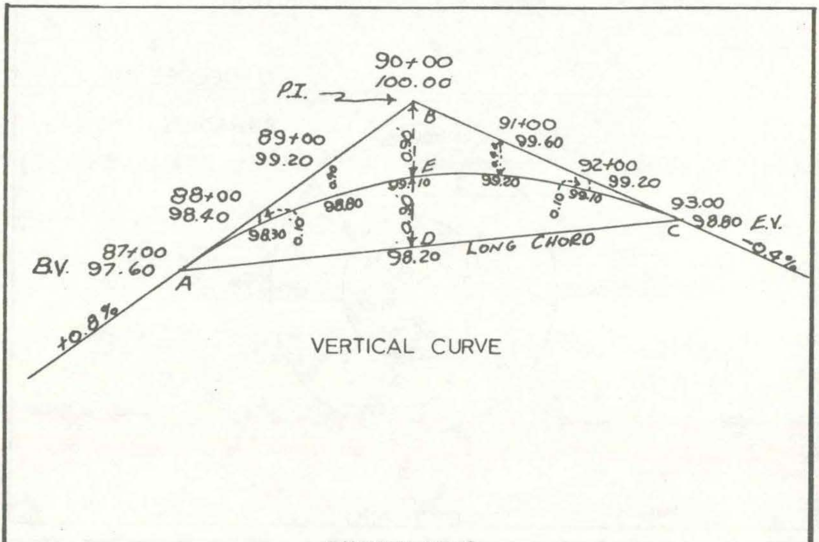


SKETCH NO. 1



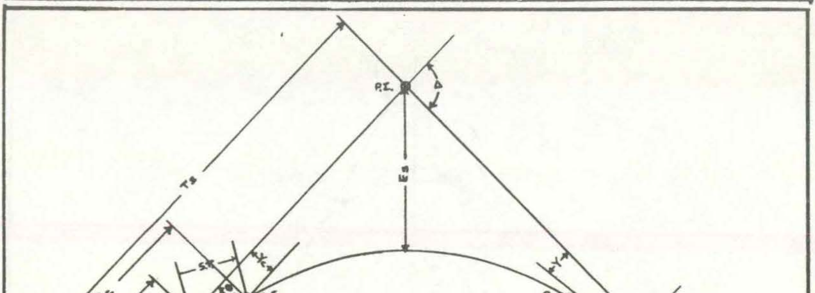
PARTS OF A CIRCULAR CURVE

SKETCH NO. 2



VERTICAL CURVE

SKETCH NO. 3



CURVE WITH TRANSITION BOTH ENDS

$$\frac{45.9^2}{200^2} \times \frac{300 \text{ minutes}}{3} = \frac{2106.81}{40{,}000} \times 100 =$$

.05267025 X 100 minutes = 05.27′

Deflection for 992+00 = 0° 05′16″

Deflection for Sta. 993+50:

```
      993+50.0
TS – 991+54.1
      195.9'
```

$$\frac{195.9^2}{200^2} \times \frac{300 \text{ minutes}}{3} = \frac{38376.81}{40{,}000} \times 100$$

.9594201 X 100 95.94202

```
     1
60 ) 95.94202          1°  35.942'
     60                    or
     35                1°  35'  56½"
```

993+50 = 1° 35′ 56½″

Transition Symbols

P.I. Point of intersection of the main tangents.

T.S. Tangent spiral, common point of tangent and spiral of near transition.

S.C. Spiral curve, common point of spiral and circular curve of near transition.

C.S. Curve spiral, common point of circular curve and spiral of far transition.

S.T. Spiral Tangent, common point of spiral and tangent of far transition.

SCS Spiral curve spiral, common point of both spirals or midpoint of a curve transitional, throughout (except where special reference is advisable).

Rc	Radius of the circular curve.
Ls	Length of spiral between TS and SC.
L	Length between T.S. and any other point on spiral.
L1	Length between any two points on spiral.
Ts	Tangent distance P.I. to T.S. or S.T. or tangent distance of the complete curve.
E	External distance P.I. to center of circular curve portion, or to SCS of a curve transitional throughout.
LT	Long tangent distance of spiral only.
ST	Short tangent distance of spiral only.
LC	Straight line chord distance T.S. to S.C.
P	Offset distance from the tangent of P.C. of circular curve produced.
K	Distance from T.S. to point on tangent opposite the P.C. of the circular curve produced.
Δ	Intersection angle between tangents of the entire curve.
Δ c	Intersection angle between tangents at the S.C. and at the C.S. or central angle of the circular curve portion of the curve.
Ø s	Intersection angle between the tangent of the complete curve and the tangent at the S.C., the spiral angle.
ϕ	Intersection angle between the tangent of the complete curve and the tangent at any other point on the spiral, the spiral angle of any other point.

Dc Degree of the circular curve same as the degree of curvature of spiral at the S.C. (arc definition).

D Degree of curvature of spiral at any other point on spiral (arc definition).

Øc Deflection angle from tangent at T.S. to S.C.

Ø Deflection angle from tangent at any point on spiral to any other point on spiral.

XcYc Coordinates of S.C. from T.S.

XY Coordinates of any other point on spiral from the T.S.

Slope Stakes

A slope is defined as, "A piece of ground that is not flat or level; rising or falling ground; a deviation from a horizontal line and the amount or degree of such." In highway construction work, the term "slope" is used frequently and before grading construction can be started, slope stakes must be set as a guide to the contractor and inspector in making excavations and embankments.

Slope stakes are set at points where the side slopes of the graded road will intersect the ground surface; they mark the limits of excavation and embankment. Slopes are designated by the ratio of the horizontal distance to the vertical distance. The vertical distance is always taken as the unit 1, with the horizontal distance variable. For example, a 3 to 1 slope extends 3 feet horizontally for each vertical foot of rise or fall. This is the same in other slopes such as 2 to 1, 2½ to 1, 4 to 1, 5 to 1, 6 to 1, etc. Slopes which extend downward from the shoulder of a highway grade to natural ground or the bottom of a side ditch are called 'foreslopes'. Those which extend upward from the bottom of a cut to the natural ground at the extremities of a section are called 'backslopes'.

After the preliminary cross sections are completed, the centerline or profile line can be determined, and final elevation of this line set for the proposed new grade. This profile grade line is shown at the bottom of the standard road plan and indicates the final elevation of the road after construction. In the following paragraphs the profile grade will be used to indicate the final elevations on the centerline of a concrete paving and slope stakes will pertain to staking of subgrade and ditch cuts.

Before starting the procedure of slope staking, it is necessary to understand clearly what cross sections, bench marks and elevations are. Sketch No. 1 is a typical grading cross section, showing the distance the subgrade is below profile grade, the percent of slope from centerline to shoulders and type of slopes. This type of drawing is found in the first few pages of the road plan and gives information needed to stake cuts, fills, slopes, ditches, etc.

Sketch No. 2 shows the original and final lay of ground right of Station 77+00, and where ground shots were taken. Original shots are shown by θ, and final shots are shown by △. Note that scale of the sketch is 1" horizontal equals 10 feet, and 1" vertical equals 5 feet. Also elevation lines are given at the right, to be able to determine the elevation of the ground at each place. An elevation was taken to build the area that is shown as fill on the sketch, and a fill stake will have to be set someplace between 42' and 44' from centerline. To determine the place where the cut section will start a ditch cut, a stake will be set somewhere between 53' and 57' from centerline.

First a slope stake book must be drawn up, showing centerline, shoulder, ditch, and bench mark elevations. On Sketch No. 1, the centerline elevation of the subgrade is 8" below the profile grade, which indicates that 8" of paving will be placed on the subgrade after it is complete. After the difference is noted, take the road plans and minus from the road plan profile at each station (in this case) 8 inches, or .67 hundredths, which gives the elevation at centerline of the subgrade. This elevation of the subgrade is placed in the field book at the proper place, making sure the figure is correct. (See Sketch No. 3).

Looking back to Sketch No. 1, it is shown that the distance to the shoulders is 25', and the rate of slope is 1.5%. The percent of slope is how much the road will slope from centerline of the subgrade to the shoulder.

```
 0.0150  rate of slope
   X 25  shoulder distance
 ------
    750
   300
 ------
  .3750  use .38 feet
```

In Sketch No. 1 the shoulder elevation will be .38 feet lower than the centerline elevation of the subgrade. In Sketch No. 2 the profile grade has an elevation of 1247.37, which, when dropped .67, gives an elevation of 1246.70 at subgrade centerline. Subtracting .38 from the subgrade centerline gives 1246.32, the shoulder elevation, which is entered in the book under shoulder elevation.

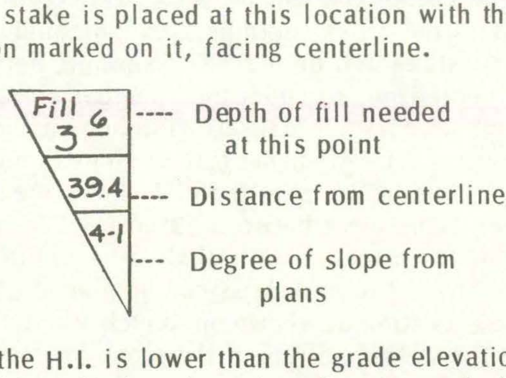
The ditch grade information is found above the profile grades on the road plan, and is listed as being so many feet below the profile grade, or a special ditch grade is given. A typical cross section of ditches and backslope is found in the front part of the road plan. Sketch No. 4 shows this typical section. Note that depth of ditch is so many feet below the profile grade, not below the subgrade. After the ditch elevations have been listed in the slope stake book it will be helpful to list the approximate locations where the fill and cut stakes will be set. These locations can be found on the cross sections. As indicated on Sketch No. 2, the fill stake will be placed somewhere between 41' and 44' from centerline, so under the shoulder elevation in the slope stake book this approximate distance can be listed. (See Sketch No. 3). Also, the rate of slope can be shown in the slope stake book. Sketch No. 2 shows the ditch cut stake will be somewhere between 83' and 87' from centerline, and the bottom or toe of the backslope is 57' from the centerline. These two distances can be placed under the ditch grade elevation as shown on Sketch No. 3.

The actual setting of the slope stakes is a trial and error method based upon calculations involving the height of the instrument, the grade rod, the ground shot, the shoulder distance, and the distance to the toe of the proposed backslope. The level is set up at any convenient location, and the H.I. is obtained by a shot on a bench mark. If the H.I. is higher than the proposed grade elevation, the grade rod is found by subtracting the proposed grade elevation from the H.I. The grade rod should be entered in the slope stake book in the elevation column. (See Sketch No. 3). In case the H.I. is lower than the proposed grade elevation, the H.I. is subtracted from the grade elevation and the difference is a plus "+" grade rod. The ditch grade rod is figured in the same way. The procedures are listed below:

1) The rod reading minus the grade rod, times the rate of slope, plus the shoulder distance, equals distance to place fill stake.

Example:	17.0	rod reading (ground)
	− 13.4	grade rod
	3.6	fill
	X 4	rate of slope
	14.4	
	+ 25.0	shoulder distance
	39.4′	distance of fill stake from ℄

Information is placed in the field book on the right page. (See Sketch No. 3). The rod may have to be moved a few times so that when figures are calculated the rod is at the distance figured. The fill stake is placed at this location with the following information marked on it, facing centerline.

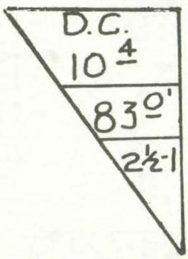


2) In case the H.I. is lower than the grade elevation, the grade rod will be added to the rod reading instead of subtracted. Example: rod reading, plus the plus grade rod, times the rate of slope, plus the shoulder distance, equals the fill stake distance.

The procedure for setting the cut stake is the grade rod minus the rod reading, times the rate of slope, plus the distance to the toe of the backslope, equals distance of cut stake.

Example:		
	18.1	grade rod
	-7.7	rod reading
	10.4	cut
	× 2.5	rate of slope
	26.00	
	57.00	distance to proposed toe of backslope from ℄
	83.00	feet, distance from ℄ cut stake is set

As in setting the fill stake, the rod may have to be moved to be at the correct calculated distance.



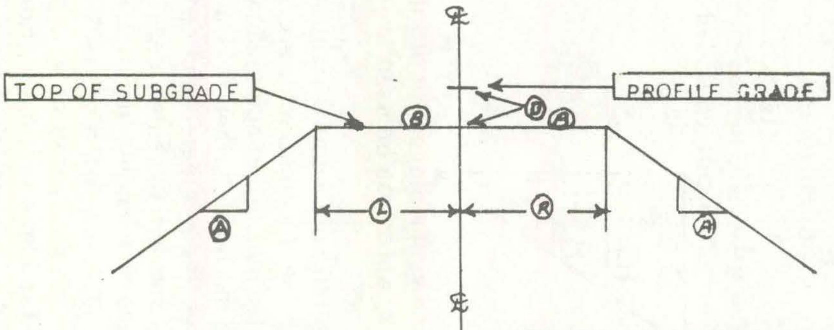
Sketch No. 3 shows the placement of information in the slope stake book, which can be used to replace the stake if necessary.

A grade is generally placed on a right of way hub both right and left to give the road contractor a cut or fill from hub to the subgrade centerline. If the hub reading is less than the centerline grade rod reading, then it is a cut from hub to centerline. If hub reading is greater than centerline grade rod, then it is a fill from hub to centerline.

Sketch No. 3 shows a hub reading of 7.16 and the centerline grade rod is 13.0, the difference is 5.8, which is how much lower than the hub the centerline will be. In very hilly terrain, as explained in cross sectioning, more than one instrument may be used to accomplish the staking.

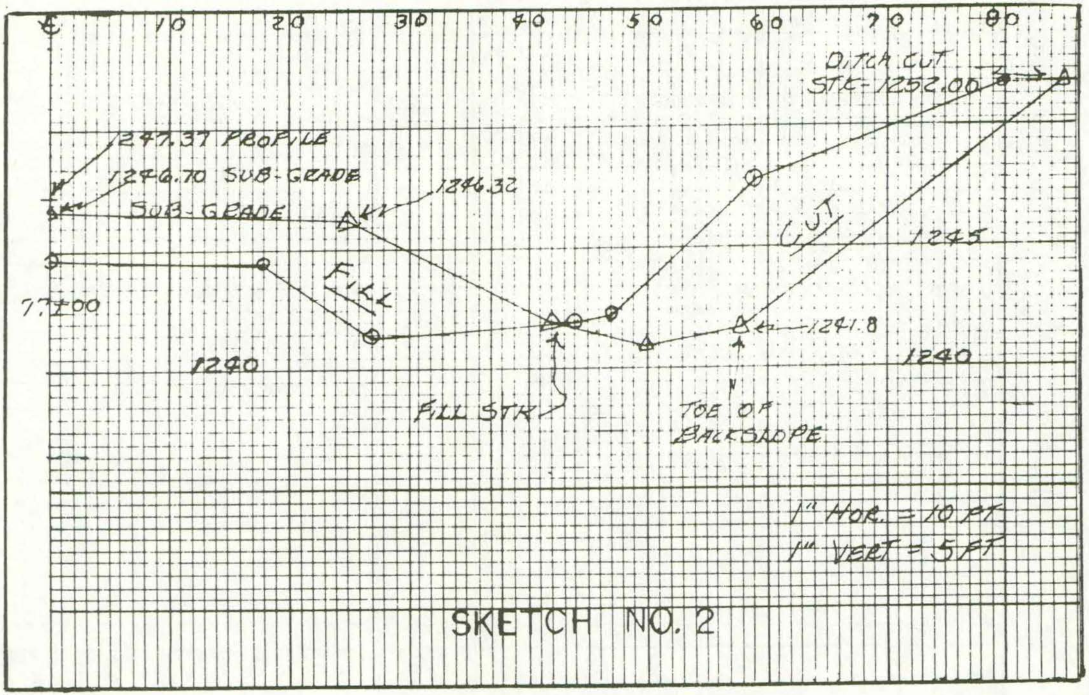
The foregoing procedures are not a standard or fixed way of staking, and some survey party chiefs may differ in the setting up of the book and the procedure of the stake placing. The correct stake location, and a correct record of the stake in the book, is the final goal.

