Indiana Department of Transportation

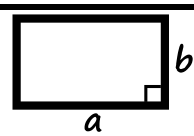
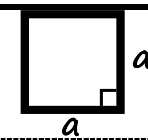
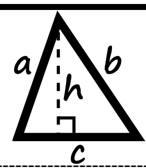
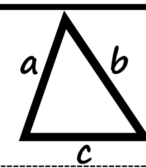
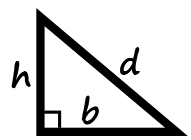
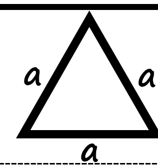
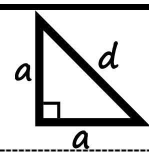
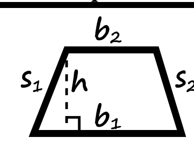
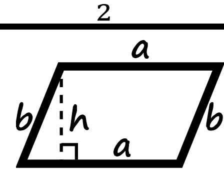
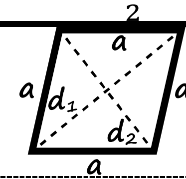
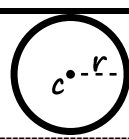
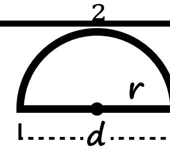
CERTIFIED TECHNICIAN PROGRAM
TRAINING MANUAL FOR

Construction Procedures
Part I

2026 Revision

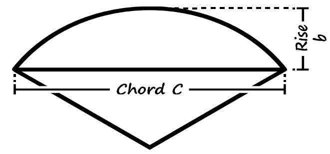
MATH REFERENCES

1 foot = 12 inches	1 square foot = 144 square inches	1 cubic foot = 1728 cubic inches
3 feet = 1 yard	9 square feet = 1 square yard	27 cubic feet = 1 cubic yard
5280 feet = Mile	1760 yards = 1 mile	1 acre = 4840 square yards

Rectangle		Square	
Perimeter	$2(a+b)$	Perimeter	$4a$
Area	$a \times b$	Area	a^2
Triangle		Triangle (any)	
Perimeter	$a+b+c$	Area by sides (no height)	$s = \frac{1}{2}(a+b+c)$
Area	$\frac{1}{2}(b \times h)$		$A = \sqrt{s(s-a)(s-b)(s-c)}$
Right Triangle		Equilateral Triangle	
Perimeter	$b+h+d$	Perimeter	$3a$
Area	$\frac{1}{2}(b \times h)$	Area	$\frac{\sqrt{3}}{4}a^2$
Isosceles Right Triangle		Trapezoid	
Perimeter	$2a+d$	Perimeter	$b_1+b_2+s_1+s_2$
Area	$\frac{1}{2}a^2$	Area	$h \times \frac{b_1+b_2}{2}$
Parallelogram		Rhombus	
Perimeter	$2(a+b)$	Perimeter	$4a$
Area	$a \times h$	Area	$\frac{d_1 \times d_2}{2}$
Circle		Semicircle	
Perimeter	$2\pi r$	Perimeter	$\pi r + 2r$
Area	πr^2	Area	$\frac{\pi r^2}{2}$

AREA OF A CIRCULAR SEGMENT

$$\text{Area} = C \times b \times \text{coefficient}$$



Coefficient	$\frac{b}{C}$
0.66667	0.00218
0.66668	0.00436
0.66669	0.00655
0.66671	0.00873
0.66673	0.01091
0.66676	0.01309
0.66679	0.01528
0.66683	0.01746
0.66687	0.01965
0.66692	0.02183
0.66697	0.02402
0.66703	0.02620
0.66710	0.02839
0.66717	0.03058
0.66724	0.03277
0.66732	0.03496
0.66740	0.03716
0.66749	0.03935
0.66759	0.04155
0.66769	0.04374
0.66779	0.04594
0.66790	0.04814
0.66802	0.05035
0.66814	0.05255
0.66826	0.05476
0.66839	0.05697
0.66853	0.05918
0.66867	0.06139
0.66882	0.06361
0.66897	0.06583
0.66913	0.06805
0.66929	0.07027
0.66946	0.07250
0.66964	0.07473
0.66981	0.07696
0.67000	0.07919
0.67019	0.08143
0.67039	0.08367
0.67059	0.08592
0.67079	0.08816
0.67101	0.09041
0.67122	0.09267
0.67145	0.09493
0.67168	0.09719
0.67191	0.09946

Coefficient	$\frac{b}{C}$
0.67215	0.10173
0.67240	0.10400
0.67265	0.10628
0.67291	0.10856
0.67317	0.11085
0.67344	0.11314
0.67372	0.11543
0.67400	0.11773
0.67429	0.12004
0.67458	0.12235
0.67488	0.12466
0.67519	0.12698
0.67550	0.12931
0.67582	0.13164
0.67614	0.13397
0.67647	0.13632
0.67681	0.13866
0.67715	0.14101
0.67750	0.14337
0.67786	0.14574
0.67822	0.14811
0.67859	0.15048
0.67897	0.15287
0.67935	0.15525
0.67974	0.15765
0.68014	0.16005
0.68054	0.16246
0.68095	0.16488
0.68136	0.16730
0.68179	0.16973
0.68222	0.17216
0.68265	0.17461
0.68310	0.17706
0.68355	0.17952
0.68401	0.18199
0.68448	0.18446
0.68495	0.18694
0.68543	0.18943
0.68592	0.19193
0.68642	0.19444
0.68692	0.19696
0.68743	0.19948
0.68795	0.20201
0.68848	0.20456
0.68901	0.20711

Coefficient	$\frac{b}{C}$
0.68956	0.20967
0.69011	0.21224
0.69067	0.21482
0.69123	0.21741
0.69181	0.22001
0.69239	0.22261
0.69299	0.22523
0.69359	0.22786
0.69420	0.23050
0.69482	0.23315
0.69545	0.23582
0.69608	0.23849
0.69673	0.24117
0.69738	0.24387
0.69805	0.24657
0.69872	0.24929
0.69941	0.25202
0.70010	0.25476
0.70080	0.25752
0.70151	0.26028
0.70223	0.26306
0.70297	0.26585
0.70371	0.26866
0.70446	0.27148
0.70522	0.27431
0.70600	0.27715
0.70678	0.28001
0.70758	0.28289
0.70838	0.28577
0.70920	0.28868
0.71003	0.29159
0.71087	0.29452
0.71172	0.29747
0.71258	0.30043
0.71345	0.30341
0.71434	0.30640
0.71524	0.30941
0.71615	0.31243
0.71707	0.31548
0.71800	0.31854
0.71895	0.32161
0.71991	0.32470
0.72088	0.32781
0.72187	0.33094
0.72287	0.33409

Coefficient	$\frac{b}{C}$
0.72388	0.33725
0.72491	0.34044
0.72595	0.34364
0.72701	0.34686
0.72808	0.35010
0.72916	0.35337
0.73026	0.35665
0.73137	0.35995
0.73250	0.36327
0.73364	0.36662
0.73480	0.36998
0.73598	0.37337
0.73717	0.37678
0.73838	0.38021
0.73960	0.38366
0.74084	0.38714
0.74210	0.39064
0.74337	0.39417
0.74466	0.39772
0.74597	0.40129
0.74730	0.40489
0.74865	0.40852
0.75001	0.41217
0.75140	0.41585
0.75280	0.41955
0.75422	0.42328
0.75566	0.42704
0.75713	0.43083
0.75861	0.43464
0.76011	0.43849
0.76164	0.44236
0.76318	0.44627
0.76475	0.45020
0.76634	0.45417
0.76795	0.45817
0.76959	0.46220
0.77125	0.46626
0.77293	0.47035
0.77463	0.47448
0.77636	0.47865
0.77812	0.48284
0.77990	0.48708
0.78171	0.49135
0.78354	0.49566
0.78540	0.50000

MANUAL DISCLAIMER

The references in this manual are reflective of the 2026 INDOT Standard Specifications. The material covered herein is for training purposes only. The Standard Specifications, Contract Information Book, General Instruction to Field Employees, and Construction Memos should be consulted for determining the current inspection procedures for a given contract. On-site procedures, field tests, and other operating procedures may vary from those described within this manual.

TABLE OF CONTENTS

Chapter One: INTRODUCTION

This introduction is intended to improve the Technician's ability to solve problems and to do various calculations required in construction layout and determining pay quantities.

GENERAL DEFINITIONS

Before there is any discussion of construction layout and measurements, there needs to be an understanding of the definitions of the generally used figures in this process.

POLYGON

A polygon is *a closed figure bounded by straight lines lying in the same plane*.

The sum S of the interior angles of a closed polygon is calculated as:

$$S = (N - 2) \times 180°$$

where:

N = number of sides

Thus, the sum of the interior angles of a triangle is 180º, a rectangle is 360º, a five-sided figure is 540º, and so on.

TRIANGLE

A polygon of three sides.

RIGHT TRIANGLE

A triangle which has one right angle (90º).

ISOSCELES TRIANGLE

A triangle which has two equal sides and two equal angles.

EQUILATERAL TRIANGLE

A triangle which has three equal sides and three equal angles.

OBLIQUE TRIANGLE

A triangle which has no right angle and no equal sides.

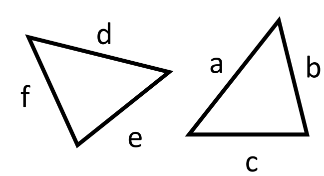


Figure 1-1 Congruent Triangles
a = d, b = e and c = f

CONGRUENT TRIANGLES

Two triangles are *congruent* if their corresponding sides and corresponding angles are equal. Congruent triangles have the same area. Triangles *abc* and *def* are congruent. **(Figure 1-1)**

SIMILAR TRIANGLES

Two triangles are *similar* if their corresponding angles are equal and their corresponding sides are proportional. Similar triangles may have different areas and rotation, but with one larger or smaller than the other. **(Figure 1-2)**

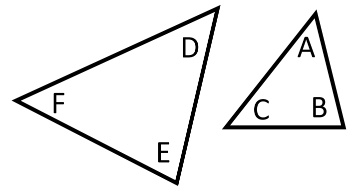


Figure 1-2 Similar Triangles
∠A = ∠D, ∠B = ∠E and ∠C = ∠F

RECTANGLE

A four-sided polygon with four right angles. A *square* is a rectangle with equal sides.

TRAPEZOID

A four-sided polygon which has two parallel sides and two non-parallel sides.

CIRCLE

An enclosed curve on a plane whose perimeter points are equidistant from center. (***Figure 1-3***)

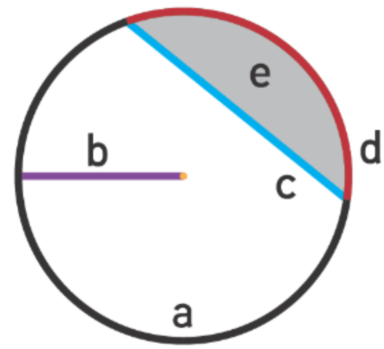


Figure 1-3 Parts of a Circle
a – circumference, b – radius
c – chord, d – arc, e – segment

CIRCUMFERENCE

The boundary (outer limits) of a closed area. The perimeter of a circle is its *circumference.* (***Figure 1-3a***)

RADIUS

The distance from the center of the circle to any point on its perimeter. (***Figure 1-3b***)

CHORD

A straight line between any two points on the perimeter of a circle. (***Figure 1-3c***)

DIAMETER

A chord that passes through the center of the circle. The diameter is twice the radius.

ARC

A section of a circumference measured from one point to another. (***Figure 1-3d***)

SEGMENT

The area enclosed within any arc of a circle when the two endpoints are joined. (***Figure 1-3e***)

A *semi-circle* is half a circle, or *a segment made using a diameter and the arc it creates*.

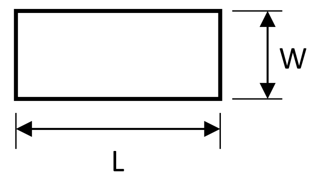
AREA DEFINITIONS

Area is the surface within a set of lines. Area is measured in square units, square inches, square feet, square miles, etc.

AREA OF A RECTANGLE

The area A of a rectangle is equal to the product of the length and the width.

$$A = L \times W$$



where:

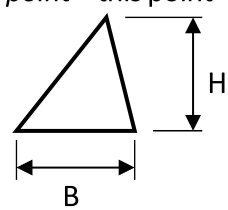
L = length of rectangle
W = width of rectangle

AREA OF A TRIANGLE

The area of a triangle is expressed in terms of its base and altitude. Any side of a triangle may be called the base. The altitude is the perpendicular distance from the base to the vertex opposing the base.

An angle is defined as *the space between two lines diverging from a common point* – this point is called the vertex. The area A of any triangle is:

$$A = \frac{1}{2}\mathrm{B} \times H$$



where:

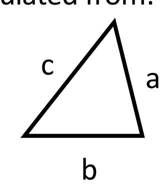
B = base length
H = altitude length

The area of a *right triangle* is calculated in the same manner.

AREA OF A TRIANGLE WITH KNOWN SIDES

If the length of the three sides of a triangle are known, the area A may be calculated from:

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$



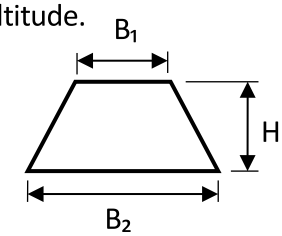
where:

a = length of side a
b = length of side b
c = length of side c
$s = \frac{1}{2}(a+b+c)$

AREA OF A TRAPEZOID

The area A of a trapezoid is equal to the average width times the altitude.

$$A = \frac{B_1 + B_2}{2} \times H$$



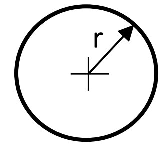
where:

B_1 = length of Base 1
B_2 = length of Base 2
H = altitude height

Expressed in another way, the area is the sum of the bases, divided by two, times the height.

AREA OF A CIRCLE

The area A of a circle is π times the square of its radius.



$$A = \pi r^2$$

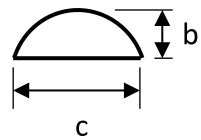
where:

π = a constant, generally given as 3.14 or 3.14159
r = the radius of the circle

AREA OF A CIRCULAR SEGMENT USING RISE AND CHORD

The area A of a circular segment is determined by multiplying the chord length and rise by a coefficient from the *Area of a Circular Segment* table above. The formula is as follows:

$$A = \mathrm{c} \times \mathrm{b} \times \mathrm{C}$$



where:

c = chord length
b = rise
C = Coefficient from table

COMPOSITE AREAS

Irregular shaped areas may be divided into components and then the areas calculated. This method is very helpful where the technician is measuring sod, concrete driveways, etc.

ACCURACY OF CALCULATIONS

ROUNDING

When calculations are conducted, rounding is required to be in accordance with Section **109.01(a)** using the standard *5-up* procedure. There are two rules for rounding numbers:

1. When the first digit discarded is less than 5, the last digit retained should not be changed:
   - 2.4 rounds to 2
   - 2.43 rounds to 2.4
   - 2.434 rounds to 2.43
   - 2.4321 rounds to 2.432

2. When the first digit discarded is 5 or greater, the last digit retained should be increased by one unit:
   - 2.6 rounds to 3
   - 2.56 rounds to 2.6
   - 2.416 rounds to 2.42
   - 2.4157 rounds to 2.416

DEGREE OF ACCURACY

The degree of accuracy is defined as *how precise a number needs to be, reliably*. INDOT Spec bases the degree of accuracy on the dollar value per the item's Unit of Measure – for example, EA, SQ YD, or LFT. Items that are more expensive therefore have higher accuracy requirements. While all measurements are made to the nearest first decimal place (0.1), calculations and final pay quantity degrees of accuracy are as follows:

		Degree of Accuracy specified for:	
Unit Price	**Field Measurement**	**Calculation Results & Subtotals**	**Final Pay Quantity**
$ 0 - 9.99	0.1 unit	0.1 unit	1 unit
$ 10 - 99.99	0.1 unit	0.01 unit	0.1 unit
$ 100 - 999	0.1 unit	0.01 unit	0.01 unit
$ 1000+	0.1 unit	0.001 unit	0.001 unit

EXCEPTIONS

- Weigh tickets are considered original notes for many items and are required to be measured to the nearest 100 pounds
- Pavement striping and pipe (except concrete pipe) is measured and calculated to the nearest one foot. The Specifications for concrete pipe should be checked to determine the measurement units
- Seed is weighed to the nearest one pound
- Fertilizer is weighed to the nearest one hundredth ton or 10 pounds
- Items whose proposal unit is listed as "each" or "lump sum" are measured or counted to that whole unit
- Linear grading is field measured to the nearest 0.001% of the unit, with calculations, sub totals, and final pay quantities as shown in the accuracy table
- Field measurements, calculations, sub totals and final pay quantity on herbicide contracts are made to the nearest one unit

Chapter Two: HISTORICAL SURVEYING

Surveying, as a practice, dates back to ancient Egypt, where surveying was used to lay out construction, using ropes and plumb bobs for measurement. There have been many advancements throughout history, from the invention of the magnetic compass in China around 200 BC, to the first recorded land plots in 11th century England, the invention of the theodolite and dumpy levels in the 1700s & 1800s, to modern GPS and LiDAR instruments used today. This chapter covers equipment used by surveyors in the late 1900s and early 2000s.

DEFINITIONS

ELEVATION

A point of vertical control is known as an elevation. Elevations are measured to a reference which is usually mean sea-level so that a point having an elevation of 722.95 ft means that the particular point is 722.95 ft above sea-level. Sometimes in paving or in roadwork an elevation is referred to as a grade.

MEAN SEA LEVEL

The height of the sea surface averaged over all stages of the tide over a long period of time

BENCHMARK

A benchmark, or *BM*, is a ***definite point on a stationary, permanent object*** which has a known elevation and a known location. A benchmark is a point of reference which is convenient for leveling in a given locality. The relation to sea-level is very precise and obtained by running a level circuit such that the elevation of the beginning and the end of the circuit are known and tied together.

TEMPORARY BENCHMARK

Temporary benchmarks, or *TBM*s, are used supplement permanent benchmarks. They help provide temporary convenient access to a known elevation, and they are usually removed at the end of a project.

VERTICAL CONTROL

A point of vertical control is known as an elevation.

LEVELING

In highway surveying, leveling is done to provide the necessary vertical control to construct a highway or a bridge. Differential leveling is the operation of determining the elevations of points some distance apart. This is the method used in highway surveying to establish the necessary vertical control for construction. Historically, this procedure is done by differential leveling. Differential leveling requires a series of set-ups of the instrument along the general route. For each set-up, a rod-reading back to the point of known elevation and then forward to a point of unknown elevation is taken. One use of differential leveling is the level circuit.

LEVEL CIRCUIT

A level circuit involves a survey crew using a permanent or temporary benchmark to determine the elevation of another point. Below describes the various points in the circuit and how they are used to determine the elevation of the object in question.

TURNING POINT

A turning point, or *TP*, is an intermediate point between benchmarks which provides a temporary point of known elevation for a level circuit between two benchmarks a long distance apart. A turning point may be an iron pin which is driven firmly into the ground at a convenient location. Rod readings are taken on the pin before an instrument is advanced and again as the initial rod readings are taken before the instrument has been re-established ahead on the circuit. After the second reading, the pin is pulled and carried ahead. A turning point may be an existing convenient object upon which a rod reading may be taken; however, the object is required to be solid, stable, and not move or change in elevation for the few minutes needed between set-ups. A permanent or temporary benchmark may be used as a turning point.

BACKSIGHT

A backsight, or *BS*, is a rod reading taken at a point of known elevation, such as a benchmark or turning point. Another term for backsight is plus sight.

FORESIGHT

A foresight, or *FS*, is a rod reading taken on a point for which the elevation is to be established. A foresight is sometimes called a minus sight.

HEIGHT OF INSTRUMENT

The height of instrument (HI) is the elevation of the line of sight of the center of the cross-hairs in the telescope when the instrument is properly leveled. The height of instrument is equal to the elevation of the benchmark sighted plus the rod reading taken on the benchmark. In mathematical terms this may be written as follows:

$$H_I = BM_e + BM_s$$

where:

H_I = Height of Instrument
BM_e = Benchmark elevation (rod reading)
BM_s = Benchmark (sighted)

The precision of work done with these instruments is excellent to approximately 200 ft.

EQUIPMENT

PLUMB BOB

The plumb bob dates back to ancient Egypt and can still be purchased at your local hardware store today. It consists of a weight with a point on its end attached to a string, as shown in ***Figure 2-1***. It is used to find a point on the ground directly below another object.

Figure 2-1 Plumb Bob

THEODOLITE

Theodolites (***Figure*** 2-2) are used to measure both vertical and horizontal angles. A surveyor looks through a telescope that can be adjusted to point directly at a point in the distance. Originally, they would have used printed gauges that a surveyor would have to interpret and record, but these eventually transitioned to providing digital readouts for simplicity. Transits are theodolites with a telescope that can rotate on the vertical plane to allow backsights to be taken.

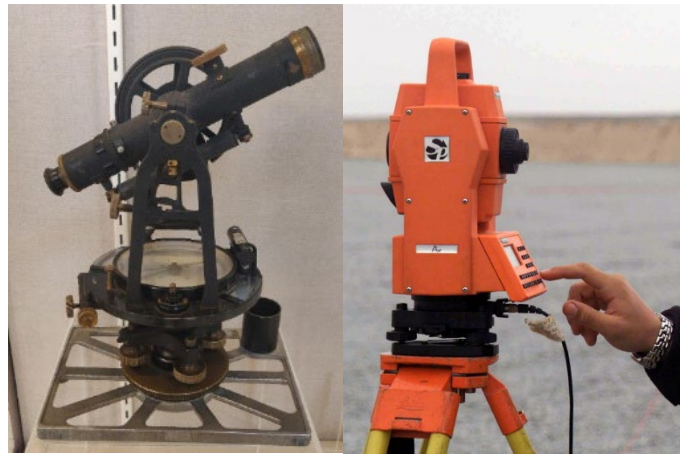


Figure 2-2 Two Transit-type Theodolites

LEVEL

The level is an instrument used to determine and establish elevations and differences in elevation between points. It contains a telescope that the surveyor will look through toward a rod in the distance to determine the elevation difference between two points.

Figure 2-3 Dumpy Level

An old type of level is the dumpy level. (***Figure*** 2-3) While similar to the self-leveling level, the telescope has no self-correcting attributes and is less accurate.

The most common type of level used by INDOT is the self-leveling level. (***Figure 2-4***) The telescope *(1)* has the usual eyepiece system, objective lens, focusing mechanism, and reticle with cross lines. Also, there are three leveling screws at the base *(3)*, and the instrument is supported on a tripod. The head *(4)*, which encloses the tops of the leveling

Figure 2-4 Self-Leveling Level
1) Telescope; 2) Viewing Prism; 3) Leveling Screws; 4) Head

screws, may be leveled by means of these screws. To enable the operator to determine when the head is level, there is a circular level vial, which may be viewed through the window *(2)*. With this bubble in position, the level may be turned and will stay the level allowing the operator to look horizontally at the target through the telescope. There is a hanging prism in the body to aid making the level more accurate (***Figure 2-5***). These have evolved over the years to include digital components that allow automatic reading of special rods and are still used today.

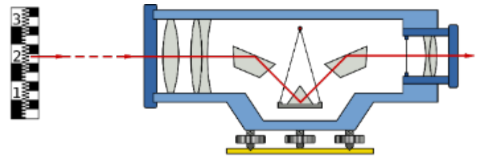


Figure 2-5 Internal Diagram of Self-Leveling Level

LEVELING ROD

Used in conjunction with the level, the second most important piece of equipment needed for differential leveling is the leveling rod. Several types of leveling rods are used in highway construction. The Chicago Rod and the Philadelphia Rod (***Figure 2-6, b***) are the two types which are generally preferred. The Chicago Rod is a slip-joint rod which has a total length of 12 ½ ft when all sections are used. The Philadelphia Rod is a sliding joint type of rod that extends to 15 or 16 ft and is a more convenient rod when using a target. Selection of a rod type is a matter of personal preference or availability. More recent rods have a barcode like image on one side to allow for the instruments to digitally read the rod.