TYPICAL GRADING CROSS SECTION

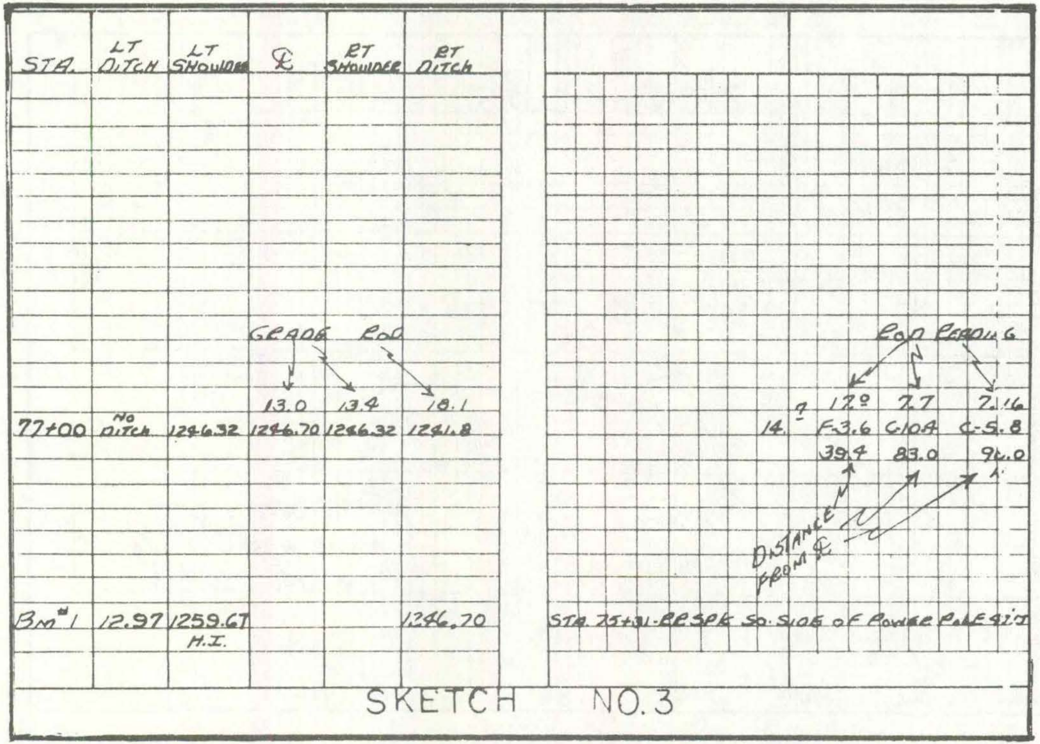


DIMENSIONS			SLOPES	
L	R	D	A	B %
25′	25′	8″	3	1.5

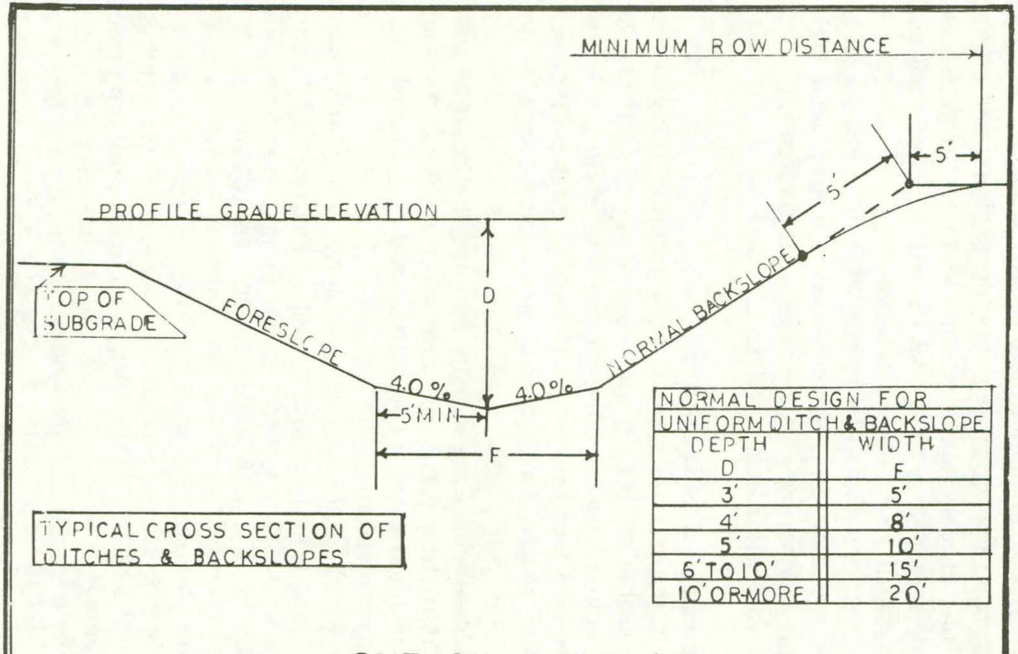
SKETCH NO. 1


10
20
30
40
50
60
70
80
DITCH CUT
STK-1252.00
1247.37 PROFILE
1246.70 SUB-GRADE
SUB-GRADE
1246.32
CUT
1245
FILL
1240
1241.8
1240
FILL STK
TOE OF
BACKSLOPE
1" HOR. = 10 FT
1" VERT = 5 FT

SKETCH NO. 2


STA.
LT DITCH
LT SHOULDER
℄
RT SHOULDER
RT DITCH
GRADE ROD
13.0
13.4
18.1
77+00
NO DITCH
1246.32
1246.70
1246.32
1241.8
ROD READING
14.
12.0
7.7
7.16
F-3.6
C-10.4
C-5.8
39.4
83.0
96.0
DISTANCE FROM ℄
BM#1
12.97
1259.67
H.I.
1246.70
STA. 75+31 - RR SPK. SO. SIDE OF POWER POLE 21.7

SKETCH NO.3



NORMAL DESIGN FOR UNIFORM DITCH & BACKSLOPE	
DEPTH D	WIDTH F
3'	5'
4'	8'
5'	10'
6' TO 10'	15'
10' OR MORE	20'

SKETCH NO. 4

Measurement of Pay Items

In general, the specifications are clear regarding the method of measurement of pay items. It should be constantly kept in mind that original notes, dimensions, and other data constitute primary documentation as to pay quantities and must be recorded in field books neatly, legibly, and without the possibility of misinterpretation.

Sketches should be employed if they will be an aid in computing quantities. Irregular areas of pavement are an example. A review of the method of measurement specified for an unfamiliar item is advisable.

Measurement of Removal Items

In the construction or reconstruction of highways there are a number of items to move or remove to facilitate new construction. On the contract and a tabulation sheet will normally be found the various items of each project which are to be removed and units of measurement such as square yard, cubic yard, square feet, etc. These unit quantities are determined by preliminary surveys, but must be measured by construction survey because many times the preliminary was taken quite some time earlier and a number of changes may have occurred.

On urban projects you will have, along with construction plans, a working plat called an Engineer's 10 scale. The 10 scale shows, among other things, area boundaries that are to be sawcut and removed. These areas are to be marked plainly enough for the contractor to snap a chalk line on. A good method is to paint a narrow line approximately every 25' on tangents, oftener on curves and each corner of saw cut. This method includes portland cement and asphalt concrete, drives, sidewalks, etc. On occasion there may be a reason to change the location slightly such as a joint in the existing paving or a bad condition of the paving. In the field book a drawing of each area to be removed and the location should be made. Record any additional removal separately and a simple explanation of it for verification of overrun or underrun of quantity. This additional removal, however, will be totaled with the plan removal quantity.

Sample sketches and field book entries will be found on succeeding pages.

CLASS II BRIDGE REPAIR

COMPUTATION SHEET

Crew

Date 17

Weather

Area	Total	
8.6×3.9 =	33.54	sq. ft.
1.0×6.1 =	6.10	" "
4.2×3.1 =	13.02	" "
1.7×1.7 =	2.89	" "
1.3×6.8 =	8.84	" "
2.6×2.7 =	7.02	" "
1.9×1.6 =	3.04	" "
3.0×1.2 =	3.60	" "
	78.0	sq. ft.

Totals

Page		
4	565.0	sq.ft.
5	476.0	" "
6	438.0	" "
7	776.0	" "
8	388.0	" "
9	166.0	" "
10	358.0	" "
11	625.5	" "
12	1185.9	" "
13	312.8	" "
14	256.8	" "
15	209.1	" "
16	166.2	" "
17	78.0	" "
	6001.3	sq.ft.

$$\frac{6001.3 \text{ sq.ft.}}{9} = 666.8 \text{ sq. yd.}$$

Method of measurement — — —

Computed by J.J.D.

Checked by B.J.L.

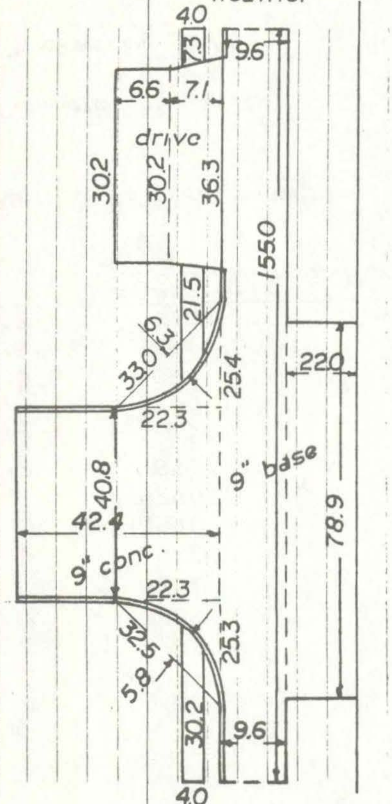
CONCRETE MEASURE

Crew | Date | Weather | 9

$\frac{30.2 + 36.3}{2} \times 7.1$	236.1	sq. ft.
30.2 × 6.6	199.3	" "
Drives	435.4	sq. ft.
4.0 × 30.2	120.8	sq. ft.
4.0 × 21.5	86.0	" "
4.0 × 7.3	29.2	" "
Sidewalk	236.0	sq. ft.
42.4 × 40.8	1729.9	sq. ft.
$\frac{25.4 \times 22.3}{2}$ (-) 2/3 C.M.	144.6	sq. ft.
$\frac{25.3 \times 22.3}{2}$ (-) 2/3 C.M.	156.4	" "
9" Conc.	2030.9	sq. ft.
9.6 × 155.0	1493.8	sq. ft.
78.9 × 22.0	1735.8	" "
9" Conc. base	3229.6	sq. ft.

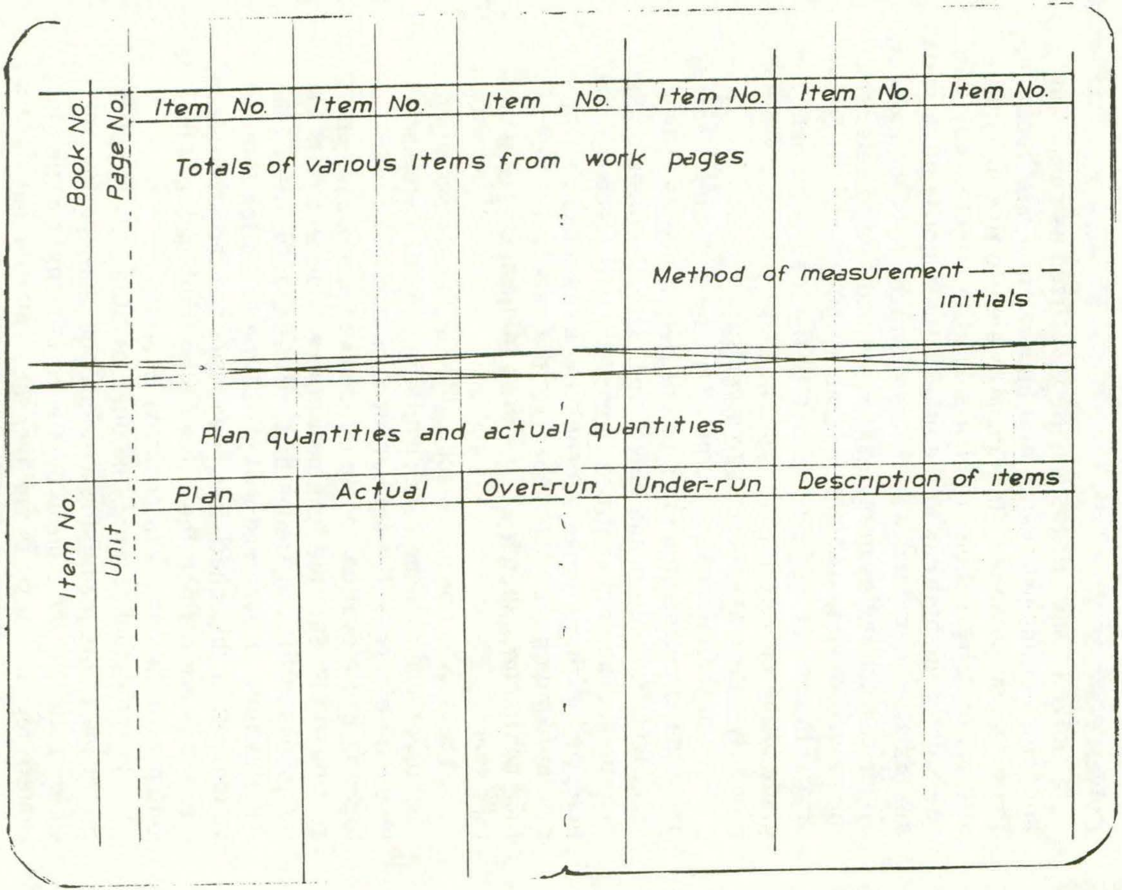
438+00

437+00



52

CONCRETE MEASURE



Culvert Pipe

Culverts and bridges may be visualized as composing the "cross-drainage" system of a highway in a rural location. Their general purpose is to transmit water flowing in natural streams or collected on the high side of the right of way from one side of the highway to the other. The majority of culverts are installed in natural watercourses which cross the highway, either at right angles or on a skew. In addition to selecting the proper location or "station number" for the culvert crossing with respect to the centerline of the road, alignment and grade of the culvert are of importance. This section will deal primarily with cross road pipe culverts.

From the information gathered by the preliminary survey party, the drainage structures can be determined as to type, size, length, location and elevations, and are placed on the road plan. The road contractor generally will place the road pipe, and all the information concerning the cross road pipe can be found on the sheet that lists drainage structures by road contractor. Sketch No. 1 shows information given on this sheet.

The survey party is responsible for the staking of cross road pipes and extreme care should be used to make sure the pipes are placed at the correct location and elevation. The location and elevation should be checked against the cross sections to be sure the length of pipe will be sufficient for the proposed fill and slopes that will be placed over it, and the elevation at each end will match the new ditch line elevation. After this check has been made and the location and elevations are correct, the culvert pipe field book can then be set up with the correct information listed.

In the actual staking, the pipe location is first set on centerline of the road using a transit and chaining from a known point. If the pipe to be staked is at right angles to centerline, the transit is set over the centerline nail, and a 90 degree angle from centerline is turned. Hubs are then driven and tacked on a line at a predetermined distance beyond each end of the pipe or apron. The distance from the end of the pipe or apron to the tack in the hub is known as the offset distance and is written on the flat as Ⓢ 20', Ⓢ25', Ⓢ30', as the case may be. The offset distance should be far enough so the hubs will be outside of the working area. Sketch No. 2 shows one way of staking and grading pipe. The cross section of the pipe can be taken along with the regular cross sections, but a section should be shown in either the original cross section book or in the pipe culvert book as shown in Sketch No. 2.

Note that the offset (S) distance is shown in the staking diagram, and also, the distance the hub is from centerline of the road. The diagram of the pipe can be placed in the book before staking is done, and the offset distance can be determined at the site.

In Sketch No. 3 the pipe is to be placed on a 45° skew, and the hubs are driven and tacked on the skew centerline of the pipe, at an offset from the ends.