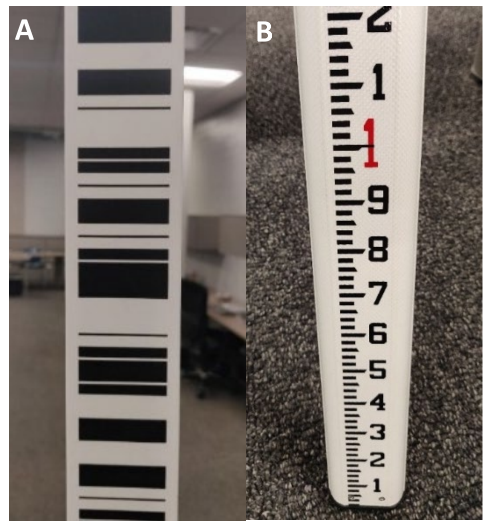


Figure 2-6 Leveling Rods
a) Digital Barcode; b) Philadelphia

CHAINS AND TAPES

One common method of determining distance is by direct measurement with a tape. The steel tape is usually 100 ft in length. The term "chain" comes from the Gunter's Chain (***Figure 2-7***) which was sixty-six feet long and was composed of 100 links, each being 7.92 inches long. Brass tags were fastened at each ten links and notches in the tags indicated the number of ten link segments between the tag and the end of the tape. Therefore, the early tapes looked like a chain of one hundred links. Chain is also applied to the operation of measuring lines with tapes. The term "taping" is gradually being used more exclusively.

Figure 2-7 Gunter's Chain

The distance measured with a steel tape (***Figure 2-8***) is much more precise than the distance obtained by pacing. The precision obtained depends upon the degree of refinement with which the measurements are taken. Ordinarily, taping over flat, smooth ground with a steel tape or chain, divided in hundredths of a foot, provides a precision of one in three thousand to one in five thousand.

Figure 2-8 Steel Tape

LEVEL RUN PROCEDURE

1. Set up the level part way to the desired point from the benchmark and level the instrument properly.
2. The rodman sets the rod on the BM and rocks the rod on this point. The instrument operator reads the rod for the backsight, making sure that the rod is at the center of the cross hairs and that the level bubble is truly centered when the reading is taken.
3. The rodman moves up to the first turning point, sets the rod on the stake, and rocks the rod as the instrument operator turns the instrument to obtain a precise reading of the rod at the first turning point. Once again, the bubble level is centered when the reading is taken. The instrument operator reads the rod for the foresight toward the turning point. This is the first set-up.
4. The level is then moved to a new location past the turning point and toward the point where the elevation is needed. Like in step 2, The rodman sets the rod on the turning point and rocks the rod. The instrument operator reads the rod.
5. The crew will continue the pattern until the point in question is reached.

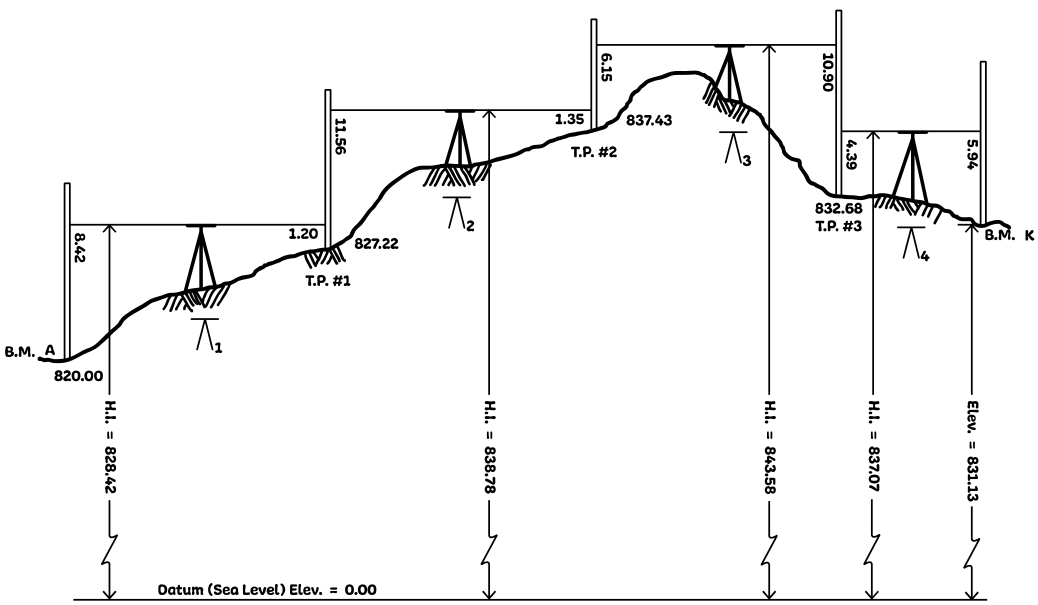


Figure 2-9 Level Set-up

DISTANCE MEASUREMENTS

In surveying, the distance between two points is understood to mean the horizontal distance, regardless of the relative elevation of the two points. Frequently, the lay of the land between the two points is not uniform, or the elevation of the two points is very different. Special equipment and techniques may be needed to obtain an accurate determination of the distance. Various methods of determining distance are available along with special and different types of equipment. The degree of precision required is another factor which is required to be considered before a measurement of distance is undertaken so that the correct type of equipment and method of measurement may be done.

PACING

Pacing is a rapid means of approximately checking more precise measurements of distance. Pacing over rough country may be done with a precision of one in one hundred. In average conditions, a person with some experience should have little difficulty in pacing with a precision of one in two hundred. Obviously, there is not much precision in this method and the procedure provides only an approximation of distance. The natural pace of each individual normally varies from 2 ½ to 3 ft. A convenient relation between the pace and the foot is 40 paces approximately equal 100 ft. Technicians involved in surveying standardize their pace by walking over known distances on level, sloping, and uneven ground. Pacing should never be used to determine official measurements.

TAPING

There is a formal procedure to be followed in measuring the distance between two points. Presented below is a simplified version of the procedure. The person moving ahead or away from the instrument is called the head chainman. The head chainman takes the zero end of the tape or the end of the tape with the graduated foot, and moves on the line toward the distance point. The person remaining behind to hold the end of the tape on the last established point of beginning is called the rear chainman. During this time, the rear chainman is responsible for keeping the head chainman on line and to make sure the tape does not snag or kink which could result in damage to the tape. As the hundred foot end of the tape reaches the rear chainman, he should call ahead to the head chainman to tell him he has gone far enough.

The next step requires a general lining-in procedure and a check to make sure that the tape is straight, not twisted. Obviously, the graduations on the face of the tape should be up at both ends. When the tape is straight and on line the rear chainman holds the 100 ft mark on the established point.

The head pulls the tape taut with the tension indicated by the tape's manufacturer (typically around 15 pounds). The stake or pin are held upright with the zero mark of the tape centered and low on the stake or pin. The instrument operator tells the head chainman to move the stake left or right to come precisely on line. When the instrument operator indicates the stake is exactly on line and the rear chainman calls that all is good, the head chainman sets the pin or begins to drive the stake. When the stake is solidly set, at least ¾ of the length in the ground, the top of the stake is marked for line and distance. A point is then established on the stake by the head chainman. A check of the point is made, and the head chainman takes the zero end of the tape, moves forward as before, and repeats the process.

If an odd distance is to be measured between two points, the head chainman holds the zero end of the tape approximately on the forward point. The rear chainman pulls the tape somewhat taut and checks to see where the rear point intersects the tape. The tape is then pulled so that the smaller graduation of the tape is on the point, and then this number is called out to the head chainman. The head chainman then pulls the tape with the proper tension and reads the fine division of the extra foot on the tape. The graduation held by the rear chainman on the new point added to the graduation read by the head chainman on the forward point gives the measurement between the two points in hundredths of a foot.

EXAMPLE

1. The distance between two stakes is less than 100 ft
2. The tape is pulled so that the head chainman is holding zero very close to the forward point, and the rear chainman pulls the tape and finds that the point is between the 63 and 64 graduations on the tape
3. The rear chainman then pulls the tape and holds the 63 mark on the rear point
4. The rear chainman then calls to the head chainman saying HOLDING 63
5. Both chainmen check to make sure the tape is straight, not twisted, and pulled taut
6. The head chainman reads 0.58 on the extra foot
7. The distance between the two points is 63.58 ft

Breaking tape is the measurement of a line when increments less than 100 ft are measured due to the roughness of the terrain. The tape does the adding of the increments to 100 ft. This is done by having the head chainman pull the zero end of the tape completely along the line down the rugged slope until the 100 ft mark is even with the rear chainman. The tape is left lying on the line in this fashion. With the rear chainman holding the 100 ft mark on the rear point, the head chainman backs up on the tape to a graduation which he can plumb comfortably and under which a stake may be set accurately. He proceeds to plumb, line and place the stake at this point on the line. This procedure is repeated until 100 ft are measured. The tape is not moved ahead until the zero mark is reached. The rear chainman occupies the mark that is just vacated by the head chainman as he moves ahead on the line and down the slope. ***Figure 2-10*** shows how horizontal measurements are obtained on steep slopes by the process of breaking tape.

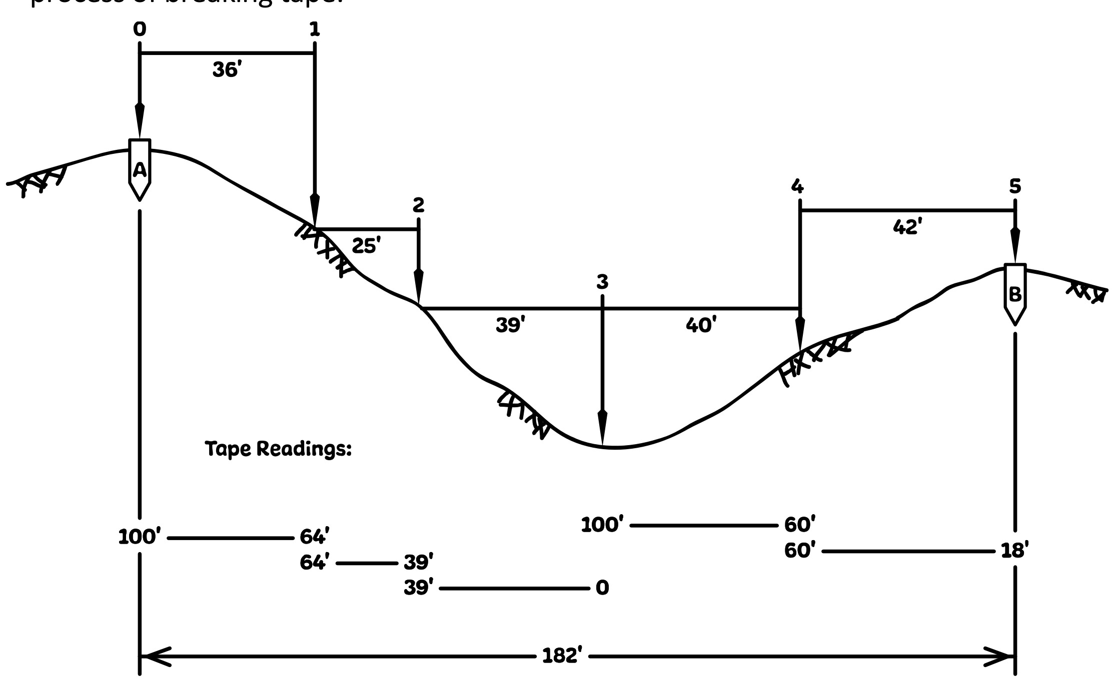


Figure 2-10 Breaking Tape

Taping Error

Error is defined as the difference between the true value and the measured value of a quantity. Errors result from instrument imperfections, personal limitations, and natural conditions affecting the measurement. An error is either systematic or random. A mistake is not considered an error, but is a blunder on the part of the observer such as the failure to record each 100 ft in taping, misreading a tape, forgetting to level the instrument, etc. While the reasons for errors below are specifically for steel tapes, many of them apply to other types of tapes as well:

1. The tape is not the standard length. This results in systematic error which may be eliminated by standardizing the tape or comparing the true length of the tape with some permanent standard of length. The tape may be sent to the Bureau of Standards in Washington D.C. for standardization or may be standardized in a local laboratory equipped for this type of work. Generally, errors due to this reason may be offset by varying the amount of tension applied to the tape
2. Poor alignment of the tape. Both chainmen are required to be constantly aware of the condition of the tape as they move along the line. The instrument operator also helps ensure that the tape is on line over the entire length from point to point. Poor alignment results from sloppy or lazy habits developed by the chainmen. A variable systematic error is produced which may be reduced almost completely if care is exercised in aligning the tape. This is probably the least important of the chaining errors because in 100 ft the error amounts only to 0.005 ft if one end is off line one foot. This type of error tends to make the measured length greater than the true length, therefore, the error is positive
3. Tape not horizontal. This error produces an effect similar to that due to poor alignment. Once again, this error results from a sloppy procedure and with a little care may be virtually eliminated. Even an experienced chainman probably underestimates the rate of slope. This may be a large source of error and in rough or deceptive terrain, a hand level may eliminate the error
4. Tape twisted or not straight. When taping through fairly dense undergrowth, when the wind is blowing, over a stubble field, or across a harvested cornfield, keeping all parts of the tape in perfect alignment with both ends is difficult. The error in this case is systematic and variable and has the same effect as that which arises from measuring with a tape that is too short
5. Human error of observations. There are accidental errors caused by misreading the tape, improper setting of pins and stakes, and errors due to plumbing improperly due to inexperience or sloppy procedure. All accidental errors may be kept to a minimum by exercising care and following proper procedures
6. Variations in temperature. Materials expand as the temperature rises and contract when the temperature falls. In Indiana the ambient air temperature may vary from 10 or 15° below zero to 100 to 105° F. Daily temperatures may vary from the 40 to 50°F early in the morning to 80 to 90°F by mid-afternoon. These temperature extremes cause the tape to expand and contract. A change in temperature of 15° F will result in a change in length of about 0.01 ft for a 100 ft tape
7. Variations in tension. A steel tape is elastic and stretches when tension is applied. The amount of pull is most important and is required to be known to make the tape the right length. Again, this type of error is systematic and depends on the methods

employed and who is doing the taping. Generally, a pull of 10 pounds is sufficient when the tape is fully supported. A pull of 20 pounds or more is necessary when the tape is unsupported throughout its length. This information is obtained when the tape is standardized

8. Tape Sag. Error due to sag in the tape is significant if the tape is relatively heavy and unsupported over the length of the tape. This may be a very important consideration when both rear and head chainmen are plumbing over rough ground. The tapes typically used for highway surveying are heavy, and both the head and rear chainmen are required to be constantly aware of the amount of sag in the tape when plumbing. Controlling a plumb bob, when applying a tension of 30 pounds to a 100 ft tape which is fully unsupported, is very difficult. This procedure takes considerable effort and experience to do a good job

Chapter Three: MODERN SURVEYING AND MEASURING

While the modern Highway Technician is rarely called upon to perform surveying tasks, it is helpful to know modern equipment and what it is used for. Understanding what a Contractor's surveyor is doing will help an HT double check that layouts are in accordance with the plans and may help identify concerns before they impact the project.

SURVEYING EQUIPMENT

The total station has taken the place of several traditional tools such as the theodolite and tape measures. Total stations allow a single surveyor to quickly record measurements that would traditionally take 2 people. They utilize various satellite systems like GPS and GLONASS to achieve base location accuracy within just a few centimeters. Once the surveyor has locked in the location of the station distance measurements are accurate to about 1mm for a 300m shot and angle measurements can be as accurate as 0.5 seconds which is 0.000139°. Measurements can then be uploaded into CAD software to create 3D models or used to verify accuracy of the construction progress.

Figure 3-1 Robotic Total Station

ROBOTIC TOTAL STATION

The most common type of total station seen on INDOT projects is a robotic total station (***Figure 3-1***). This type is almost always used in conjunction with a rover, and handheld controller. The rover is attached to a rod and has a series of prisms that allow the total station to automatically track it. The surveyor will setup the station on a tripod then takes the prism and controller with them and acquire the required measurements.

SCANNING TOTAL STATION

A scanning total station (***Figure 3-2***) does exactly what its name implies. It can use its laser to automatically scan an area very quickly without the need for a surveyor to take individual shots with a rover. These are useful for measuring ADA ramps. Under the right conditions a scanning total station can measure all the ramps at an intersection in minutes after it is setup.

SELF-LEVELING LEVEL

As mentioned in Chapter 2, self-leveling levels are still used when a surveyor needs to run a level circuit.

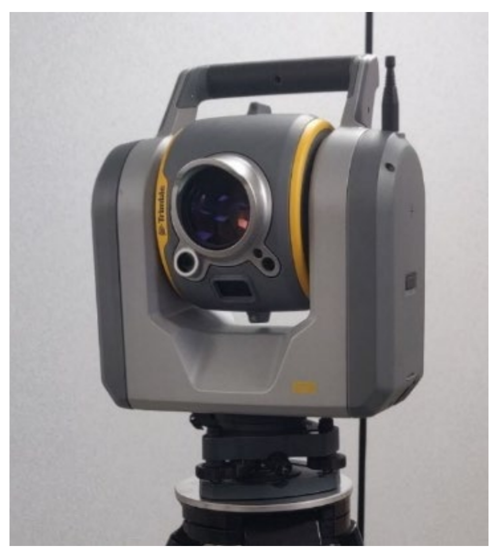


Figure 3-2 Scanning Total Station

INCORS

Figure 3-3 INCOR Station at the Indianapolis Division of Materials and Tests Building

INDOT's Land Survey Section coordinates a network of continuously operating reference stations (CORS). These CORS operate on the Global Navigation Satellite Systems (GNSS) which include GPS, Galileo, and GLONASS. The network is the backbone that allows surveyors in the state to make accurate measurements without running physical measurements to a known fixed point. There are about 45 fixed stations maintained by INDOT, constantly reading satellite data. The data is fed into a central server that allows contractors to download real-time correction data for their equipment on site.

TAPE MEASURES

Finally, we come to the trusty ole tape measure. They may not be glamorous, but they are still widely used on the jobsite by workers and inspectors alike. There are many varieties of tape measures. We covered steel tapes in Chapter 2, but let's take a quick look at three other types you'll likely use in your day-to-day assignments.

POCKET TAPE

A tool you'll already be familiar with is the pocket tape measure. This type isn't used for surveying but is a common tool for length measurements on the jobsite. These are convenient for short distances and can be easily used by a single person.

Figure 3-4 Cloth, Pocket, and Laser Tapes

CLOTH TAPE

The cloth tape is a ribbon of waterproof fabric into which small brass or bronze wires are woven to prevent stretching. This tape may be 50, 100, or even 300 ft long and graduated in feet, tenths, and half-tenths. This type of tape is used principally for earthwork cross-sectioning or in similar work where a light, flexible tape is desired and where small errors in length are not critical. Due to the metallic wires woven into the fabric, a cloth tape conducts electricity and is used carefully near power lines.

LASER TAPE

The newest of the three tapes, this uses a laser to measure distances at the push of a button. These are very convenient to take quick accurate measurements and a welcome addition to an inspector's toolbox.

MEASURING WHEEL

The measuring wheel (***Figure 3-5***) is one of the least accurate tools used on a jobsite for distance measurements. Measured distances are affected by the operator moving the wheel side to side and objects in the path of the wheel among other difficulties. Nonetheless, they are often the quickest and most convenient method an inspector has when measuring long distances.

Figure 3-5 Measuring Wheel

Chapter Four: DAILY REPORTING

Daily Work Reports, or *DWR*s, contain valuable information which details and describes the layout, elevations, and quantities of features and materials incorporated in a construction contract. As such, they are part of the official and legal record of the work done. Notes are required to be kept so that sufficient documentation of original data becomes part of the permanent contract record.

FIELD ASSISTANT - OPTIONAL

INDOT's own data entry method, Field Assistant, or *FA* for short, allows for entry on any device with a browser and only requires internet connection at the beginning of a shift to download the contract information and at the end of a shift to upload your data. There are templates that can only be used in Field Assistant and not in the older SiteManager system. SiteManager remains in use for contracts awarded through April 2025. Subsequently awarded contracts use the new AASHTOWARE Project (AWP) system.

Data can be entered directly in SiteManager and AWP. Guidance is provided in the training manuals now focusing on the new AWP. Field Assistant as a data entry option, does offer a clean interface, easy access, and more entry options. Data entered into Field Assistant is uploaded into SiteManager or AWP.

In addition to DWRs, tests can be entered through Field Assistant, including for HMA and concrete.

CREW

In Field Assistant, the first tab (***Figure 4-1***) as you start a DWR is for crew information. You can use the dropdowns to enter your info and even enter more than one crew for a contractor. The required fields are Contractor, Personnel Type, Crew No., and Qty.

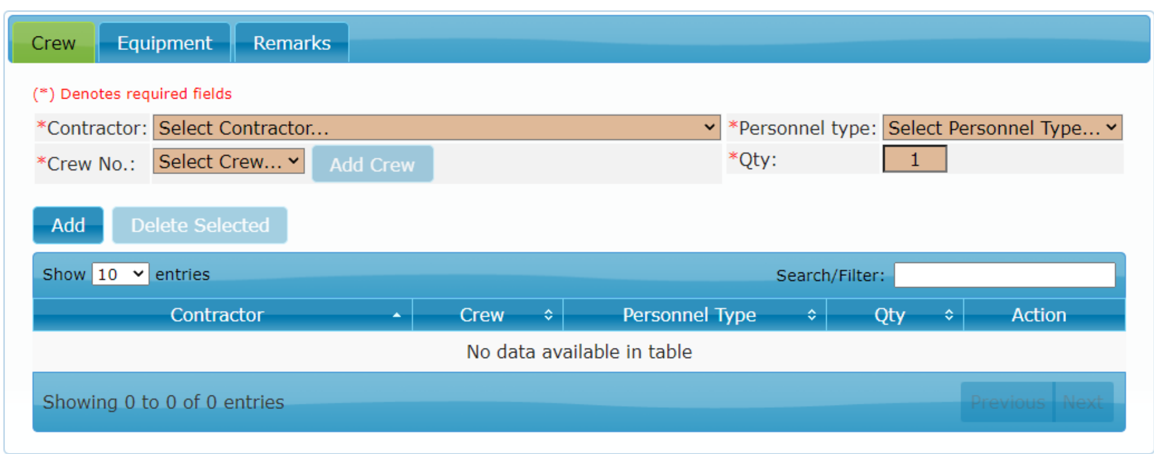


Figure 4-1 The Field Assistant "Crew" tab

EQUIPMENT

The Equipment tab (***Figure 4-2***) is very similar to the crew tab. Select the correct equipment for each crew and add it to the DWR. The required fields are Contractor, Crew No., Equipment, Qty, and Qty Used.

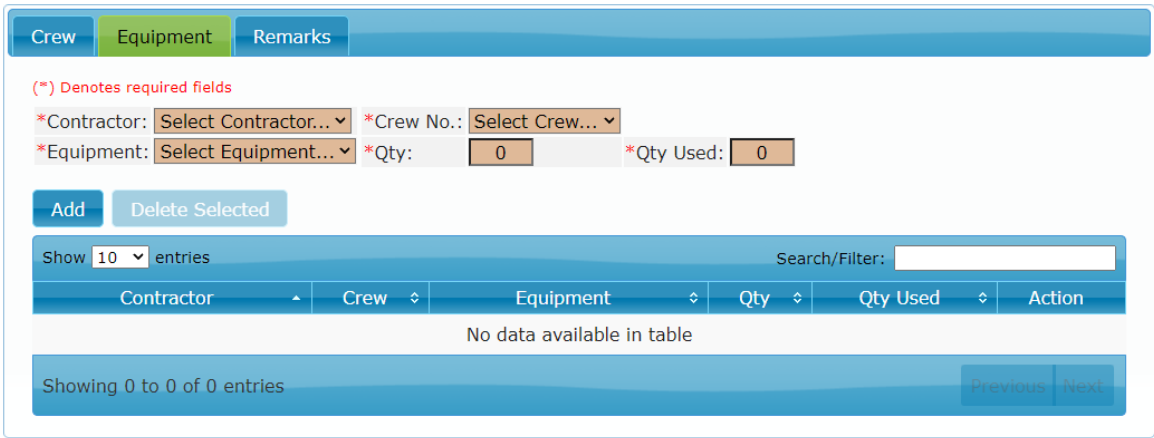


Figure 4-2 The Field Assistant "Equipment" tab

REMARKS

Remarks (***Figure 4-3***) will cover your description of the day's work operations and other various remark types. After selecting the type of remark you want, type out your information in the box below. The only required remark is *DWR Work Operations*. In the remarks portion of the DWR be sure to include enough information that someone reading your DWR has a picture of the work accomplished for the day. Consider answering the six basic questions: Who? What? When? Where? Why? How?