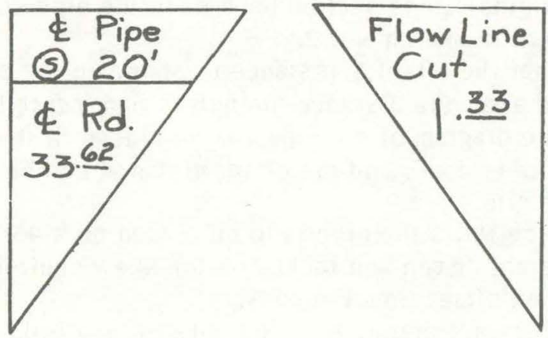
When it is not practical or possible to locate the offset hub on the centerline of the pipe, it is necessary to use a different procedure in staking to be sure the pipe is located in the correct location. Sketch No. 4 shows one way of placing hubs so centerline and the end of the pipe can be readily located by placing string between tacked hubs and measuring in the offset distance. These hubs are set on a line 90° from centerline of pipe by use of the transit.

When staking a cross road pipe where there is a median pipe connecting into it, or a tee section, extra stakes will be needed. See Sketch No. 5. Careful checking is necessary to be sure the connection location and elevation are correct. When the contractor is placing this type of pipe it is very important that the connection point is placed at the correct angle, so the median pipe will connect to the main pipe correctly. See Sketch No. 5.

Accuracy in the measuring and grading of pipe culverts is of extreme importance and any error can be costly in time and money. Rechecking of distances, figures, and measurements is a good policy to follow to insure a correct outcome.

Information must be placed on flats by the offset hubs so the contractor can complete the pipe-laying operation, and hubs and flats should be clearly marked by painted or flagged lath or by some other means. Information necessary is shown on the following page.

If necessary, more than one flat may be placed by each offset hub to be sure the contractor has all the information needed.



FRONT SIDE BACK SIDE

A friendly and cooperative relationship between contractor, survey party, and inspectors will generally insure a good final outcome.

DRAINAGE STRUCTURES BY RD CONTRACTOR

TYPE	LOCATION	D SIZE	LENGTH LIN. FT.	KIND	SKEW AHEAD RT	SKEW AHEAD LT	APR. NO.	DIMENSIONS LT.	DIMENSIONS RT.	FLOW LINE ELEV LT	FLOW LINE ELEV RT	CL 20 EXCA CY	REMARKS
1101	321+29	24"	54'	RF-1	-	-	2	32.62	33.62	1190.20	1189.94	28	
1401	RT. 60' 304+90	24"	110'	CMP		70°	2			No. 1356.00	So. 1367.30		ELBOW 1156.10
1601	RT. 60' 377+34	24"	64'	UNCL	90°		2	W-32	E-32	1408.7	1408.5	49	

PIPE CULVERT

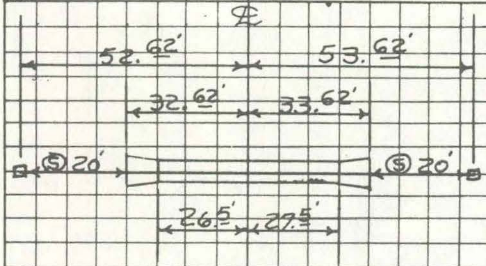
SKETCH NO. 1

SKETCH NO 2

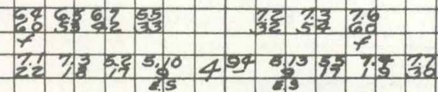
		STA. 321+29			
	24"	X 54' Conc. Pipe			
		2-RF-3 Aprons			
		Elev.	Gr.Ro	Stk	Cut-Fill
Lt.	Hub	1190.20	8.29	6.42	C=1.87
Rt.	Hub	1189.94	8.55	7.22	C=1.33
321+29	Cross	Section ℄ of Culvert			
Bm#11	5.53	1198.49 H.I			1192.96

SURVEY CREW

DATE



TACKED HUBS

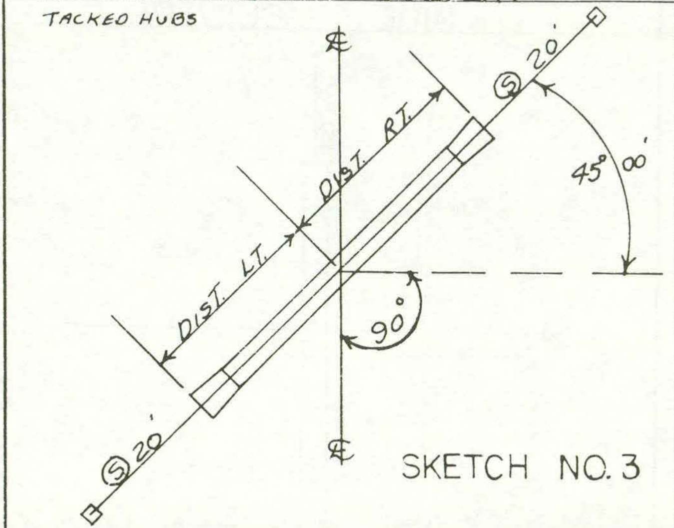


STA. 321+29 "X" - W. Howl Conc. Culv. 16' LT

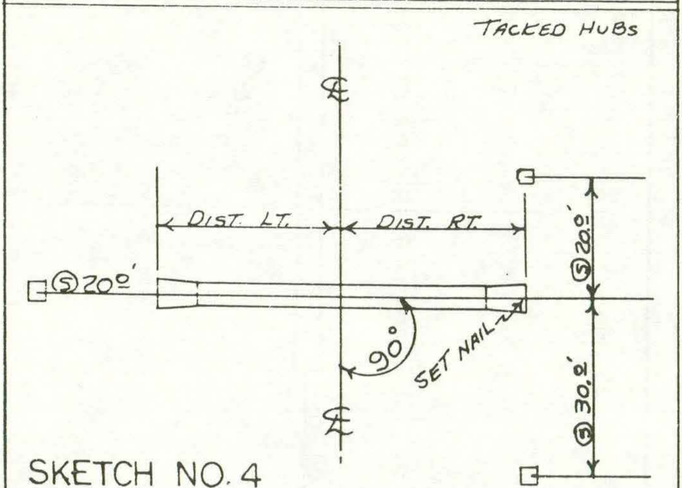
PIPE CULVERT

58

PIPE CULVERT

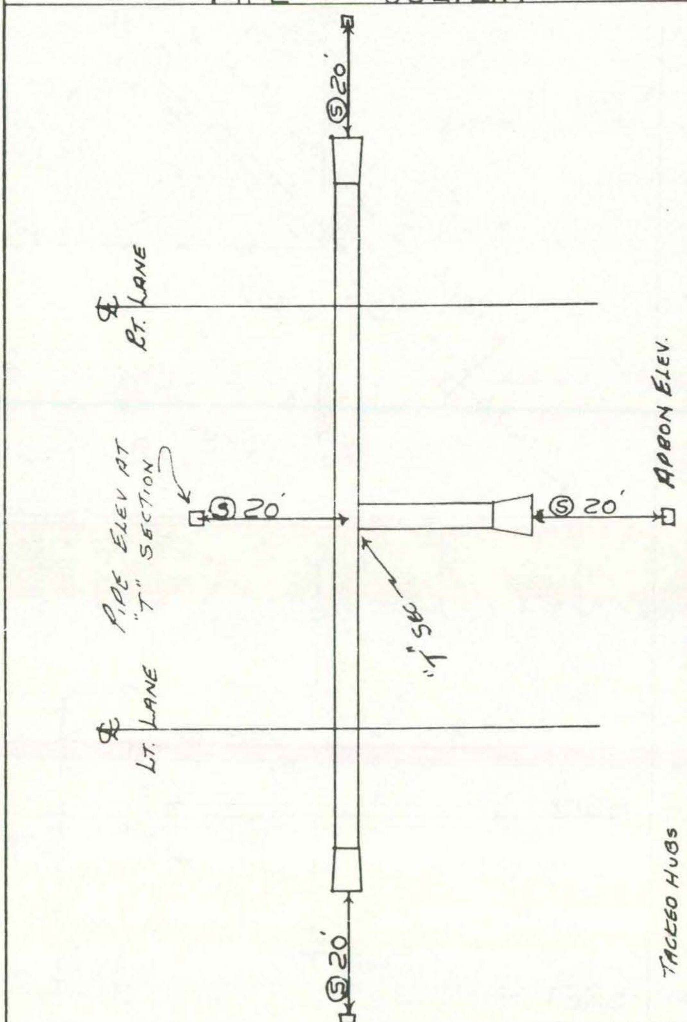


SKETCH NO. 3



SKETCH NO. 4

PIPE CULVERT



SKETCH NO. 5

Storm and Sanitary Sewers

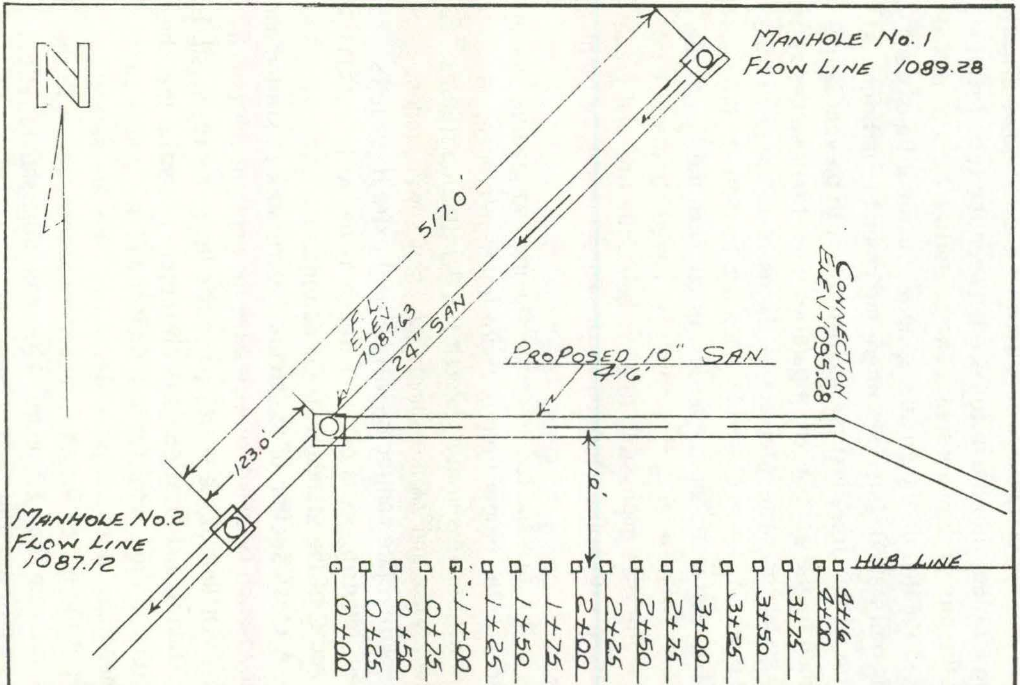
When staking sewer lines the rate of drop must first be determined by using the elevations at the beginning and end of the line and the distance in feet between the two. Dividing the distance in feet into the difference between the two elevations gives the rate of drop per foot. The centerline for a proposed sewer is located on the ground, generally using a transit and setting nails at 50' intervals where the ground is uniform. At one side of this line, just far enough from it to prevent being disturbed by the excavation, a parallel line of hub stakes is set, with hubs at the same intervals as the nails on the centerline of the pipe. A flat is placed by each hub to indicate the station, the offset distance, and the amount of cut from the hub to the flow line of the sewer at that point. In paved streets or hard roads where it is impossible to drive hubs, the line and grade are marked with spikes (driven flush), chisel marks, or paint marks.

A diagram and record of the staking and grading should be placed in the proper field book for future reference. A sample diagram is shown in Sketch No. 1 with drop figures. Sketches No. 2 and 2A are sample pages of sewer grades.

Note: The contractor will be paid extra if grade is changed, requiring extra depth of trench as per Article 2503.05 A, B, and C of the Standard Specifications.

A cross section of the ground before work is started and after the trench is complete will show the depth of the trench.

Even though the survey party has the prime responsibility for staking and location, it is absolutely essential that the inspector and the contractor both understand the stakes and their meaning. Wherever possible, sewer lines are staked beginning at the outlet end and proceeding to the inlet, with the stakes not more than 25' apart. The stationing should reflect any change in the line such as an intake or manhole by beginning again with Station 0+00. See Sketch No. 3.


MANHOLE No. 1
FLOW LINE 1089.28
517.0'
24" SAN
F.L. ELEV. 1087.63
123.0'
MANHOLE No. 2
FLOW LINE 1087.12
PROPOSED 10" SAN.
416'
CONNECTION ELEV. 1095.28
10'
HUB LINE
0+00
0+25
0+50
0+75
1+00
1+25
1+50
1+75
2+00
2+25
2+50
2+75
3+00
3+25
3+50
3+75
4+00
4+16

SKETCH NO. 1

			FLOW LINE ELEV.		
			11.96		
1+50			1090.39		
			12.88		
1+00			1089.47		
			13.80		
0+50			1088.55		
			14.72		
0+00			1087.63		
	MANHOLE No. 2 - F.L. ELEV =				
	MANHOLE No. 1 F.L. ELEV. =				
TBM:	2.35	1102.35 H.I			1100.00

CREW

DATE
WEATHER

11.96
6.84
C- 5.12

12.88
6.81
C-6.07

13.80 GR. ROD
8.21 HUB
C-5.59

14.72 GR. Rd
8.53 HUB
C-6.19

ROD READING = 15.23 = 1087.12

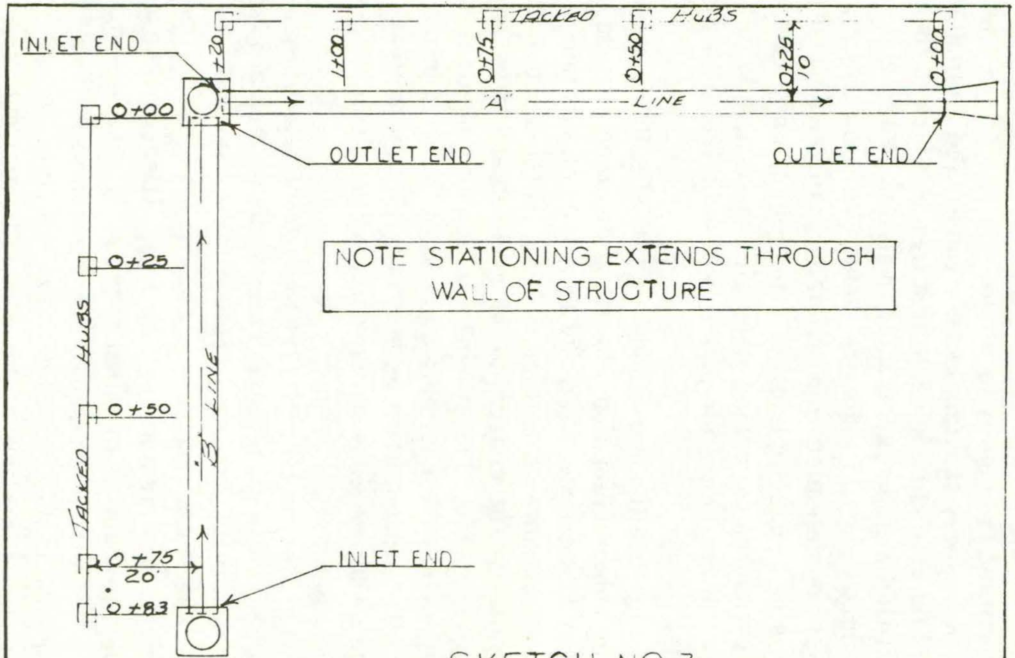
ROD READING = 13.07 = 1089.28 -

STA. 4+50± "X" No. E. COR. GAS PUMP ISLE 10' RT

SKETCH #2

T.B.M			2.35	1100.00	1100.00	
			7.36			7.36
4+00			1094.99			2.24
						C-5.12
			8.28			8.28
3+50			1094.07			3.17
						C 5.11
			9.20			9.20
3+00			1093.15			5.18
						C 4.02
			10.12			10.12
2+50			1092.23			5.00
						C-5.12
			11.04			11.04
2+00			1091.31			6.03 H.J.B
						C-5.01
		1102.35 H.I				

SKETCH No 2A



INLET END
TACKED HUBS
+20
1+00
0+75
0+50
0+25
10
0+00
"A" LINE
0+00
OUTLET END
OUTLET END
NOTE STATIONING EXTENDS THROUGH WALL OF STRUCTURE
0+25
TACKED HUBS
"B" LINE
0+50
0+75
20'
0+83
INLET END

SKETCH NO.3

Subdrains

Subdrainage relates to the control of ground water encountered in highway locations.