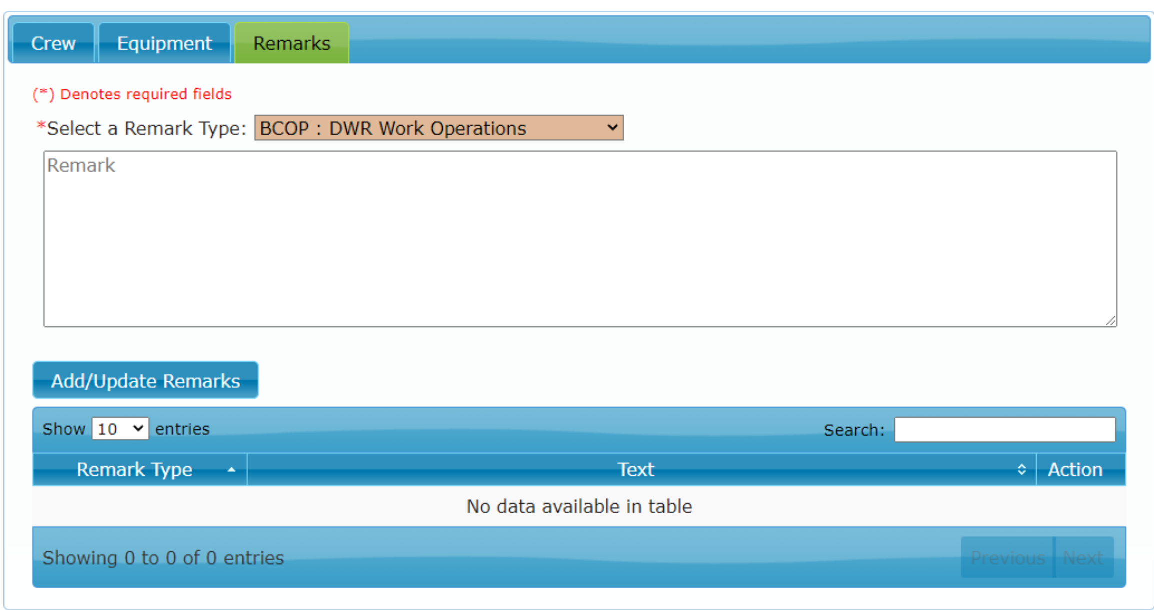


Figure 4-3 The Field Assistant "Remarks" tab

WORK ITEMS

The last tab filled out in a typical daily is the work items tab. You will need to select the appropriate item for payment and input additional information on the following tab including location, station, quantity, and contractor who installed the item. Many items have templates that will calculate the paid quantity based on field measurements. If you have an item that has these select the appropriate shape and input the required information.

Icon	Name	Requirement	Icon	Name	Requirement
	Rectangle	Base, Height		Rectangular Volume	Base, Height, Length
	Circle	Diameter		Sphere	Diameter
	Trapezoid	Base 1, Base 2, Height		Trapezoidal Volume	Base 1, Base 2, Height, Length
	Right Triangle	Base, Height		Right Triangle Volume	Base, Height, Length
	Triangle	Side A, Side B, Side C		Pyramid	2-D Base Shape, Height
	Segment	Chord Rise		Cone	Base Diameter, Height
	Planned Quantity*	Pay Quantity, Plan Pg #		Cylinder	Diameter, Height
*Not a geometric shape				Average End Area	Two 2-D Base Shapes, Length

Figure 4-4 Field Assistant's Template Options

Pay Items

Show 10 entries Search:

PLN	CLN	Item Code	Item Desc	Item Unit	Bid Qty	Remaining Qty	Daily Qty
0013	0013	202-02240	PAVEMENT REMOVAL	SYS	73263	-196.96	
0014	0015	202-02637	PIPE ABANDON AND GROUT FILL	LFT	730	488	
0015	0016	202-51368	SLOPEWALL, REMOVE	SYS	390	-65.86	
0016	0017	202-91385	INLET, REMOVE	EACH	11	0	
0017	0018	202-93995	SIGNAL POLE FOUNDATION, REMOVE	EACH	1	0	
0018	0019	202-94954	BARRIER WALL, CONCRETE, REMOVE	LFT	896	-604.80	
0019	0020	202-96133	PIPE, REMOVE	LFT	2171	-72	
0020	0021	203-02000	EXCAVATION, COMMON	CYS	505	505	
0021	0022	203-02000	EXCAVATION, COMMON : , FOUNDATION IMPROVEMENT	CYS	4302	4302	
0024	0026	207-09934	SUBGRADE TREATMENT, TYPE IB	SYS	95628	-29013.65	

Showing 1 to 10 of 145 entries Previous 1 2 3 4 5 .. 15 Next

Figure 4-5 The Field Assistant "Pay Items" panel

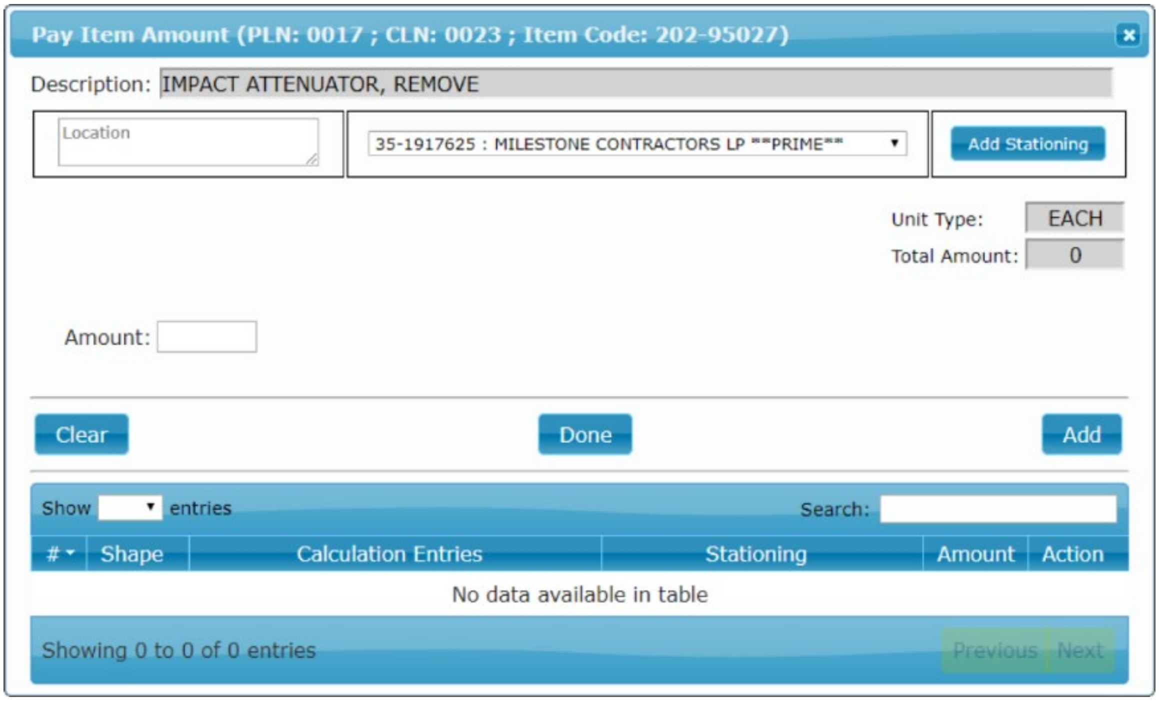


Figure 4-6 The Pay Item Amount screen

SITEMANAGER DWR

SiteManager is INDOT's legacy record-keeping software and has been in use for decades. While Field Assistant is an optional, convenient method to enter Dailies and Pay Quantities, the data generally ends up in SiteManager, or AWP with some exceptions. SiteManager and AWP are viable places to enter data directly but require a reliable internet connection which may cause issues in the field. For SiteManager, there is a maximum amount of sign-in time which, if eclipsed, may cause entered data to be lost.

This section covers the tabs that need filled out on a typical DWR in SiteManager.

DWR INFO

Your SiteManager DWR should contain information on the crews you observe each day. Take notes of the work progress, and questions or concerns that arise, and bring any concerns to the attention of the PEMS. On multi-project contracts it may be helpful to keep notes in separate paragraphs for easier tracking. The only required remark is the DWR Work Operations. In the remarks portion of the DWR be sure to include enough information that someone reading your DWR has a picture of the work accomplished. Consider the six basic questions: Who? What? When? Where? Why? How?

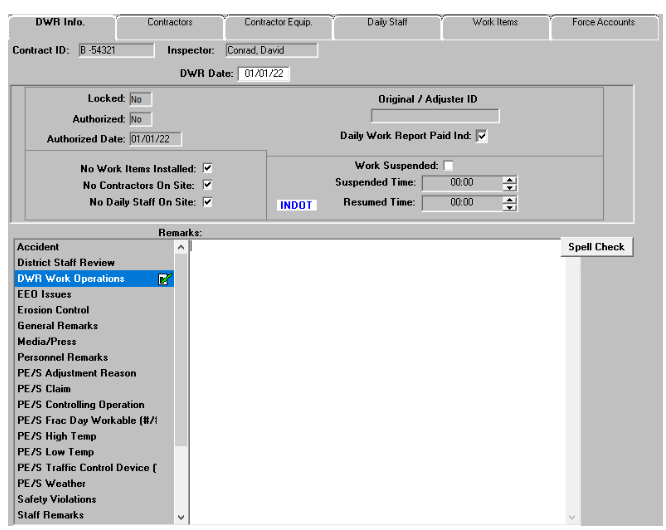


Figure 4-7 SM DWR Info

CONTRACTORS

On the Contractors tab you will need to select the contractors you observed for the day and input the supervisors and workers from each trade that were on site.

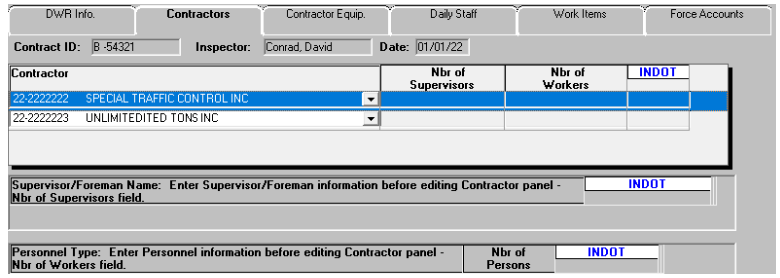


Figure 4-8 SM Contractor tab

CONTRACTOR EQUIPMENT

On the Contractor Equip tab you will need to select the equipment types on-site and how many of each were used for the day.

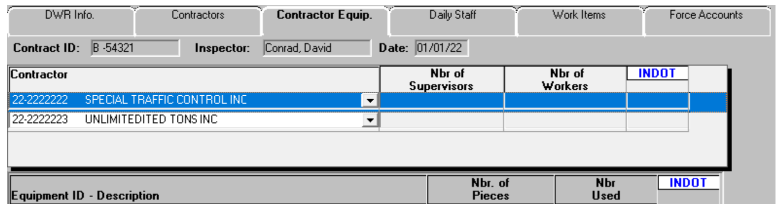


Figure 4-9 SM Contractor Equipment tab

WORK ITEMS

The last tab filled out in a typical daily is the work items tab. You will need to select the appropriate item for payment and input additional information on the following tab including location, station, quantity, and contractor who installed the item.

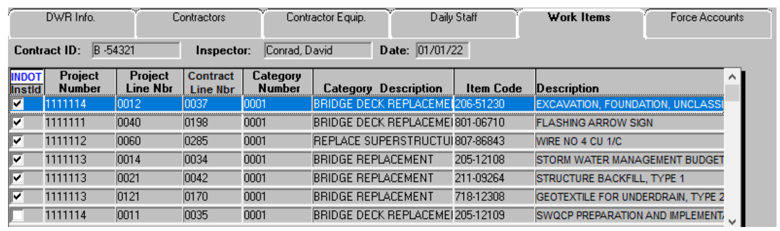


Figure 4-10 SM Work Items tab

AASHTOWARE PROJECT (AWP)

AASHTOWare Project (AWP) is a comprehensive web-based construction management tool developed by the American Association of State Highway and Transportation Officials (AASHTO). INDOT is phasing out SiteManager and replacing it with AWP. INDOT has customized AWP for INDOT's specific uses as applicable. AWP has capabilities for use in managing the entire construction contract lifecycle. Like with SiteManager, these uses include covering construction management, inspection, daily work records and dairies, materials management, and pay estimates across the entire program.

DWR INFO

The AWP Manual covering daily work records is found at the following location:
https://erms12c.indot.in.gov/sitemanagermanuals/

ADDITIONAL RESOURCES

For additional technical information on Field Assistant, SiteManager, and AWP, please go to the INDOT Construction Information website found below and scroll down to the AWP & SiteManager Manuals link under Construction Applications and Tools. The Manuals link includes manuals not only for AWP and Field Assistant, but also for other frequently used INDOT applications like *DMF Entry*, *Contractor Payroll Management System*, and more.

https://www.in.gov/indot/div/construction.htm

Chapter Five: CROSS SECTIONS

Cross sections are necessary for measurement of earthwork volumes in roadway construction. They are profile views of the ground, perpendicular to the centerline or base line, and indicate ground elevations at points of change in the ground slope.

Sections are taken at pre-determined intervals, normally 50 ft or 100 ft along the centerline or baseline.

An elevation is taken at the centerline and at intervals right and left of the centerline, normally 25 or 50 ft. Sometimes elevations are taken at points other than normal intervals depending on the terrain, for instance, at locations of change in the slope of the ground, lane lines, etc.

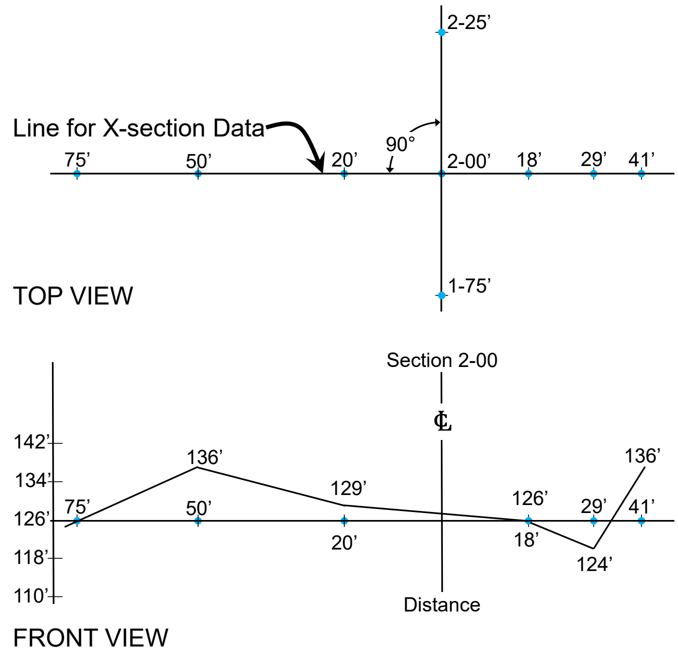


Figure 5-1 Cross Section

SIDE SLOPES

Side slope (***Figure 5-2***) is defined as the slope of the cut or fill expressed as the ratio of horizontal distance to vertical distance.

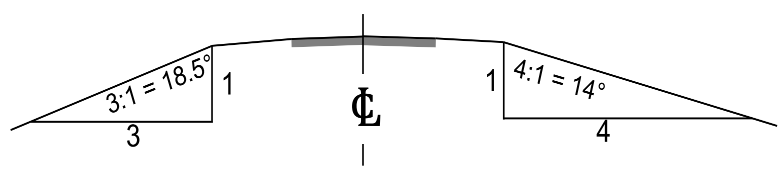


Figure 5-2 Side Slope

EXAMPLE

A 2:1 side slope indicates that for every horizontal distance of 2 ft, the corresponding vertical distance is 1 ft as indicated in ***Figure 5-3***.

$$Side\ Slope = \frac{Horizontal\ Distance}{Vertical\ Distance} = \frac{50'}{25'} = \frac{2}{1} = 2{:}1$$

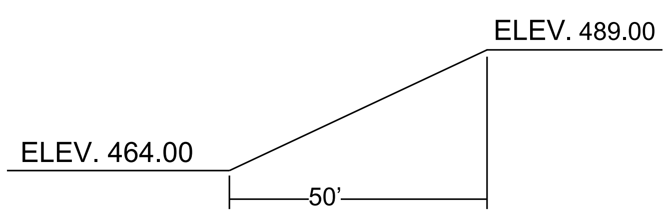


Figure 5-3 Slope Example

ORIGINAL CROSS SECTIONS

Original cross sections indicate the profile of the original ground before the ground is disturbed. These measurements may be used for primary design, estimating volumes, etc. Borrow pit original cross sections are taken after stripping has occurred.

Before beginning a contract, the original cross sections are checked every 500 ft and compared to the cross sections shown on the plans. If these check sections vary consistently by more than 0.2 ft, the original sections may have to be retaken.

PROFILES

Profiles indicate a vertical cross section or side view of the surface of the earth, and are necessary for design and construction of the roads, curbs, sidewalks, drainage systems, etc.

The plotting of profiles is generally a graph of elevations plotted on the vertical axis as a function of horizontal distance (stations or offset distances). The vertical scale is usually exaggerated in comparison to the horizontal scale, which helps make the shape of the ground more easily visible. This is especially helpful when plotting profile grades at intersections, railroad crossings, bridge approaches, wedge levels, etc.

Profiles are plotted on plan and profile sheets in the plans**.** ***Figure 5-4*** is one example:

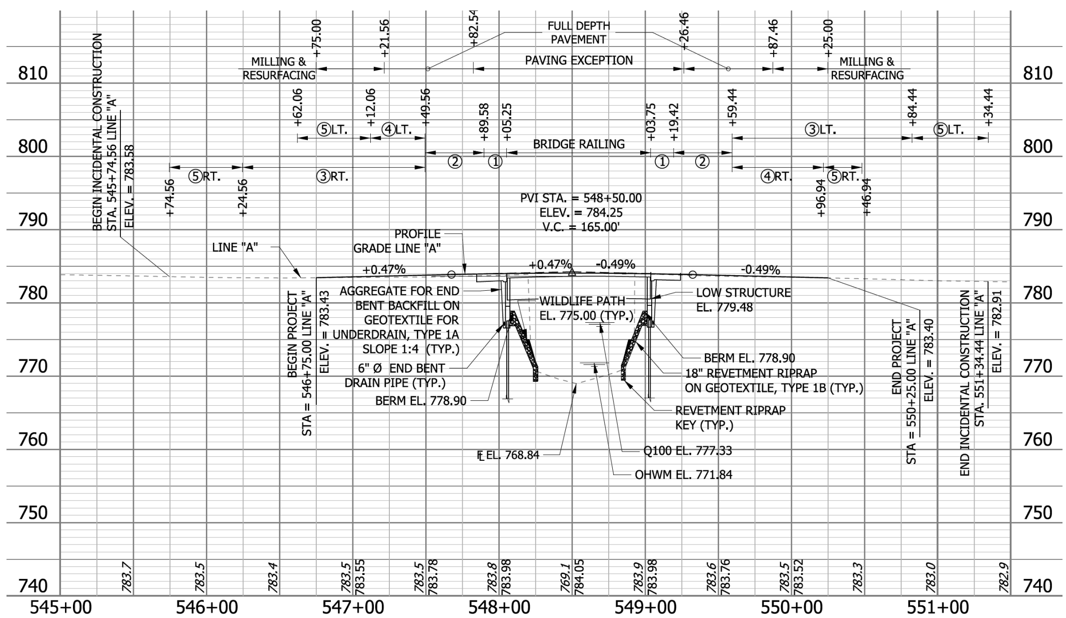


Figure 5-4 Profile

ZERO SECTION

A zero section is a section in which no earthwork was done. These usually occur at the beginning and ending of contracts.

SPLIT SECTION

A split section is sometimes necessary so earth quantities are not overestimated. They consist of two sets of cross sections taken at the same station. You might find a split section at an MSE wall where there is an abrupt change in fill from one side of the wall to the next.

EXAMPLE

Two Sections would be required at station 5+50, one labeled *5+50 back* and one labeled *5+50 ahead*. Not splitting the section into *back* and *ahead* sections would result in an erroneous quantity. Splitting the section ensures that a break is made in the earthwork calculations, so the assessment is accurate.

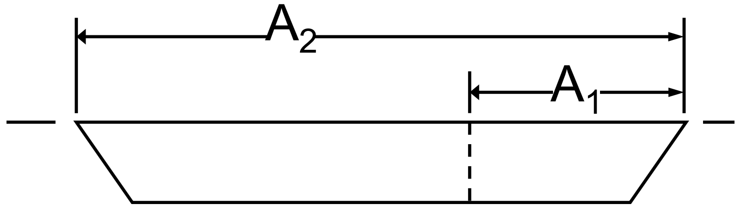


Figure 5-5 Section Break Example

SECTION AT 5+50
A1 = Area to be used for 5+50 back
A2 = Area to be used for 5+50 ahead

MATCH LINES

Match lines occur when two sections from two separate baselines intersect at a point common to both baselines. Match lines are also those lines made when there is not enough cross section paper to accommodate the entire section.

INTERPOLATION

The estimation of an unknown section from two known adjacent sections is called interpolating that section. Usually, an original section requires to be interpolated since the original conditions no longer exist. The number of required interpolated sections varies depending on the number of changes in ground elevation between the two known sections. To interpolate, assume that the ground is on a straight grade between the known sections. Points that are equidistant from the baseline for the known sections are selected. This distance is figured for the unknown section.

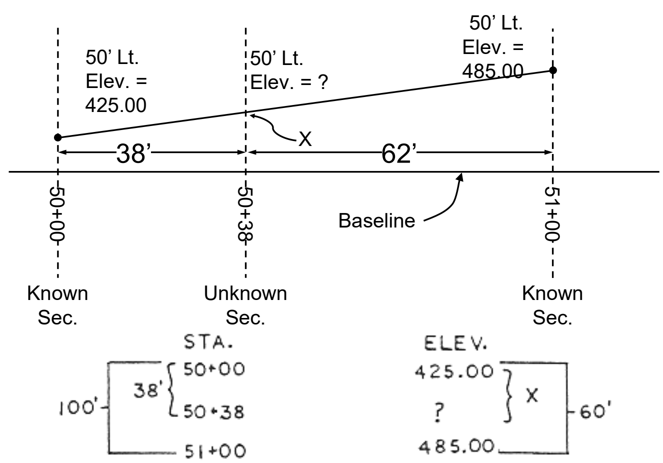


Figure 5-6 Interpolation Example

Example

To figure the elevation of a point 50 ft left of a baseline at station 50+38, ***Figure 5-6*** is explained in the procedure outlined below.

1. x is the difference in elevation from station 50+00 to station 50+38
2. 38 is to 100 as x is to 60,

$$\frac{38}{100} = \frac{x}{60}$$

3. Therefore,

$$x = \left(\frac{38}{100}\right) \times 60 = 22.80 \text{ ft}$$

4. Note that the ground elevation from station 50+00 to 51+00 is rising. This means that the elevation at station 50+38 is greater than the elevation at station 50+00, so we add 22.8 ft to 425.00 to obtain the elevation at station 50+38:

$$425.00 + 22.80 = 447.80 \text{ ft}$$

EARTHWORK QUANTITIES

Earthwork quantities are usually measured in cubic yards and may be a cut or fill. The volumes are computed as the product of an area and a distance. Methods for determining volume include:

1. Picking or stripping
2. Plane geometry
3. Planimeter
4. Coordinates

Plane geometry is the most commonly used method at INDOT. It simplifies volume calculation by reducing complex shapes into more basic geometric figures.