A highway subdrain usually consists of a circular pipe laid at a suitable depth in a trench, which is then backfilled with porous, granular material. Materials principally used in subdrains include vitrified clay pipe, porous concrete pipe, and perforated corrugated metal pipe. Clay pipe is usually laid with open joints, while concrete and perforated corrugated metal pipe are generally laid with sealed joints. Concrete pipe may also be laid with open joints.

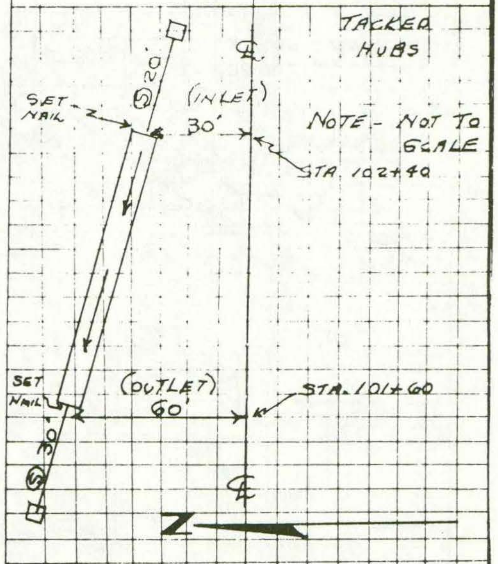
The location, size, and flow line elevations are shown on the construction plans, having been predetermined by the design department. There are two types of subdrain installation on highway construction. One type is used to drain an area under or adjacent to the road bed and is usually on a straight grade. The staking requires only one tacked hub at each end with a suitable offset from the ends of the pipe. The offset should never be less than 15', and a greater distance should be allowed depending on the depth of trench excavation.

The second type is a letdown structure usually used on a backslope of the grade or on a fairly steep and large side road drainage area, to prevent excessive erosion. This type of drainage normally has at least one and usually more than one break in the flow line. At each of these breaks an elbow is installed in the pipe. The staking detail sheet will give the size and dimensions of the elbow. When staking this type of drainage structure, tacked hubs are required, not only at the inlet and outlet end of the pipe, but at each break in the flow line as well. (Note: when the hubs are set, all offset distances should be plumb chained, and the distances marked plainly on one side of the flat. A lath with red or orange ribbon should be set by the hub and flat to help locate each hub.)

LOCATION (STA.) DESCRIPTION					
BM#3			3.40	1043.50	1043.50
HUB	ELEV	GR. ROD	STAKE	CUT-FILL	
EAST	1038.70	8.20	5.05	C-3.15	
WEST	1036.60	10.30	7.65	C-2.65	
(EXAMPLE TYPE 1)					
BM#3	3.40	1046.90 H.I			1043.50

SURVEY PARTY

DATE WEATHER



STA 103+50 RR SPK. NO SIDE 18" ELM 80' RT

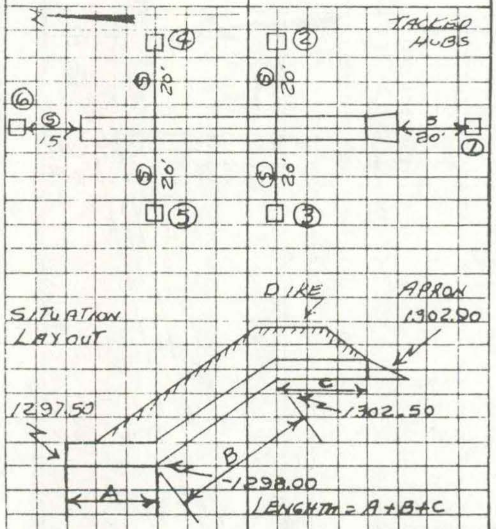
SUBDRAIN LOCATION

SUBDRAIN DESCRIPTION

BM#4			1.45	1302.00	1302.00
HUB No	ELEV	GR.ROD	STK	CUT-FILL	
1	1302.90	0.55	0.20	C-0.35	
2	1302.50	0.95	0.25	C-0.70	
3	1302.50	0.95	1.45	F-0.50	
4	1298.00	5.45	5.40	C-0.50	
5	1298.00	5.45	6.00	F-0.55	
6	1297.50	5.95	6.10	F-0.15	
	(EXAMPLE TYPE 2)				
BM#4	1.45	1303.45 H.I			1302.00

SURVEY PARTY

DATE WEATHER



STA 155+56-RR SPK No SIDE RR POLE 120' RT

Box Culverts

The general purpose of a box culvert is to transmit water flowing in natural streams or collected on the high side of the right of way from one side of the highway to the other. The majority of culverts are installed in natural watercourses which cross the highway, either at right angles or on a skew. In addition to selecting the proper location or "station number" for the culvert crossing with the respect to the centerline of the road, alignment and grade of the culvert are of importance.

Information concerning the box culverts is found on the road plans under drainage structures by the culvert contractor, or on a culvert plan. The information shown will be design number, location, size, length, kind, skew, if any, dimensions right and left, flow line right and left, dikes, if any, and remarks pertaining to the structure. The following will deal mostly with the staking of box culverts.

A check of the cross sections at the location of the box culvert is of extreme importance to be sure the dimensions and flow lines will match the intended slopes of the fill and the drainage. If, by checking cross sections, it is noted that the new structure will not match the finished slopes or the flow line elevations do not seem correct, notify the construction engineer and he will check with the design department and corrections will be made. Do not start any staking until plans and sections have been checked. Also, check to be sure that the top of the culvert is at least one foot or more below the bottom of the pavement slab.

The size of a culvert is listed by two dimensions such as 2' x 3' RCB; the first figure, 2', is the horizontal dimension and the second figure, 3', is the vertical dimension of the interior of the barrel. The barrel is that part of the culvert between the headwalls and consists of a top slab, wall, trough, and bottom slab. From the inside of one headwall to the inside of the opposite headwall is the back to back of parapet, which is the horizontal length of the culvert.

Before the actual staking, a diagram of the culvert can be drawn in the culvert field book, being careful to get the correct dimensions in the correct location. The placement of the stakes will have to be determined at the construction site and these drawn in the book after the staking is complete.

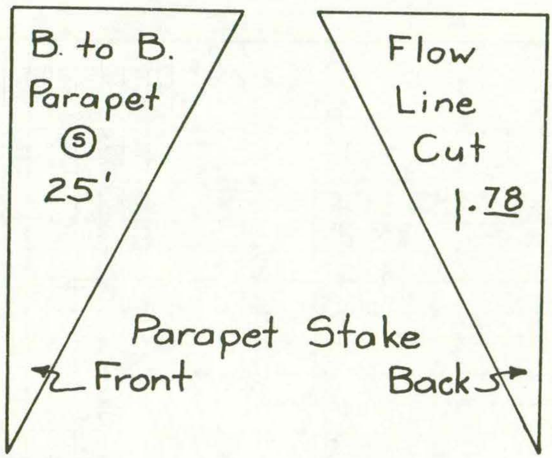
The survey party will then locate the culvert station on the road centerline by using the transit, and chaining the correct distance from a known point or station. After the culvert station has been correctly set, the centerline of the culvert can be turned from the centerline of the road, either at right angles or on a skew as required.

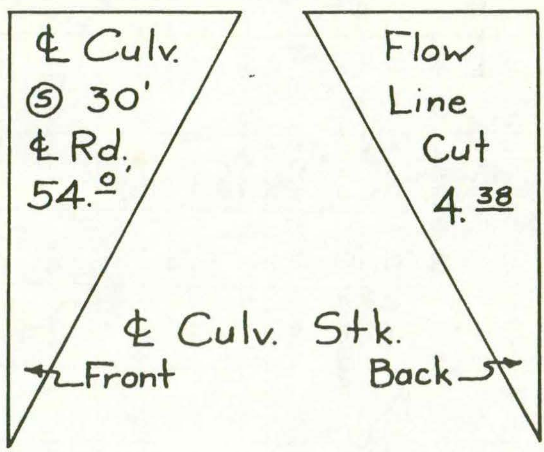
In Sketch No. 1, the culvert is at right angles to centerline of the road at Station 237 59.7, and is a 12' x 5' x 48' RCB or 12' wide, 5' high, and 48' long. The transit is set on centerline at Sta. 235 59.7, 90° is turned sighting a point on centerline, which gives the centerline of the culvert. At 24' from the road centerline, a nail is placed, making sure of the distance and the line. A hub, or some other type of stake is then driven, tacked, or marked on the centerline of culvert at an offset distance that will be outside of the contractor's working area, making sure the offset distance from back of parapet is clearly marked on the flat and in the culvert book. Sketch No. 1 shows the centerline of culvert offset hub is 30'. The scope of the transit is then reversed and the same procedure is followed on the other side of the road. The transit is then set on the parapet nails that were set 24' from centerline and 90° is turned from the culvert centerline, and offset stakes are set ahead and behind the centerline of the culvert.

In Sketch No. 1 the parapet stakes are offset 25' each way. More than one stake can be set on the parapet line back and ahead if necessary, making sure the offset distance is marked on the flat and in the field book. In some situations it may be necessary to use a longer stake such as a two by four, or a reinforcing bar in order to reach solid ground Sometimes in order to keep stakes out of a stream, they are set too far apart to stretch a string line between them, so it is necessary for the survey crew, or sometimes the inspector to shoot the lines in for the contractor.

After the necessary stakes are set, the flow line grades can be established.

In Sketch No. 2, the culvert is on a 45° skew, with the parapet lines parallel to the centerline of the road and angles to turn are shown. Offset stakes are placed outside the working area. Note that an extra stake was placed on each parapet line so that if one of the near stakes is destroyed, the line can be readily replaced. Consult the contractor on the method of staking before staking the construction.


B. to B.
Parapet
Ⓢ
25'
Flow
Line
Cut
1.78
Parapet Stake
Front
Back


℄ Culv.
Ⓢ 30'
℄ Rd.
54.0'
Flow
Line
Cut
4.38
℄ Culv. Stk.
Front
Back

DESIGN No. 1864
STA. 237+59.7
12' x 5' x 48' R.C.B. CULVERT

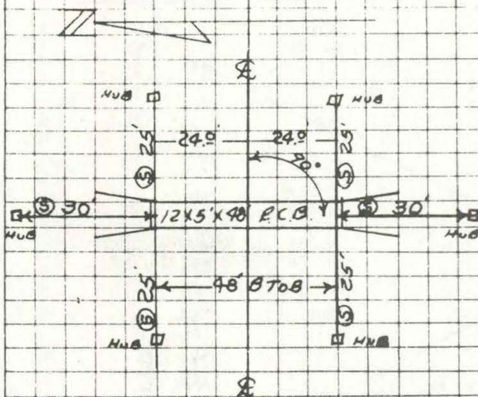
	FLOW LINE ELEV	GR. RD.	STK	CUT-FILL
LT. ℄ STK	980.40	9.11	7.73	C-1.38
LT. PARPT E. STK	980.40	9.11	5.76	C-3.35
LT. PARPT W. STK	980.40	9.11	6.13	C-2.98
RT. ℄ STK	980.20	9.31	4.93	C-4.38
RT. PARPT E. STK	980.20	9.31	7.53	C-1.78
RT. PARPT W. STK	980.20	9.31	7.38	C-1.93

237+59.7 CROSS-SECTION

BM #220	5.33	989.51 H.I.			984.18

SURVEY PARTY

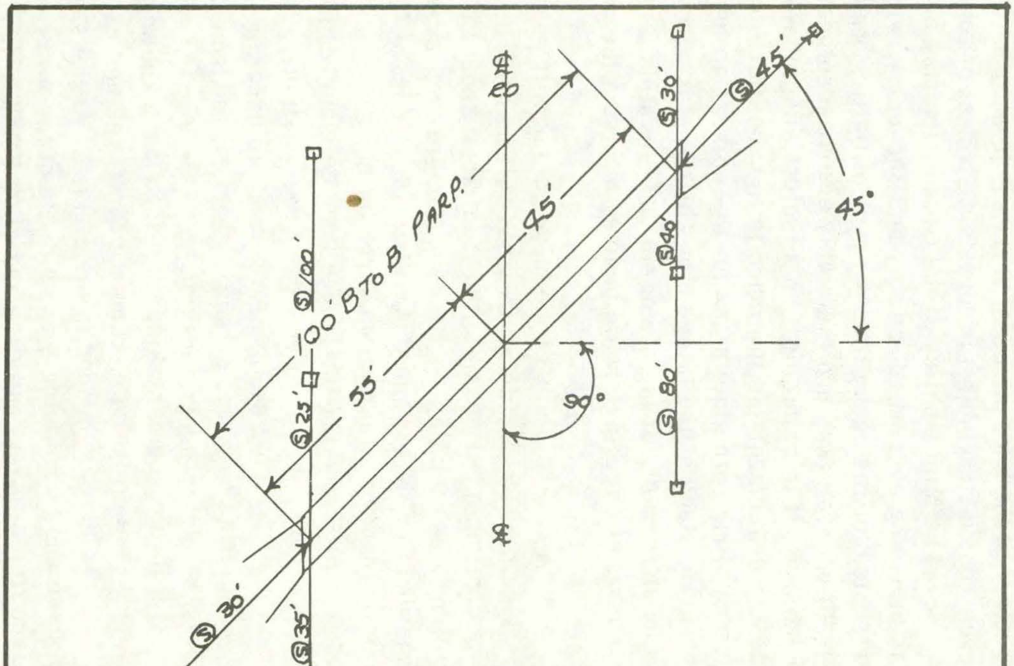
DATE-WEATHER



ALL STKS = TACKED HUBS

STA. 237+60 "X" No. HOVL TWIN 8'X2' +26' LT

SKETCH NO. 1



SKETCH NO. 2

Bridges

The construction of bridges and culverts constitutes a considerable proportion of the work of the highway commission. Because of the large number of streams in Iowa, practically every construction project involves some bridges or culverts.

The bridge policy of the commission may be stated as providing every road, primary and secondary, with bridges designed for the heavy loads of modern traffic, ample as to width and waterway and preferably of permanent materials. Plans for all the structures on a project are prepared by the design department and furnished to the construction field forces along with other plans for the work. Careful and accurate study of the bridge plans by the staking crew is mandatory, both for the alignment and elevations. All known methods of checking should be used to insure the correct staking.

A careful study of the bridge plans will enable the staking party to decide which lines will be most useful to the contractor. If possible, the contractor should be asked which lines he prefers. If the contractor is not available, and there is some doubt as to what lines to stake, consult the resident construction engineer for his advice.

After staking lines have been determined, the bridge staking book can be set up as to lines, stations, elevations, and detail bridge drawing. Be sure all information needed is placed in the book and carefully checked; the more checks made, the less chance for error.

In the actual staking, starting from a known point close to the bridge site, chain on centerline and establish all points that are needed in the staking. At the same time, at each end of the bridge, and outside of the working area, place iron pins on centerline and drive below ground so they will not be disturbed. It is important at this point that all the points be rechecked as many times as necessary to be sure of the stations and alignment. Larger bridges are usually under construction a considerable length of time and require heavier stakes and more checking as work progresses.

When all the necessary points are located and checked on centerline, the abutment and pier stakes can be set. Using the transit to turn the right angle or skew angle from centerline to these stakes should be checked a number of times to be sure of the correct distance. Also the tacks or marks in stakes should be checked. When hubs or longer wooden stakes are used, tacks or nails are driven in the top at the correct line and distance. When iron pins are used a punch mark or "X" is placed in the top of the iron pin and on line and at the correct distance. Wherever possible, stakes for abutments and piers should be placed the same distance from centerline so a check in distance between them can be made.