Plane Geometry starts by dividing the section into regular shapes such as triangles and trapezoids, with dimensions being determined either by scaling or from field data. Areas are then computed from basic geometric formulas.

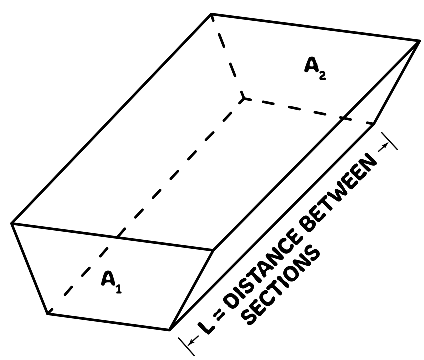


Figure 5-7 Average End Area

Once the areas of the sections are determined, the volume V between two adjacent sections may be computed by using the Average End Area Method shown in ***Figure 5-7*** and described below:

$$V\ (yd^2) = \frac{A_1 + A_2}{2} \times L \times \frac{1\,yd^3}{27\,ft^3} \qquad or \qquad \frac{(A_1 + A_2)(L)}{(2)(27)}$$

where:

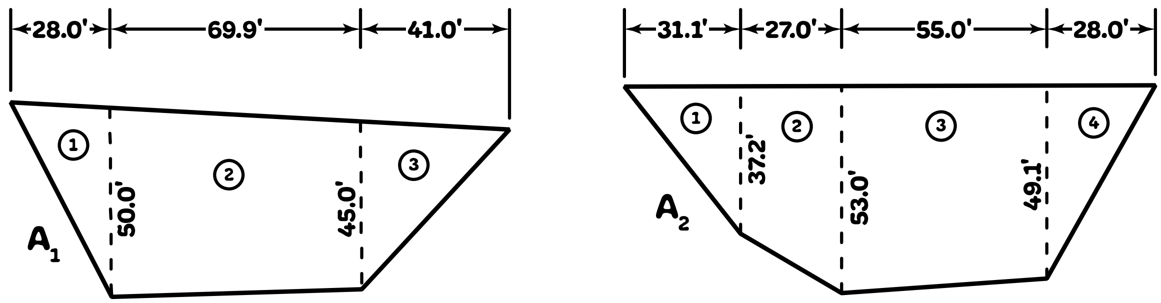
A_1 = End Area 1 in ft²

A_2 = End Area 2 in ft²

L = distance between stations in LFT

Example

Given the following end sections A_1, located at 805+75.00, and A_2, located at 805+00.00, as shown below, determine the quantity of earthwork.



For End Area A_1:

Area 1:

$$\frac{1}{2} \times 28.0\ ft \times 50.0\ ft = 700.0\ ft^2$$

Area 2:

$$\frac{50.0\ ft + 45.0\ ft}{2} \times 69.9\ ft = 3320.25\ ft^2$$

Area 3:

$$\frac{1}{2} \times 41.0\ ft \times 45.0\ ft = 922.5\ ft^2$$

Total Area A_1:

$$700\ ft^2 + 3320.25\ ft^2 + 922.5\ ft^2 = 4942.75\ ft^2$$

For End Area A_2:

Area 1:

$$\frac{1}{2} \times 37.2\ ft \times 31.1\ ft = 578.46\ ft^2$$

Area 2:

$$\frac{37.2\ ft + 53.0\ ft}{2} \times 27.0\ ft = 1217.7\ ft^2$$

Area 3:

$$\frac{53.0\ ft + 49.1\ ft}{2} \times 55.0\ ft = 2807.75\ ft^2$$

Area 4:

$$\frac{1}{2} \times 28.0\ ft \times 49.1\ ft = 687.4\ ft^2$$

Total Area A_2:

$$578.46\ ft^2 + 1217.7\ ft^2 + 2807.75\ ft^2 + 687.4\ ft^2 = 5291.31\ ft^2$$

Total Volume V:

$$V = \frac{4942.75\ ft^2 + 5291.31\ ft^2}{2} \times 75.0\ ft \times \frac{1\ yd^3}{27\ ft^3} = 14213.97\ yd^3$$

Chapter Six: SLOPE STAKES

Slope staking is a special form of leveling to determine the point at which the proposed slope intersects the existing ground. Since these stakes define the actual construction limits, they are set in the early stages of a contract and as such require preservation for later use.

Information that is required to be known before the setting of slope stakes may proceed is:

1. The profile grade for each station.
2. Typical cross section for each station.
3. Original cross section with elevations.

Scaling the distance from plots of original and proposed cross sections is a graphical method for establishing the slope stake location. While this method is widely used, the procedure may not be advisable for the following reasons:

1. Incomplete or incorrect information at needed stations.
2. Original survey of sections may not be accurate, especially in rough terrain.
3. Changes in the original ground, due to farming, erosion, etc., may have occurred if the time from design to construction is extensive.

The Trial and Error method using the centerline as the reference is the proposed method discussed in this chapter.

DEFINITIONS

CONTROL POINT

The control point for a fill section is the shoulder break. For a cut section the control point is the bottom of a side ditch (**Figure 6-1**). The elevation of these points and the distances from the centerline are required.

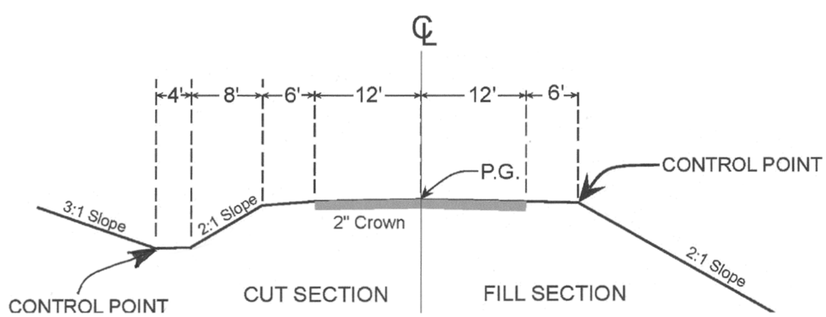


Figure 6-1 Control Points

GRADE ROD

A grade rod is defined as the height of instrument (HI) minus the control point elevation.

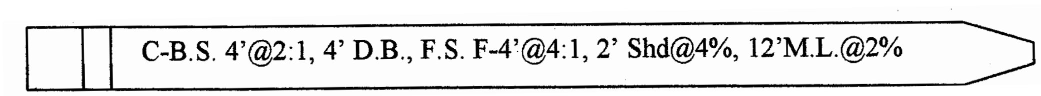
GROUND ROD

The ground rod is the actual rod reading during a trial. The grade rod reading minus the ground rod reading designates whether the section is a cut or fill section.

READING SLOPE STAKES

Historically, slope stakes have been necessary to determine if the roadway is being built to the required lines and grades. The slope stake is the tool that is used to ensure that slopes are graded correctly and fill or cuts are made to the required elevations. The following example explains how to read a typical slope stake.

EXAMPLE



Starting at the slope stake, the following steps are taken:

1. Cut the back slope 4 ft deep at a 2:1 slope.
2. Grade a 4 ft ditch bottom.
3. Go up the foreslope 4 ft at a 4:1 slope.
4. Go 2 ft at a 4 % slope for the shoulder.
5. Go 12 ft at a 2 % slope to the centerline.

The outcome of these steps is presented in the cross section shown in **Figure 6-2**.

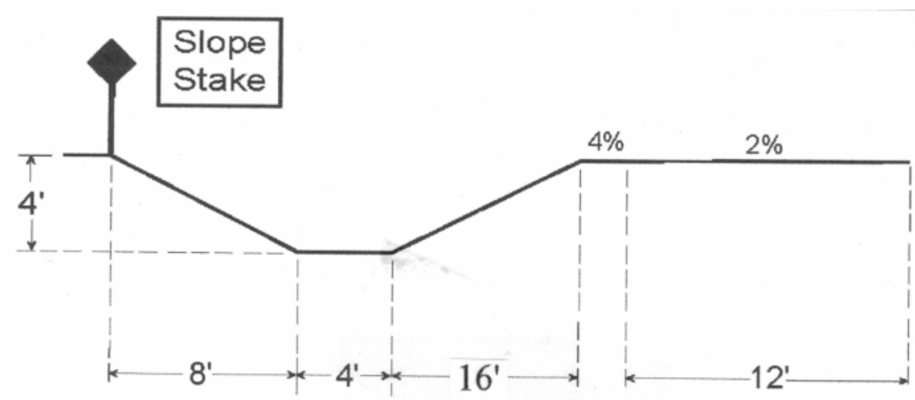


Figure 6-2 Example Slope Stake Grading Cross Section

Chapter Seven: RADIUS POINTS

LAYING OUT RADIUS POINTS FOR DRIVES/APPROACHES

The layout of a radius point may be done by a single person with a steel, fiberglass, or cloth tape. Since a cloth tape is subject to stretching or shrinking, depending upon the age and/or weather conditions, a steel or fiberglass tape is preferred.

LAYOUTS FOR SQUARE DRIVES/APPROACHES

The procedure for determining a layout for a square drive or approach (***Figure 7-1***) is:

1. Determine the point, or station, where the drive or approach and the width of the drive or approach intersect
2. Measure one half of the drive width along the edge of pavement from the intersection and mark this point *A*
3. Measure the radius distance from point *A* along the edge of pavement and mark this point *B*
4. Measure the radius distance from point *B* perpendicularly and mark this point *C*, the *radius point*

To verify, a chaining pin is used to mark point *C*. When the radius is swung from this point, it should intersect the edge of pavement and the edge of the drive, in which case a hub with a nail should be set to mark the radius point *C*. If the radius does not fit, point *C* may be adjusted by moving the chaining pin and rechecking until the above criteria are met prior to driving the hub. After the hub is set, the *drive radius* can be determined by hooking the end of the tape over the nail (***Figure 7-1***).

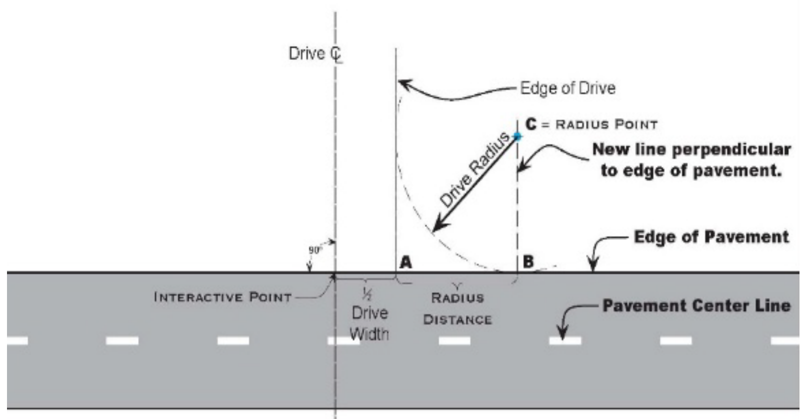


Figure 7-1 Radius Layout for Square Drive/Approach

LAYOUTS FOR SKEW DRIVES/APPROACHES

Driveways and approaches on skew angles are determined as indicated in ***Figure 7-2***.

Examples of drives and approaches can be found in these Standard Drawings:

- **E 610-DRIV**
- **E 610-PRAP**

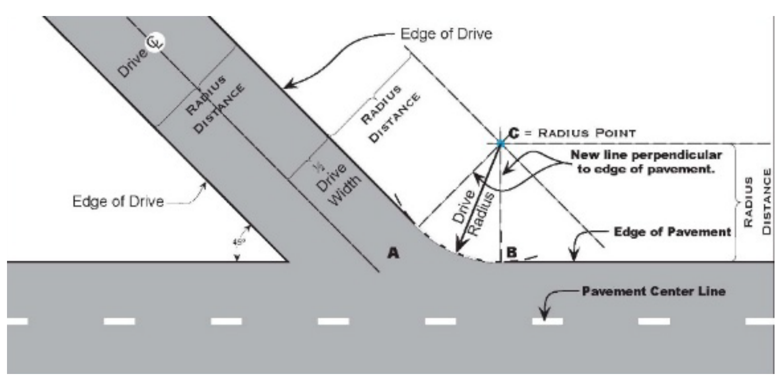


Figure 7-2 Drive/Approach on Skew Angle

Example

A new road is being constructed in an East-West direction. A Class II Drive intersects the new pavement on the north side at Station 49+75 at a 90 degree angle. The radius is 15 ft on the west side and 25 ft on the east side. The drive width is 14 ft, the lane width is 12 ft and there is no paved shoulder. Stationing increases from west to east. Find the station and offset of the radius points.