When all stakes are placed on one side of the road and thoroughly checked, the transit should be set on the front stake, the centerline point sighted and a line of stakes set on the opposite side of the road and checked for distance and line. The reason for setting on the one side and sighting through the centerline point is that the transit may not plunge exactly and an error in line may be made. After stakes are set on both sides, check all measurements again to be sure they are placed correctly, making sure the correct distance and what line staked is shown clearly on the adjacent flats. Use extra flats if necessary for all information and as a protection for stakes. One good way of protecting stakes is to drive one or more steel posts close to the stakes, but making sure that a transit can be set over the stakes. These posts should be painted or flagged so they will be clearly visible.

In grading the stakes that are set, the bench mark that is to be used must be checked to be sure of the correct elevation. This bench is then used for all footing elevations, pile cutoffs, bridge seats, etc. Resetting the level and reading bench mark and stakes again will prevent a mistake in reading the rod and winding up a foot too low or too high. Make sure that each stake is labeled to show elevation, distance from centerline, and the point referred to so the contractor and inspector will know exactly what the stakes and elevations are for.

After the footing of a pier or abutment has been poured and the final portion is formed, the survey party or inspector should establish some final or finished elevations on the top forms. Using the level and bench mark used in staking, these elevations can be set by driving nails, or marking top forms or any other way the contractor desires, making enough checks to insure the correct elevation is set. These elevations are of great importance and extreme care should be used in their placement. The bridge foreman and inspector should be present when these elevations are placed, so they will know the exact location and elevation.

When a pier or abutment is complete a check of the top elevation is necessary. If the elevation is found to be just slightly off it should be taken as being correct, and the remaining piers and abutment elevations graded from it.

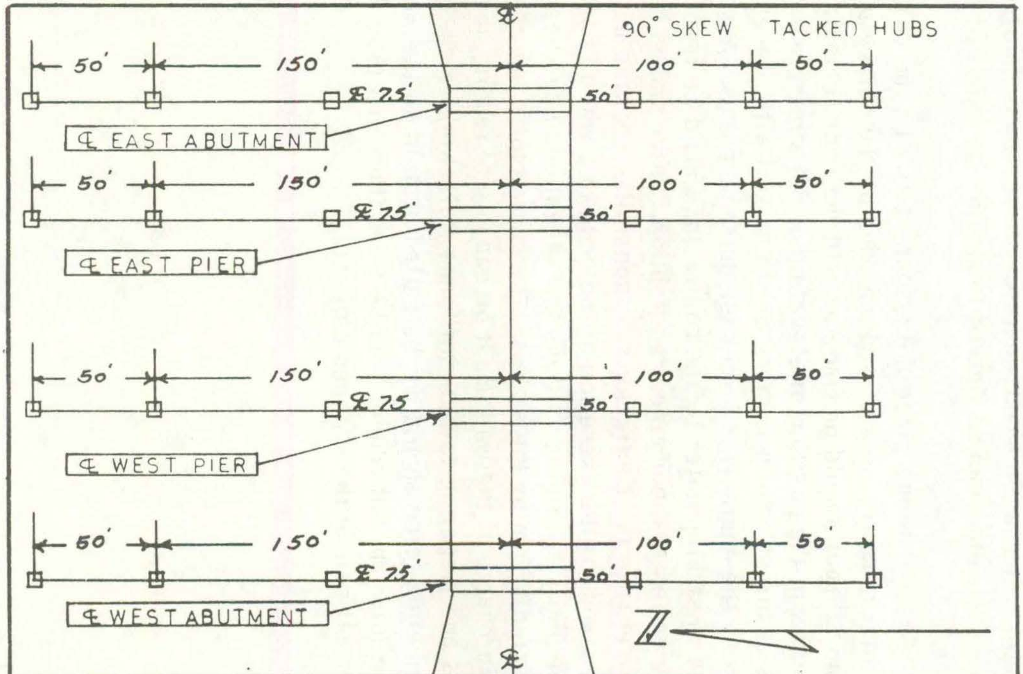
Do not use a bench mark for final elevation of the other piers or abutments. Use the structure that has been completed as a bench mark, marking the spot used with a chiseled "X".

The survey party will have to do considerable checking of lines and elevation as the contractor's work progresses. The contractor or inspector should notify the survey party in advance so it will not conflict with their other duties. Cooperation between contractor, inspector, and survey party will help to insure a satisfactory final outcome of the structure.

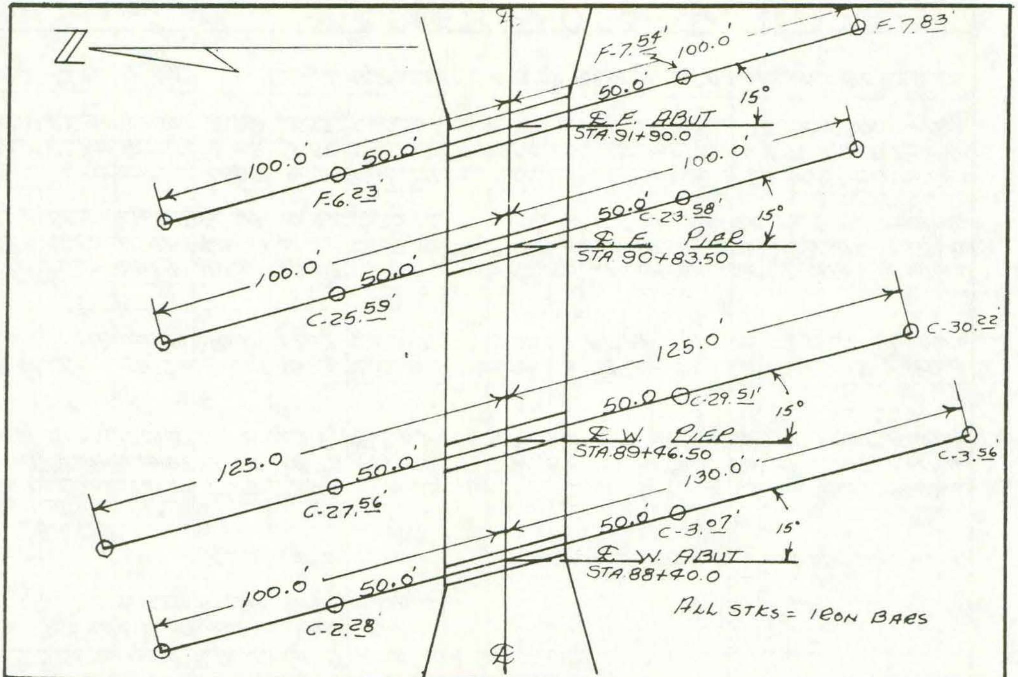
In the following sketches, some bridge staking diagrams are shown. The staking details in Sketch No. 1 are mainly to show one way of placing staking information in the bridge book. It may not be possible to stake a structure as shown, due to a river or stream or the lay of the land. Pier stakes may have to be placed a considerable distance from centerline to be on solid ground. The distance is not necessary, but the line is very important and must be checked.

Sketch No. 2 shows a simple staking detail of a skewed bridge. Distance between stakes on pier and abutment lines should be carefully checked. In Sketch No. 2A, the bridge elevations, stake readings, stake cuts, or fill and location of the stakes are listed, for the bridge stakes shown on Sketch No. 2. The cuts or fills and what they are for will be placed near the correct stake. Note that the stakes were all graded to the bottom of the footing and any other elevations that are needed such as cutoffs, top of footing, bridge seat, etc., can be figured from hub elevations of the stakes.

Specifications place the responsibility on the commission for the correctness of staking done by the survey party, and no attempt should be made to hold the contractor liable for errors in the position or elevation of the structure or parts of the structure, if these are in accord with stakes given by the engineer's forces for those purposes. Any errors in staking noted by the contractor should be immediately called to the engineer's attention. After stakes have been set it is the contractor's responsibility to save the stakes and for the execution of the work in a way to conform to the plans after the positions and elevations have been indicated to him by the stakes. The contractor's representative in charge of the work must be capable of reading the plans and preparing layouts for forms, falsework, etc. The engineering force should not be called upon to do the work of the foreman, but cooperation between them will play an important part in the finished product.


90° SKEW TACKED HUBS
50'
150'
100'
50'
℄ 75'
50'
℄ EAST ABUTMENT
℄ EAST PIER
℄ WEST PIER
℄ WEST ABUTMENT
N

SKETCH NO. 1


N
℄
F-7.83'
F-7.54'
100.0'
50.0'
15°
℄ E. ABUT
STA. 91+90.0
100.0'
50.0'
F-6.23'
100.0'
50.0'
C-23.58'
15°
℄ E. PIER
STA. 90+83.50
100.0'
50.0'
C-25.59'
C-30.22'
125.0'
50.0
C-29.51'
15°
℄ W. PIER
STA. 89+46.50
125.0
50.0'
C-27.56'
C-3.56'
130.0'
50.0'
C-3.07'
15°
℄ W. ABUT
STA. 88+40.0
100.0'
50.0'
C-2.28'
ALL STKS = IRON BARS
℄

SKETCH NO. 2

						SURVEY CREW	WEATHER DATE
STA. 90+15.0 ℄ GIRDER BRIDGE							
350' X 32' CONTINUOUS WELDED							
		BOTT. FTG	GR. ROD	STK	CUT-FILL		
BM# 3			2.73	1229.38	1229.38	STA. 92+08 "X" IN SO. E. WING OLD BR. 52' LT	
E. ABUT	LT. STK	1224.92	7.19	13.42	F-6.23	STK. 50' LT. OF ℄ - GR. TO BOTT. FOOTING	
E. ABUT	RT. STK	1224.92	7.19	14.73	F-7.54	STK. 50' RT. OF ℄ - GR. TO BOTT. FOOTING	
E. ABUT	RT. STK	1224.92	7.19	15.02	F-7.83	STK. 100' RT OF ℄ - GR. TO BOTT. FOOTING	
E. PIER	LT. STK	1191.36	40.75	16.16	C-25.59	STK. 50' LT OF ℄ - GR. TO BOTT. FOOTING	
E. PIER	RT. STK	1191.36	40.75	17.17	C-23.58	STK. 50' RT. OF ℄ - GR. TO BOTT. FOOTING	
W. PIER	LT. STK	1191.47	40.64	13.08	C-27.56	STK. 50' LT. OF ℄ - GR. TO BOTT. FOOTING	
W. PIER	RT. STK	1191.47	40.64	11.13	C-29.51	STK. 50' RT. OF ℄ - GR. TO BOTT. FOOTING	
W. PIER	RT. STK	1191.47	40.64	10.42	C-30.22	STK. 125' RT OF ℄ - GR. TO BOTT. FOOTING	
W. ABUT	LT. STK	1225.22	6.89	4.61	C-2.28	STK.-50' LT. OF ℄ - GR. TO BOTT. FOOTING	
W. ABUT	RT. STK	1225.22	6.89	3.82	C-3.07	STK.-50' RT. OF ℄ - GR. TO BOTT. FOOTING	
W. ABUT	RT. STK	1225.22	6.89	3.33	C-3.56	STK.-130' RT. OF ℄ - GR. TO BOTT. FOOTING	
BM#3	2.73	1232.11 H.I.			1229.38	STA. 92+08-"X" IN SO. E. WING - OLD BR. 52' LT	

SKETCH NO. 2A

Blue Tops

After the slope stakes are set the road contractor begins his part of the construction work, making the cuts, fills, ditches, drainage structures and various other work involved in grading. By following the cuts and fills of the slope stakes, the contractor is able to build the proposed new grade fairly close to the finished intended elevation. When this point is reached it is necessary for the survey party to set stakes to be sure the new grade is built to the finished grade. These stakes are known as finishing stakes or "blue tops", and are usually set on the shoulder line and driven to finished shoulder grade. When so driven they are marked on top with blue lumber crayon to indicate this fact. These stakes are a distinctive help in securing neat shoulder lines and smooth grades, and are needed on all rough grading projects regardless of the type of surface.

On a road being graded in preparation for paving, the stakes set for the paving contractor may be satisfactory substitutes if the rough grading has been brought to subgrade level with considerable exactness.

Before the blue tops can be set, it is necessary for the survey party to replace the previously referenced centerline control points. These points are correctly placed with one or two transits, crossing the reference lines at centerline and driving an iron pin exactly at the cross point and below the ground approximately six to ten inches, and marked with a lath so they can be readily located when needed.

After the control points have been replaced, the blue tops can then be set along the shoulder lines. This is done by setting on one control point, sighting back or front control points if on a straight line, and turning 90 degrees from that line. When the angle is turned, a hub is driven and tacked at the correct shoulder distance, both right and left of centerline, or a nail is placed. The advantage of the hubs is that if they are clearly marked the road contractor can save them and the survey party can use them at a later time to find the control point. When all control points that are needed have been turned and shoulder points correctly measured, flat stakes can be driven firmly in the ground at 100' stations or less if needed, with the flat surface facing the centerline. This is done by setting the transit on shoulder points turned out from centerline and sighting on a shoulder point ahead, then setting flats on line, at the station points. After the flats are set on one shoulder line, the flats on the other shoulder line can be set by either of two methods. First the transit can be used as in the setting of the first line, or two chains can be used. In using two chains, one is used to measure across the subgrade from the shoulder stake already set, the full width of the subgrade, and the other used to measure the correct distance along the shoulder. Where the two measurements cross, the shoulder stake is set, flat side facing the centerline.

After the shoulder stakes are set firmly in the ground on line, the next step is to drive them so the top of the flat is at the elevation of the finished subgrade shoulder. The blue top book should have been set up beforehand and one example of a page shown is in Sketch No. 1. The right and left shoulder grade is taken from the slope stake book, and placed in the blue top book either in column No. 2 or 3 and 5 or 6, and it may be of help in checking the slope of the subgrade to also enter centerline elevations as shown in column No. 4.

The level is set at a convenient location, generally on the subgrade, and a bench mark is shot establishing the H.I. (height of instrument). After the H.I. is recorded, the shoulder and centerline elevations are subtracted from it, which gives the grade rod, and is placed above the actual elevations. The grade rod is the figure which must be read on the level rod to locate the correct shoulder or centerline elevation.

When the grade rod has been figured and placed in the book, the man with the level rod places the rod on the ground by the shoulder stake, and the reading is recorded in the book. Then the rod is placed on top of the flat and the instrumentman indicates to the one driving the flats how far to drive the flat down, so that he will read the grade rod figure. When the top of the flat is driven to the grade rod figure, it is at the correct shoulder elevation, and is then marked on top with blue lumber crayon, covering the complete top. This procedure is done on both sides of the road, and a ground shot at centerline recorded. Sometimes the grade will have been built higher than needed, so it will be necessary to drive the flats below the ground in order to read the grade rod figure. After the blue tops have been driven to grade, the contractor can then cut or fill to the top of the flats, which gives him the finished subgrade. Also he will be able to establish a neat and straight shoulder line, which is necessary to have in finishing subgrade.

What has been explained so far is a general procedure on straight sections of subgrade, where shoulder distance and elevations are the same right and left of a station. Following are some situations where the distance and elevations are not always the same.

Where a superelevated curve is staked, the shoulder distance may be the same, but the elevations will differ, one being higher or lower than the other. This will be covered in the section covering curves.

When one shoulder line is a greater distance from centerline than the other, the elevation will also be different and care should be taken in locating these points on the road plan, generally found in the typical sections. Sometimes it may be necessary to set a blue top at the point where the high edge of the proposed road surface meets the inside shoulder line and a change in the slope occurs.

When setting blue tops on a superelevated curve it is necessary to set and grade more than the two shoulder lines. In most cases where the slab to be placed is of 24′ width, a line of blue tops should be placed on the upper side of the super at the edge of the proposed paving, 12′ from centerline. This line of stakes will help the contractor to cut or fill the subgrade to the intended super from the inside edge of the slab to the outside edge of the slab. From the 12′ point on the high part of the super to the edge of the subgrade, the slope will drop to the intended subgrade elevation to which the outside line of blue tops will be graded.

Sometimes it may be necessary to set a line of blue tops on the centerline of the road around a superelevated curve. Generally the two outside lines and the 12′ line are all that is needed, but if the contractor requests the centerline blue tops, it does not require too much extra work to place them for him.

	LT Shoulder		℄		RT Shoulder	Survey Party Blue Tops	Aug. 7-1968 Clear-Hot & Windy
80+00	9.40 1241.02		9.02 1241.40		9.40 1241.02	9.5 Rod 9.4 Gr. Rod F-0.1	9.6 Rod 9.4 Gr Rod F-0.2
T.P.	10.25	1250.42 H.I.	13.77	1240.17			
79+00	11.32 1242.62		10.94 1243.00		11.32 1242.62	11.3 Gr. Rd 11.1 Rod C-0.2	11.4 Rod 11.3 Gr Rd F-0.1
78+00	9.50 1244.44		9.12 1244.82		9.50 1244.44	9.5 Gr. Rod 9.4 Rod C0.1	9.7 Rd 9.5 Gr Rod F-0.2
T.P.	12.30	1253.94 H.I.	18.03	1241.64			
77+00	13.35 1246.32		12.97 1246.70		13.35 1246.32	13.6 Rod Reading 13.4 Grade Rod F0.2	13.4 Rod 13.4 Gr Rd F0.0
BM#1	12.97	1259.67 H.I.			1246.70	Sta. 73+41 RR. Spk. So. Side of Power Pole 49' Lt	

SKETCH NO.1

Asphalt Concrete Paving

The specifications require that on primary and interstate highway construction projects, the elevations of the road bed surface will be indicated by grade stakes. It is also stated that the surface of the subbase and some types of base courses will be indicated by grade stakes. When specified for the pavement components, the surface of the various layers shall be constructed to conform to the desired elevation as indicated by the grade stakes within the .05 foot variation.

Since it is considered that uniform methods and procedures throughout the state are desirable, it is recommended that the following be used.

Drive the reference hubs at 50′ intervals for transitions, horizontal curves and sharp vertical curves. The hubs should be driven flush with the ground on each side of the roadbed, and offset far enough to clear such operations as trimming the edges, etc. The hub line will usually be just over the edge of the foreslope. The finished surface of the roadbed should be indicated at each stake.

In order to hold the moving of earth to a minimum, it is well to check to see that the cut quantities will slightly exceed the fill.

The cut or fill indicated on the grade stakes should show the elevation of the corrected roadbed, usually at a distance 11′ right and left of centerline. It should not be necessary to change the cut or fill markings on the grade stakes for construction of the subbase or base. This is because the contractor is expected to construct the subbase and base in such a manner that all the material is utilized, with the finished profile being parallel to the grades indicated on the stakes.

It is usually necessary to make grade adjustments during construction of the components because of subgrade settlement during compaction of the subbase and base layers. The grade adjustments should be parallel, which means raising or lowering the grade uniformly for sections not less than 500′ in length.

Staking asphalt concrete paving is done in much the same manner as staking portland cement concrete paving. Control centerline points are turned 90° from the centerline and driven flush at the desired offset distance right and left. Hubs are driven every 50' between control points, less if necessary and either one or both sides tacked. Elevations are then taken at centerline, at the proposed edge and on hubs both right and left of centerline.

The following steps will give an approximate amount to raise or lower the profile grade to hold the moving of dirt to a minimum.

1) Compute the algebraic sum of each of the cuts or fills, using cuts as negative and fills as positive, for each of the three profiles. Sketch No. 1 and 1A show the cut and fill figures before profile adjustment.
2) The algebraic sum of the left and right profiles plus twice the algebraic sum of the centerline profile divided by four times the number of cross-sections will indicate the amount to adjust the profile grade. (See Sketch No. 2) The distance between cross sections must be the same for each section of roadway considered. Sections of roadway balanced should not exceed 1500'. The proposed grade should be kept about 0.05 foot low or lower, to take care of shrinkage, loss of dirt, prevent drifting of dirt great distances and to keep dirt in balance by wasting small amounts frequently rather than to borrow from backslopes and ditches.
3) Cuts and fills should be figured for the hub shots to the adjusted roadbed profile, and flats marked and driven. (See Sketch No. 3).

When the subgrade has been corrected to the desired elevation, a line of "red head" nails can be driven along the centerline to indicate the correct alignment. The nails should be placed 100' apart on tangent sections and every 25' on horizontal curves. A transit should be used to position the nails correctly. The contractor will set the fasteners used to secure the guideline string by measuring from the centerline nails. The centerline can be located for each course of asphaltic concrete after the first course covers the centerline nails, by measuring from the guideline string fasteners.

One method of checking the surface on a superelevated section is shown in Sketch No. 4. It is important that distance B.C. and F.E. are used correctly in placing string on 6' rods and that the string is pulled tight between the two rods.

Another method that may be used is to extend the rate of slope out to the offset hub and at that point, also indicating cut or fill for the edge of the slab, figure the grade.

> Example: Profile grade at Station 41+00 is 1080.79 and, using 0.033 ft. slope, the elevation of the high side 21' right of centerline would be 1081.48 and on the low side, 21' left of centerline, it would be 1080.10. If hubs were graded to these points, the stringline can be easily placed to be parallel to the intended surface and the grade can be figured and marked also for the edge of the slab. Fill or cut to the extended line can be marked on one side of the flat and fill or cut to the actual edge of the slab marked on the opposite side.

Care should be taken in placing the hubs, using the correct chaining distance for inside and outside curves to insure the hubs are at right angles to the station intended. When string-lining wedge courses after the first course is laid, paint can be used to indicate the fill for the following courses.

The resident construction engineer is responsible for setting and marking the stakes indicating alignment and profile grade desired. His forces must check the finished surface of the roadbed, subbase and base and see that all specifications applicable to the project are followed.

The contractor is responsible for the actual construction work. He must provide the necessary equipment and personnel to do each stage satisfactorily.

All blue tops or other stakes found to be necessary will be set by the contractor and he is responsible for their accuracy.

	GRADE BEFORE ADJUSTMENT				ROADBED ELEVATIONS				
	11' LT	℄	11' RT						
	8.90	8.68	8.90	10.38	9.65		9.18	9.52	10.39
42+00	78.18	78.40	78.18		8.90		8.68	8.90	
					F-0.75		F-0.50	F-0.62	
	7.70	7.48	7.70	9.07	8.43		7.82	8.41	9.01
+50	79.38	79.60	79.38		7.70		7.48	7.70	
					F-0.73		F-0.34	F 0.71	
	6.20	5.98	6.20	7.81	6.81		6.17	6.52	7.70
41+00	80.88	81.10	80.88		6.20		5.98	6.20	
					F-0.61		F-0.19	F-0.32	
	4.30	4.08	4.30	4.89	4.33		4.08	4.42	4.99
+50	82.78	83.00	82.78		4.30		4.07	4.30	
					F-0.03		C-0.01	F0.12	
	2.30	2.08	2.30	2.92	2.30		2.31	2.80	3.08
40+00	84.78	85.00	84.78		2.04		2.08	2.30	
					C-0.26		F-0.23	F0.50	
	1087.08 H.I								

SKETCH NO. 1

	GRADES BEFORE ADJUSTMENT			ROADBED ELEVATIONS				
	11' Lt	℄	11' Rt					
	9.30	9.08	9.30	10.55	9.36	9.32	9.91	9.98
+50	77.78	78.00	77.78		9.30	9.08	9.30	
					F-0.06	F-0.24	F-0.61	
	9.80	9.58	9.80	11.16	10.35	9.96	10.42	10.95
44+00	77.28	77.50	77.28		9.80	9.58	9.80	
					F-0.55	F-0.38	F-0.62	
	10.10	9.88	10.10	11.21	10.64	10.04	10.78	11.21
+50	76.98	77.20	76.98		10.10	9.88	10.10	
					F-0.54	F-0.16	F-0.68	
	10.10	9.88	10.10	11.08	10.20	10.11	10.13	10.95
43+00	76.98	77.20	76.98		10.10	9.88	10.10	
					F-0.10	F-0.23	F-0.03	
	9.60	9.38	9.60	10.32	9.60	9.38	9.60	10.26
+50	77.48	77.70	77.48		9.55	9.23	9.53	
					C-0.05	C-0.15	C-0.07	
	1087.08 H.I.							

SKETCH NO. 1A

	CORRECTIONS			ADJ. PROFILE	
	11' LT	℄	11' RT	℄	11' RT-LT
45+00	C.03	C.06	F-.01	78.19	77.97
+50	F.06	F.24	F-.61	77.69	77.47
44+00	F-.55	F-.38	F-.62	77.19	76.97
+50	F-.54	F-.16	F-.68	76.89	76.67
43+00	F-.10	F-.23	F-.03	76.89	76.67
+50	C-.05	C-.15	C-.07	77.39	77.17
42+00	F.75	F.50	F.62	78.09	77.87
+50	F.73	F.34	F.71	79.29	79.07
41+00	F.61	F.19	F.32	80.79	80.57
+50	F.03	C.01	F.12	82.69	82.47
40+00	C.26	F.23	F.50	84.69	84.47

ALGEBC SUM

+3.03 +2.05 +4.15

$$\frac{3.03 + (2)(2.05) + 4.15}{(4)\ (11\ \text{SECTIONS})} = \frac{11.28}{44} = +0.26$$

LOWER GR. +0.26 +0.05 = 0.31

		8.80	8.58	8.80	
45+00		78.28	78.50	78.28	
		1087.08			

9.66 8.80 8.58 8.81 9.75

8.72 8.52 8.80

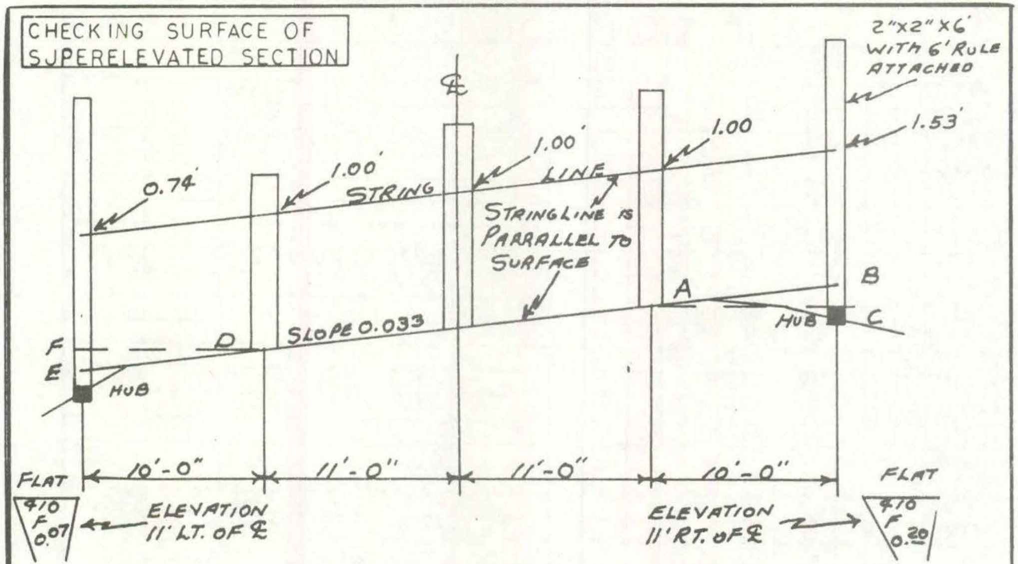
C-0.03 C-0.06 F0.01

SKETCH NO. 2

			ADJ. PROFILE		
		9.21		9.21	
42+00		77.87	78.09	77.87	
		8.01		8.01	
+50		79.07		79.07	
		6.51		6.51	
41+00		80.57	80.79	80.57	
		4.61		4.61	
+50		82.47	82.69	82.47	
		2.61		2.61	
40+00		84.47	84.69	84.47	
		1087.08			

10.38	10.34
9.21	9.21
F 1.17	F-1.13
9.07	9.01
8.01	8.01
F-1.06	F 1.00
7.81	7.70
6.51	6.51
F 1.30	F 1.19
4.89	4.99
4.61	4.61
F-0.28	F 0.38
2.92	308
2.61	2.61
F 0.31	F 0.47

SKETCH NO.3



To make stringline parallel to the intended surface the string must be raised the distance B-C on the right rod and lowered the distance F-E on left rod for this section. For this section B-C = F-E = 0.33.

SKETCH NO.4

Portland Cement Paving

After the dirt contractor has cut or filled the grade to the blue top elevation and has the subgrade in satisfactory condition, the grade is then ready for the paving stakes. Before the actual staking can be started it is necessary for the survey party chief to place the paving grades, bench marks, vertical curve data, transition points, beginning and end of curves, and other necessary information in the paving staking book. In the following paragraphs all reference will be to 9" portland cement paving, 24' wide.

The profile elevations shown on the paving plan are the elevations that the paving centerline should be when paving is complete. For staking it is necessary to know the elevation of the right and left edge of the paving at every station, plus 50's, beginning and end of curves, beginning and end of transitions and other points if needed. On straight paving, to find the elevation of the right and left edge, take the rate of slope times the distance from centerline to the paving edge, which will give the drop from centerline to the edge.

Example:	.015	rate of slope per foot
	12	distance to edge
	30	
	15	
	.180	.18 will be the drop

When the amount of drop, or crown, is established, that figure is subtracted from the profile elevation, which gives the elevations 12' right or left of that point. The paving edge elevations are placed in the paving book as shown in Sketch No. 1, Section A.

Where a superelevated curve is to be staked, the inside edge of the paving will be a lower elevation than the outside. The rate of super is found in the superelevation data under column marked "E".

Example:	.057	rate of super
	12	
	114	
	57	
	.684	.68 rise or drop

From the P.C. to the P.T., the inside of the curve will be .68 lower than the profile grade, and the outside will be .68 higher than the profile grade. Sketch No. 1 Section B shows grades on a 2 30′ curve with a .057 super.

When changing from normal crown to super a certain distance is needed to accomplish the change, which is the transition, and this distance can be found is the superelevation data under the column marked "S". The figuring of the transition grade can be found on the standard road plan RH-7.

When grades and other necessary information have been placed in the paving staking book, the actual staking can be started. First, the control points will have to be located. These points should have been placed deep enough during the blue top staking so they were not disturbed.

After the control points are found or reset, the transit is set over them and a right angle to the road centerline is turned to the right side of the road. A hub is then driven and tacked at the correct offset distance from the centerline. Generally, the paving contractor will notify the construction office or the survey party the offset distance preferred. When enough control point offsets have been set, hubs must then be driven on stations and half stations. This is done by placing the transit on one control point offset hub and sighting ahead to the next offset point, and locking transit scope on that line.

After a line is established a chain is used to measure the distance ahead and a hub is driven on line and a tack placed in the top of the hub at the correct distance and on line. A flat is placed near the hub, indicating the station or the plus of the hub. These hubs are placed every 50′ and tacked on line from one control offset to another. This line is called the tack line and is the controlling line. When the concrete is placed, station numbers will be placed in the fresh concrete using the tacked hubs to locate the stations. Station numbers are placed on the right side of the paving and that is the reason the angle was turned to the right.

After the tack line is set, the hubs on the opposite side must be driven. There are two ways that these hubs, called the offset line, can be set. First, the transit can be used and hubs set in the same procedure as the tack line, except that a tack does not have to be placed on this line, but if it will help in securing a good job with good lines then tack both sides. The other way is by using two chains, one to measure distance across the subgrade from tack line to the opposite line and the second chain to measure the offset line to be set. Where the two distances cross, drive the offset hub.

In setting paving stakes on the inside and outside of a curve, the chaining distance will not be the same as on the centerline. The outside chaining will be longer and the inside will be shorter. Before staking can be started the chaining distance will have to be figured. Below are examples of figures:

P.C. Sta 66+74.8
P.T. Sta 81+21.5
Curve Radius = 2,292.0
Offset distance = 15′ from centerline

The curve radius minus the offset distance divided by the curve radius, equals the chaining distance on the inside of curve instead of the full 100′.

$$\begin{array}{r} 2{,}292.0 \\ -15.0 \\ \hline 2{,}277.0 \end{array} \qquad \frac{2{,}277}{2{,}292} = 99.345' \text{ per } 100' \text{ inside}$$

For any distance under 100′ take distance times 0.99345.

0.99345 x 50 = 49.67 inside chaining for a 50′ chord

From P.C. Sta. 66+74.8 to Sta. 67+00 with offset of 15′, the chaining distance on the inside will be: 25.2 x .99345 = 25.03′.

For outside chaining: The curve radius plus the offset distance divided by the curve radius equals distance between stations on the outside of curve.

Example:

$$\begin{array}{rl} 2{,}292.0 & \text{curve radius} \\ +15.0 & \text{offset distance} \\ \hline 2{,}307.0 & \end{array} \qquad \frac{2{,}307}{2{,}292} = 100.65$$

Between stations the distance will be 100.65 on the outside and 50.325 per 50′ chord.

Placing paving stakes on curves can be accomplished a number of ways; some are explained in the following two paragraphs:

1) The transit is placed on centerline control point P.C., deflections are turned for each station +25 or +50, distance chained and nail driven. When all the curve centerline nails are set, two chains are then used to place hubs. One chain is used to measure from centerline nail the correct offset distance, and the other is used to measure distance along the offset line, using the correct chaining distance. Where the two measurements cross, the hub is driven and tacked and a flat with the station number placed beside it. When all the hubs are driven on one side, the distance between the offset lines is measured from the hubs already driven, making sure that the chain is crossing the centerline on the nail and the hub is driven on the opposite side.
2) The transit is placed on P.C. turn-out point, deflections turned, corrected chaining distance measured, hubs driven and tacked. After one side is driven, the two chains are used to set the other side using the correct chaining distance. Curves can be tacked on both sides.

After hubs are driven on both sides, the level is placed at a convenient location and a bench mark reading is taken. When the H.I. is established, the grade rod can be figured and placed in the book above the edge of the paving elevation as shown in Sketch No. 1. A reading to one hundredth foot is taken on each hub and placed in the book, and grades are figured and marked on flats. Careful checking of all figures and calculations will insure correct grades for the paving contractor to follow.

When an automatic grade line machine is used to place the concrete slab, the offset distance of the paving hubs will be of a greater distance and the offset on one side of the road may be greater than the opposite side. This information will have to be known by the survey party ahead of the staking time and can be determined by contacting the paving contractor.

When grading paving stakes in a superelevated curve, when an automatic grade line machine is to be used, the super is carried out to the hubs. In other words, instead of grading hubs to the edge of the slab, the super will be continued out the distance the hub is from centerline.

Example: Width of slab = 24′
Rate of super = .049
Offset distance = 22′

22′ x .049 = 1.078′, the amount the outside hub grade will be above profile grade, or the inside hub grade will be below profile grade in the curve.

		LT EDGE		RT EDGE		
		2.88		2.88 ← GR ROD		
+50		1043.11		1043.11		
		2.82		2.82	(A)	
157+00		1043.17		1043.17		
BM#2A	4.93	1045.99 H.I.			1041.06	STA. 160+00 - BALL OF R.O.W. RAIL 70' LT.

SURVEY CREW

DATE WEATHER

HUB READING

3.65	3.72
2.88	2.88
F-0.77	F-0.84
3.57	3.62
2.82	2.82
F-0.75	F-0.80

		LT EDGE	℄	RT EDGE		
		9.80		8.44		
+50		1033.57	1034.25	1034.93		
		10.67		9.31	(B)	
68+00		1032.70	1033.38	1034.06		
BM#3A	9.53	1043.37 H.I.			1033.84	STA. 68+71 - RR SPK. SO SIDE 15" ELM 100' LT.

HUB READING

LT		RT
10.72	← ROD →	8.81
9.80	← GR. RD →	8.44
F-0.92		F 0.37
11.65	← ROD →	9.80
10.67	← GR. RD →	9.31
F-0.98		F 0.49

SKETCH NO. 1

Pavement Joints

In the process of building a new highway using portland cement concrete for a riding surface, there are a number of "joints" which are needed to allow for the normal expansion and contraction of the finished pavement due to changes in temperature. Many of these do not require staking by the survey crew but one of the joints that does is termed an "ED" joint.

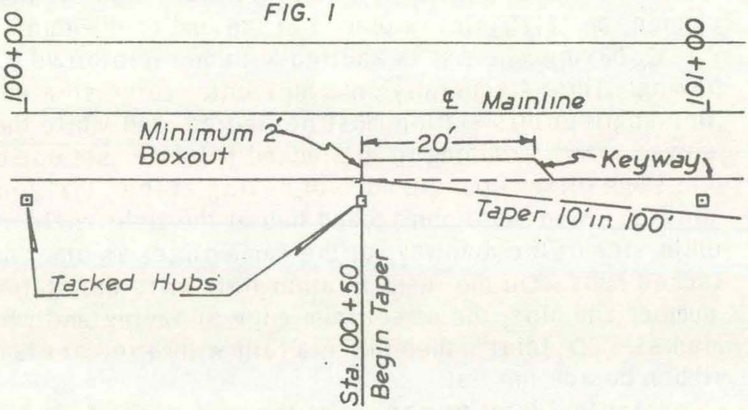
There is generally a tabulation sheet drawn up in the construction plans with the station number, street name, ramp, etc., and the lineal feet in each "ED" joint. In the case of an "ED" joint on the ramps of an interstate highway interchange, an "ED" joint is placed at the end of the reinforced P.C.C. paving where it is abutted with non-reinforced P.C.C. paving. This is generally on a horizontal curve so a deflection angle to this station must be figured, and while the survey crew is running in the tacked hub line, set one on the same offset from the edge of paving at the "ED" joint station. Also set a non-tacked hub at the right angle on the other side of the roadway, at the same offset as other non-tacked hubs. On the identification flat, write the station number and plus, the offset from edge of paving and what it marks: "ED Joint", then place a lath with a red or orange ribbon beside the flat.

Another joint to mark is at the beginning of a taper such as an exit ramp, end of taper such as an entrance ramp, beginning and end of radii at the intersection of a street or ramp with the main line of paving and at the insert area of a curb intake.

When you stake the beginning or end of a taper, drive the hub flush with the ground as on ordinary hubs along that area using same offset, place an identification flat by the hub with station number and plus, offset, and the wording, "Beg. Taper or End Taper", whichever the case may be, printed on it. Also drive a ribboned lath. The reason for this is for the contractor to know that he must set a Keyway starting from this point. (See Figure 1.)

In the case of a street intersection, it is helpful to drive a hub on the normal offset hub line at the beginning and end of the radius where it connects with the main line. The flat should be marked with station number and plus, offset, and "End Radius", "Box Out". More important is to have the radius point set and well-marked as such, so that in the event the end of radius identification previously set is destroyed in the process of form setting by contractor, you can, by using a Right Angle Viewer at the form line and sighting the radius point, determine where the end of radius should be. Mark the inside edge of the form with ink or crayon and set a flat at the back edge of the paving form marking it "End Radius" "Box Out".

FIG. I



For insert boxouts at curb intakes, determine from plans the water flow direction, what type of intake it is, and what the insert dimensions are uphill and downhill. The best time to mark these boxouts is when the main line forms are in place, measuring from the center of intake along forms. Mark the forms with ink or crayon, and place flats marked "Box Out" at both ends setting them at the back edge of the forms.

Another important set of joints are sleeper beams and anchor lugs placed in the "Bridge Approach Sections". Determine what type of section is to be used from the construction plans and standard road plans. Using a steel chain, measure along the roadway centerline from the end of the bridge floor, set a nail (Red Head) using a transit on the centerline to set the nail on the centerline, at each beam, and anchor lug. Set the transit over the centerline nails and turn a right angle at each site. Measuring along the centerline of the beam or lug, set a tacked hub at an offset distance agreeable with the contractor's wishes. These hubs will have to have an elevation taken on them and a grade at that particular station determined and marked on the flat. Make sure the contractor knows to what point the grade is given, such as top of concrete grade, so he can make his depth adjustments accordingly. Also make a grade notation on each hub to the centerline of the roadway to allow for the crown.

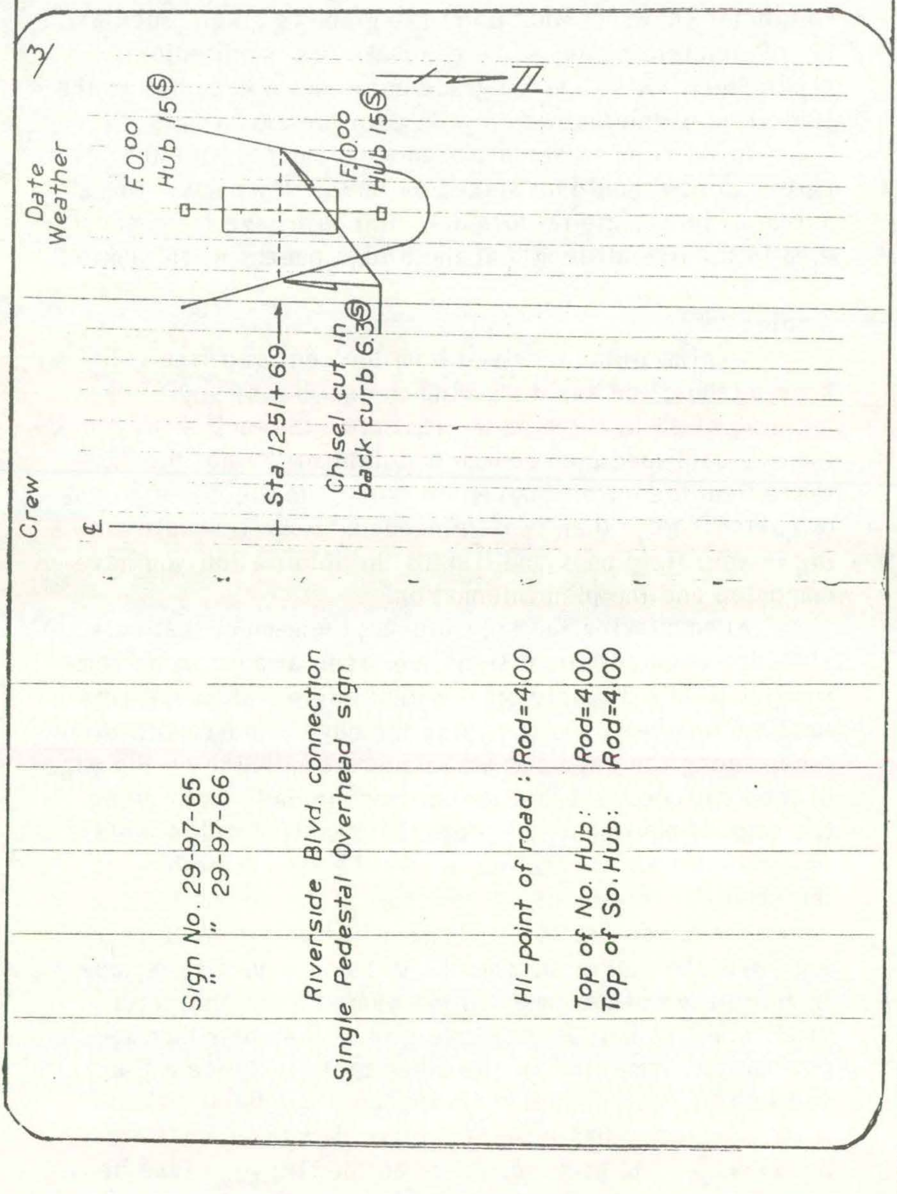
In addition to sleeper beams and anchor lugs the type A joints should be staked by the survey party. The 2" polyfoam joint material for each joint will have to be considered in the overall length of the bridge panels when staking.

Signing

Signing plans received from the central office will have a tabulation sheet showing the number of signs, the location of each, the type of sign, etc. On each sign, check the standard road plan design and determine what the distance from the edge of pavement will be to the nearest post or posts, if more than two are needed. Make a simple drawing in your field book and list all the information you have computed and the plan information.

When staking the sign you must remember that only shoulder-mounted type B signs are faced away from on-coming traffic at a 3 angle off the right angle. When the sign location has been spotted along the edge of pavement, drive a nail along the edge and also paint a small line on the edge of road surface. Set the transit over the nail, sight along the edge of pavement, then turn the transit 90 plus the 3 or minus the 3 , if required, to set the sign direction. If the shoulder is asphalt, drive a nail at the edge. This is handy for the contractor to string a line on for erecting the sign with the proper alignment. Measure with a steel tape from the edge of pavement to the nearest post and set a small stake or nail at the centerline of the post, then repeat on the same line for the other post(s). Place a flat and lath by each post site stating what you have staked. If the contractor has requested offset hubs you must remember to record the offset distance on the flat you place by it.

SIGN STAKING



The type of signs that are set back from the highway further will normally have the distance from edge of pavement given and are at right angles to the roadway. Set your stakes for the posts as on the shoulder installed signs. Two hubs offset far enough from the ends of the sign on the sign alignment line, will help the contractor erect the sign properly. An elevation difference between the edge of pavement and the two offset hubs should be marked on the flat by each hub in order that the contractor can erect the sign to the proper height.

In staking a sign that is on an entrance or exit nose of a ramp, where traffic flows on both sides, maintain the direction of the sign but move along the island until the sign width plus both clearance widths have been reached. Then chisel a small notch onttop of the curb for the contractor to use.

When staking a sign that is not along a paved highway, you must find some known control point to chain from to establish the location of the sign. More offset hubs for a shoulder installation should be set than on a paved roadway in order for the contractor to erect the sign in the proper location.

Guard Rails

The first thing a party chief should do is look through your set of plans to get an idea of the type of job that you will be staking. Check quantities with the contract and the type of installation you are building.

When staking line for guard rails, make sure you give the contractor hubs at the start and end of the guard rail and enough in between to control a good line.

Items to look out for and check when staking guard rails are shoulder width, driveways, box culverts and pipe, footings, bridges, and railroad tracks. Also check the guard rail to see if it is in the proper place and does the job it was designed for.

If any error is found or a correction is needed, notify your supervisor immediately so this item can be corrected as soon as possible.

Fences

In the construction of farm field right of way fence you will need a set of plans from the central office showing the proposed fence location. Study these and the special provisions and all right of way plats and contracts. In staking the fence, follow the detail project plans and right of way contracts. When the fence location coincides with the location of right of way lines or access control lines, the fence shall be staked one foot inside and parallel to the indicated line. When setting the stakes, a lath set on the wire line every 200', more or less, is sufficient. This line should be set with a transit. When the fence is built on a horizontal curve the lath should be set at 50' intervals or less, depending on the degree of curve. When the fence is built on rough, hilly terrain, the lath must be set at more frequent intervals.

At each point where the alignment of the fence changes laterally ten degrees or more, or vertically thirty degrees or more, the contractor is required to set angle posts. These points are determined by the survey crew. Set a lath at the angle point and a flat stating that it is an angle point. When the plans call for a gate to be placed, it will be sufficient most of the time to place a lath and flat in the centerline of the opening, marking it as such, or if the gate size is known, a lath and flat at each end of the gate can be set.

Iowa State Highway Commission Standard Specification state, "At intervals not greater than 960 feet in straight lines not intercepted by gate posts, 2 pull posts shall be set". These locations should be marked with a lath and flat. A good policy to follow is when the known distance between two corners or terminal posts is greater than 960' but less than 1920', the pull posts should be located midway of the distance and marked with a flat and lath, marking the flat "Pull Post".

Staking chain link fence is much the same as staking farm field fence. The main difference is that the distance between pull posts is 500' maximum and must be marked as such.

The method of measurement is the number of 100' stations determined by measurement along the fence at the bottom of the fabric.

Lighting

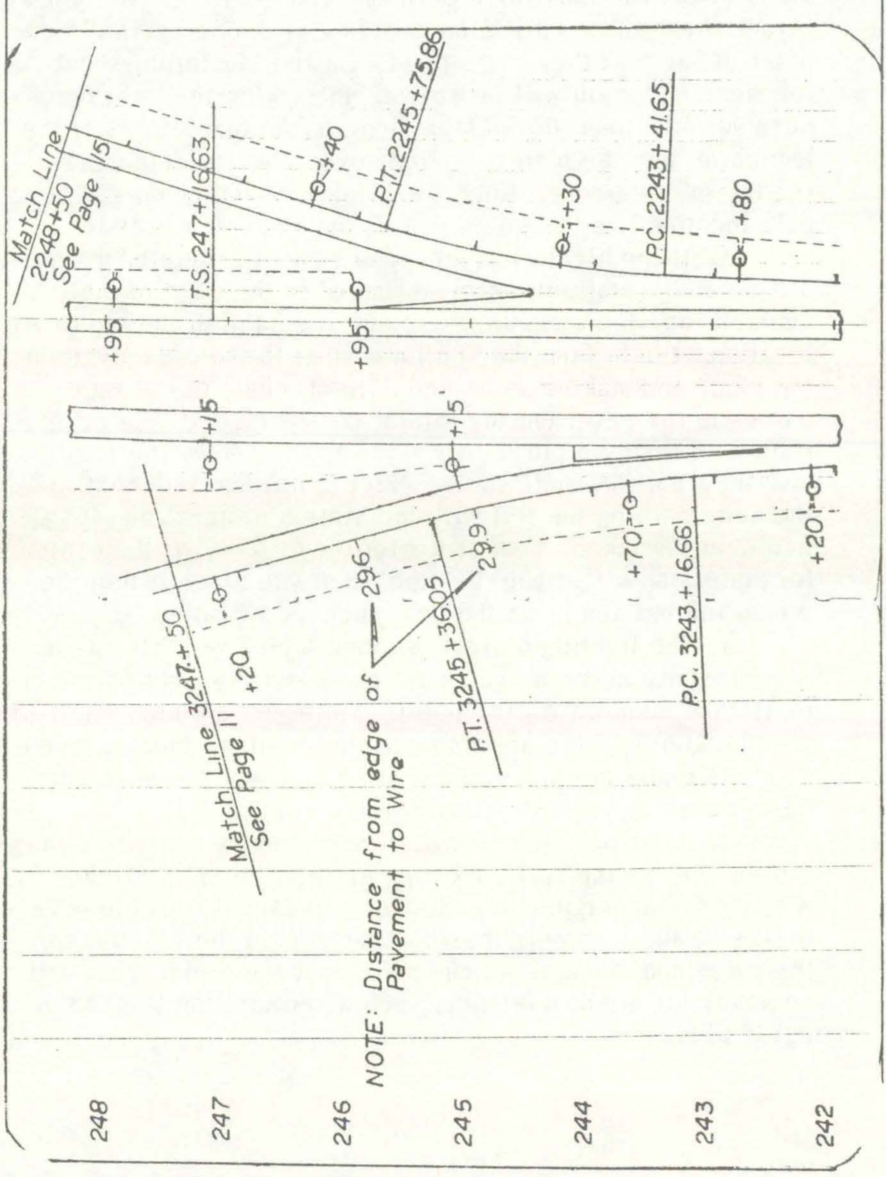
Lighting along the various highways is mostly done in urban areas or at intersections or interchanges.

In staking a lighting project, first examine the project plans to become familiar with them. The plans will contain a layout sheet and a tabulation sheet. Check one against the other to see that they correspond. On the tabulation sheet the mastarm length will be shown. In staking the light pole base you will need the mastarm length, the dimensions of the luminaire, and the plan specified "overhang" to determine the lateral clearance. When the lateral clearance on each pole location has been determined, the next step is field staking. If the highway is portland cement concrete, there are generally station numbers stamped in the edge of the concrete which are accurate enough to establish the light pole location. Chain from the station number to the plus given on the plans and make a paint mark. Next, chain out at right angles to the pavement the lateral clearance distance for that light pole, using a plumb bob for measuring down the slope, and set a nail or small stake. Place a flat and lath next to the nail, marking the flat with the station number and plus and what is staked, such as centerline of pole. If the contractor prefers an offset hub, be sure when you place it that the proper information is on the flat, such as 5'0 pole.

If the lighting project is along a highway that has no station stamp numbers, you must chain out the light pole locations from a known control point. While you are locating light pole locations, there are also certain locations to mark where conduits under the highway are to be placed. These should have a marking on both sides of the highway.

A good practice to follow is to prepare a drawing in a field book of the entire lighting project, locating all the wire placed underground by distance measured from the edge of paving and recording these. Also, record the locations of the poles and changes which may have been made. This will be handy for future reference, such as completing the "As Built" plans.

LIGHTING LAYOUT



Erosion Control

Erosion control does not require the amount of stakes that are required by other phases of work, such as grading, paving, etc., but for the beautification of a project, stabilization of the soil, and general attraction or eye appeal to the traveling public, it is very important work.

Most all seeding done is measured by surface area in acres. No plumb chaining is used in the measurement of seeding. Some seeding has to be measured in advance of the seed application, such as when a hydro-seeder is used.

Starting at the beginning of the project, measure the width of area to be seeded by using a cloth tape laid on the ground, including the foreslope, ditch bottom, backslope, and shoulder if it requires seeding. Record this in the field book. If no change in seeding width occurs before you have taped along the roadway approximately 500′, no other width need be recorded. However, at the 500′ point it is good practice to measure another seeding width and record it in the field book along with a station number at that point. The average width of the two areas can be multiplied by the 500′ length to get the square feet in this section.

If there is a break or change in seeding width, get the station number and plus, also the width at this point, and using this width, plus the previous width, compute the area as in the 500′ area. In certain areas other than those along the highway, such as a borrow pit, measure the area by itself but in the field book keep this measurement in the same general area as the roadside measurements for future use. Complete all measurements along one side, then do the same on the other side of the road. Most of the hydro-seeders are set to seed a three acre plot of ground, so three acre divisions must be calculated ahead of the time of seeding, recorded in the field book and marked along the roadway with a flat and lath set at the outer edge of the seeding area so that ground preparation operations won't disturb them.

A good practice to follow in erosion control is to draw on the Plan and Profile sheets the actual areas measured for the different steps of work to be done such as seeding, mulching, fertilizing, or sodding, and shade them in different colors. These plans then can be a helpful guide to the inspector on the project.

Following is a list of erosion control items and the Method of Measurement taken from the "Iowa State Highway Commission Standard Specifications, Series of 1964":

Seeding: Acre, surface area.

Stabilizing Crop Seeding: Acres, surface area.

Sodding: Squares of 100 square feet.

Mulching: Acres, surface area.

Staking Sod Channels: Squares of 100 square feet.

Special Seeding: Acres, surface area.

Fertilizing: Acres, surface area.

For other items not covered here, consult Article 2601.20 of the Iowa State Highway Commission Standard Specifications.

EROSION CONTROL

Pre-seeding measurement

6/

Seeding measurements Lt. side

Crew

Date
Weather

Station	Width	Computation	Sq. Ft.
105+00	150'	$\frac{150+100}{2} \times 500 =$	62,500
100+00	100'	100 × 500 =	50,000
95+00	100'	100 × 500 =	50,000
90+00	100'		

$\frac{00}{62,500}$ Sta. 110+00 = 3 Ac. div.

$\frac{18,180}{31,820}$ Sta 93+18.2 3 Ac. div.

Buildings

In staking a building the starting procedure is much the same as any structure such as a bridge, culvert, intake, etc. For a rest area along an interstate highway, for instance, the ramps are in place and a major portion of the grading is done. You will need a set of building plans, a known point on the mainline or ramp from which distances and angles to a corner of the building can be obtained, and a known bench mark for elevations.

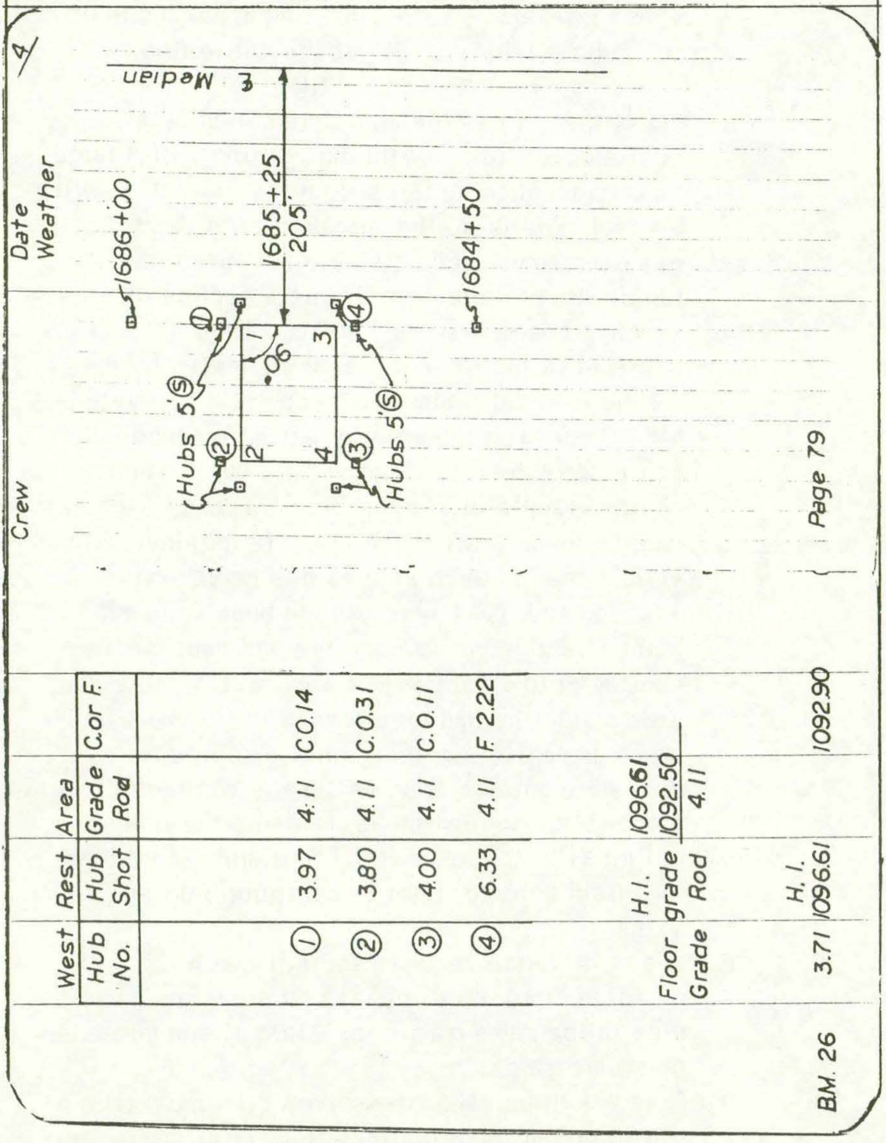
From the known point, using a transit and a steel chain to plumb-chain with, measure to one corner of the building site and set a nail. This corner is preferably on the inside face of the junction of two walls but, if not, make sure the contractor knows what line you are staking. With the transit set on this corner No.1 (Fig.1 on the following page), determine the longer side of the building and the bearing off the centerline road or ramp. Very carefully plumb-chain the distance to the far corner, No.2, and set a nail. From the nail (corner No.2), continue on the same line to set a tacked hub 5' beyond (if this offset is agreeable with the contractor). Set another tacked hub on the same line to the back side of the transit (corner No.1). With transit still at corner No.1, turn a 90° angle, measure along the short side of the building to set another corner nail No.3. Next, set the transit on corner No.2, turn 90° from the long side bearing and carefully measure along the short side to corner No.4 and set a nail. Before setting any more tacked hubs, check from corner No.3 to corner No.4, the other long side of the building. If both long sides are equal and both short sides are equal, then proceed to set 5' offset tacked hubs on the three remaining lines as shown in Figure 1.

When all tacked hubs are in place, drive an identification flat by each, stating the offset distances. From the known bench mark take a reading on each hub and determine the cut or fill, as the case may be, to some plan elevation shown, such as the finished floor elevation.

As an added check to make sure all corners are square, measure diagonally on a horizontal plane from corner No.1 to corner No.4 and from corner No 2 to corner No.3. These distances should also be equal if the corners of the building are square.

BUILDING STAKING

FIG. I



West	Rest	Area	
Hub No.	Hub Shot	Grade Rod	C.or F.
①	3.97	4.11	C.0.14
②	3.80	4.11	C.0.31
③	4.00	4.11	C.0.11
④	6.33	4.11	F 2.22

H.I. 1096.61
Floor grade 1092.50
Grade Rod 4.11

B.M. 26 3.71 H.I. 1096.61 1092.90

Bridge Floor Repair

The repair of existing bridge floors is divided into three classes:

A) Class I Repair is scarifying a minimum depth of ¼" and a maximum of ½" of the entire floor not listed as Class II or Class III.

B) Class II Repair is the area determined by a concentrated sounding of the bridge floor. If a large scarifying machine is used on the project, it will be advisable to do the sounding after the scarifying has been completed. Using a ball peen hammer, tap at close intervals covering a section of floor that has been closed to traffic. When there is a bad spot in the floor, it can be detected by the different sound made than when solid concrete is hit. On occasion there may not be a sound you can readily detect by hammering, but a bouncing of tiny granular particles around a loose section can be seen. Mark these areas temporarily with yellow chalk. When an area has been completely sounded and loose places have been chalked, paint straight lines around the bad spot for the contractor to follow with a saw, making sure you are outside the bad area. When two or more bad areas are close together, paint around them as if they were one big area. After the contractor has chipped out the bad areas, measure the individual areas to the nearest 0.1 foot and record them in a field book for later computation into square yards.

C) Class III Repair requires the full depth removal of old floor concrete. Class III areas are measured in the same manner as Class II and computed in square yards.

If Class I is to be used, the survey crew must take a series of elevations on the old bridge floor prior to any work being done by the contractor. Measure and mark every 10' along each curb and either side of the median if the bridge is more than two lanes. At each of the 10′ stations, take a rod reading on top of the curb, 12′ left and right of centerline, on centerline of roadway, and on the opposite curb or median Record all these shots in a field book in the manner of a cross section. Reduce the shots to elevations and plot the centerline, and right and left elevations on cross section paper. Using a scale of 1 inch horizontal = 10′, and 1 inch vertical = 0.50′ can be a guide. After the 10′ points have been plotted and a line drawn between them, find the high points of grade line and mark above them ¾″ (.06) and lay on the proposed grade line, using a highway curve template to obtain a smooth riding surface, or a straight edge when possible. The grades can then be transferred from the proposed grade line on the cross section paper to the left side of the field book containing the original shots. The proposed grade elevations will be used to set the screed rail, giving the contractor the fill from the marked stations on top of the curbs or median. In the case of Class III requiring new concrete higher than the existing floor, grades will be determined in the same manner as in Class I.

If the bridge floor repair consists of Class I and Class II or III, the square yards computed for Class I is a measurement of the entire floor minus the Class II or III. The contractor will be paid the contract price per square yard for each class of repair.

CLASS II BRIDGE REPAIR

FLOOR GRADES

	Proposed floor grades 15' Lt.	12' Lt.	℄	12' Rt.	15' Rt.	Crew curb	12' Lt.	℄	Date Weather 12' Rt.	21 med.
+30	26.38	26.42	26.59	26.45	26.41	F.0.42 7.21	6.32	6.51	6.40	F.0.52 7.14
+20	26.47	26.51	26.68	26.52	26.48	F.0.42 7.30	6.42	6.57	6.41	F.0.51 7.22
+10	26.55	26.59	26.74	26.58	26.54	F.0.39 7.41	6.57	6.69	6.53	F.0.48 7.31
460+00	26.61	26,65	26.81	26.65	26.61	F.0.42 7.44	6.57	6.74	6.59	F.0.54 7.32
B.M.#43-C				1127.39		Page 39				

NOTE: Fill grades are to top of screed rail, 1.25 ft. above proposed floor grade

NOTE: Direct Elev. rod used