Solution:

1. Locate the Drive ℄, Station 49+75, on the north edge of pavement
2. Measure one half the drive width, $\frac{14\,ft}{2} = 7\,ft$, in each direction from Station 49+75:
    a. $[\text{STA. } 49{+}75] - 7\,ft = [\text{STA. } 49{+}68]$ (to west of drive)
    b. $[\text{STA. } 49{+}75] + 7\,ft = [\text{STA. } 49{+}82]$ (to east of drive)

    Mark these points A_{west} and A_{east} to use for sight lines.
3. Add the radius distances to the 7 ft previously measured:
    a. $15\,ft + 7\,ft = 22\,ft$ from drive ℄ on west side
    b. $25\,ft + 7\,ft = 32\,ft$ from drive ℄ on east side

    Mark these points B_{west} and B_{east} on the edge of the mainline pavement
4. Use the distances from the previous step to determine the stations of the radius points:
    a. $[\text{STA. } 49{+}75] - 22\,ft = [\text{STA. } 49{+}53]$ (to west of drive)
    b. $[\text{STA. } 49{+}75] + 32\,ft = [\text{STA. } 50{+}07]$ (to east of drive)
5. Calculate the offset for radius points using the radius and lane width:
    a. $12\,ft + 15\,ft = 27\,ft$ LT offset for C_{west}
    b. $12\,ft + 25\,ft = 37\,ft$ LT offset for C_{east}
6. Mark radius points C_{west} and C_{east} using the determined stationing and offset

Swing in the radius for each side and check that it just intersects the Edge of Drive line, 7 ft from the Drive ℄, on the right and left of the driveway

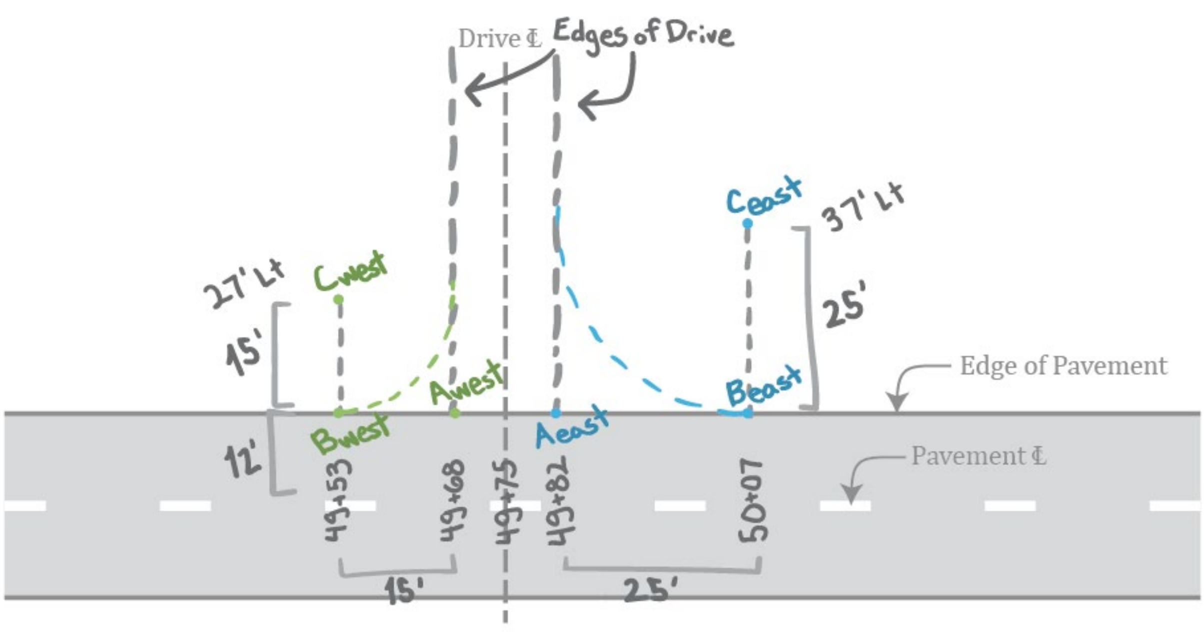


Figure 7-3 Solution to the Example

APPLICATION OF DRIVES AND APPROACHES

TURN LANES

Turn lanes are used in conjunction with Public Road Approaches *Type C* and *Type D* as indicated on Standard Drawings **E 610-PRAP**. The lengths of the tapers and turn lanes depend on the designed speed of the mainline pavement, the angle of intersection, and the intersecting approaches traffic count. The Standard Drawings include tables for determining the required distances given the design speed, vertical roadway grade, and angle of intersection. Distances are measured from the station of the approach intersection, then required offsets are measured and marked so the radius points can be set.

DRIVEWAYS

Driveways are indicated on Standard Drawings **E 610-DRIV**. There are several types of drives, as follows:

CLASS I:	Private Drive, 6" concrete, 10 to 20 ft wide
CLASS II:	Private Drive, 4" HMA, 12 to 24 ft wide
CLASS III:	Commercial Drive, 9" concrete, 20 to 40 ft wide
CLASS IV:	Commercial Drive, 10" HMA or 9" concrete, 20 to 40 ft wide
CLASS V:	Field Entrance (dirt), 24 to 40 ft width (minimum 32 ft desirable)
CLASS VI:	Heavy Industrial & truck stops, 10" HMA or 9" concrete, 32 to 50 ft wide
CLASS VII:	Heavy Industrial & truck stops (w/ curb/gutter), 10"HMA or 9" concrete, 32 to 50 ft wide

Using the class, station number, and width of the drives as given in the approach table in the plans, radius points may be set and the drives marked out as previously discussed.

MAILBOX APPROACHES

Standard Drawings **E 610-MBAP** list approaches for driveways and mailboxes. There are three types of approaches indicated in these Standard Drawings:

1. Typical Mailbox (no nearby associated drive)
2. Combination Mailbox & Drive, Mailbox Located in Advance of Drive
3. Combination Mailbox & Drive, Mailbox Located Beyond Drive

The width of the approach varies according to the traffic volume, or *ADT*, of the road. Low traffic volume width is used only when the design speed is less than or equal to 45 mph.

Approaches are a minimum 8' wide when ADT < 1500 and 10' wide when ADT > 1500.

Most HMA resurface contracts have approach widths of 8 ft maximum. On some older roads, mailbox approaches may be only 2 ft wide.

Required dimensions are given on the Standard Drawings. For new construction, approaches may be marked out using the stations given in the plans' approach table with dimensions from the Standard Drawings. Adjustments may be made for approaches to match existing driveways. On resurface contracts, stationing for driveways and mailboxes are not given and must be marked out to match what exists in the field.

Chapter Eight: PIPE STRUCTURES

Proper placement and backfilling of pipe structures is critical for maintaining the base support for the pavement placed over the pipe, and for providing correct loading of the pipe for structural integrity. This chapter discusses installation methods for pipe and sewer work.

All installed pipes must be supplied and constructed according to the contract documents and plans, including the relevant edition of INDOT Standard Specifications as indicated in the CIB. Pipes shall have all necessary certifications and tests and must be sourced from an approved supplier. The supplier must be a Buy America and Build America source as specified.


Cured In Place Pipe Liner


Slip Lined Pipe Liner


Reinforced Concrete Pipe


Round Corrugated Metal Pipe


Corrugated Thermoplastic Pipe


PVC Pipe


Arch Pipe


Elliptical Pipe


Structural Plate Pipe


Smooth Wall Thermoplastic Pipe

PIPE TYPES

Pipe is specified by types, according to the pipe use, as set out in the Standard Drawings and Standard Specifications.

Type 1 - Placed under mainline or public road approaches
Type 2 -Used for storm sewers
Type 3 - Placed under all drives and field entrances
Type 4 - Used for drainage tile and longitudinal underdrains
Type 5 - Used for broken-back pipe runs where coupled or joined pipe is desirable.

In addition, *Slotted Drain pipe*, *Slotted Vain Drain pipe*, *End Bent Drain pipe*, *Underdrain Outlet pipe*, *Grated Box End Sections, Pipe End Sections*, *Roadway Drain Casting Extensions*, *Drainage pipe through Masonry* and *Bridge Deck Drain Systems* are commonly used pipes.

E715	MPCA	01	Multiple Pipe Concrete Anchors	Multiple Pipe Concrete Anchors	1/2/98
E715	MPCA	02	Multiple Pipe Concrete Anchors	Multiple Pipe Concrete Anchor	1/2/98
E715	MPES	01	Metal Pipe End Section	Metal Pipe End Section	1/2/98

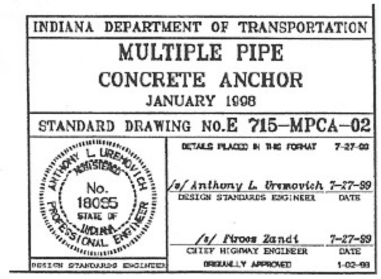


Figure 8-1 Standard Drawing

Each pipe type lists the required materials and their abbreviations (***Figure 8-1***).

- If only a type is listed, the contractor may use any material meeting that type's requirements.
- If a specific material is listed (e.g., Reinforced Concrete Pipe), that material must be used.

Always check the effective date on Standard Drawings. The date must be the most recent September 1st before the contract letting date (e.g., for a May 5, 2024 letting, the effective date is September 1, 2023).

Besides listing pipe materials, the Standard Drawings list notes for cover limits and other installation information. Standard Drawing **E 715-PIPE-01** is checked for the pipe type listing table. Construction details shall be in accordance with Standard Specifications Section **715**.

PIPE END TREATMENTS

There are several different types of pipe end treatments being used. The Technician needs to know which type is required for each structure because some pipe end treatments affect the length of pipe necessary for construction. The standard drawings indicate details for each type of pipe end treatment. The pipe end treatments used are as follows:

1. Anchors
2. Pipe end sections
    a. Metal
    b. Precast concrete
3. Safety metal end sections
4. Grated box end sections

GRATED BOX END SECTION

If a grated box end section (GBES) was being used on the same type of slopes, there would be 6 ft less pipe on each end of the pipe structure.

STRUCTURE DATA TABLE

The structure data table is a summary table at the end of the plan set that shows many important details for all the pipe structures on the project. Some of the details found in the table are:

1. Station
2. Diameter
3. Pipe Type
4. Structure Type
5. Pipe Length
6. Backfill Method
7. Backfill Quantity
8. Type of Pipe End Treatment

Construction details shall be in accordance with Standard Specifications Section **715.03**. The inspector must review all of the pipe and structure locations prior to installation to verify there are no errors in the table. Any possible problems should be reported to the PEMS.

In new construction, most structure lengths may be paid for at the listed lengths in the structure data table after verifying in the field. Take special note of locations for Tees or Elbows.

In addition to the Structure Data Table, most plan sets include a Pipe Material (Summary) Table that details the pipe structure number, pipe type, along with shape, class, D-load rating, whether the pipe is smooth wall, and what the Max Dr rating is. Deviations from this plan sheet should be approved ahead of time by the Engineer.

The remarks column is used for special notes for certain structures.

Structure lengths are affected by the following:

1) Pavement width
2) Slope
3) Horizontal skew
4) Vertical skew
5) Type of end treatment

Following are two examples (***Cross-Section View*** and ***Skew***) of how structure lengths may be affected. When calculating the length of required pipe, the final value is required to be rounded up. Assume that metal pipe end sections are being used.

CROSS-SECTION VIEW

Assuming no end sections are in place. ***Figure 8-2*** indicates an example of a cross-section view of a pipe. The total pipe length would be 164.7 ft on a horizontal distance. On structures with significant fall, the slope length of the structure is also required to be determined and may be computed like a right triangle.

Flowline up 682.00 – flowline down 673.5 = 8.5 ft fall

$$\sqrt{(8.5)^2 + (164.7)^2)}$$ = 164.92 adjusted length.
Length of pipe required would be 165 ft.

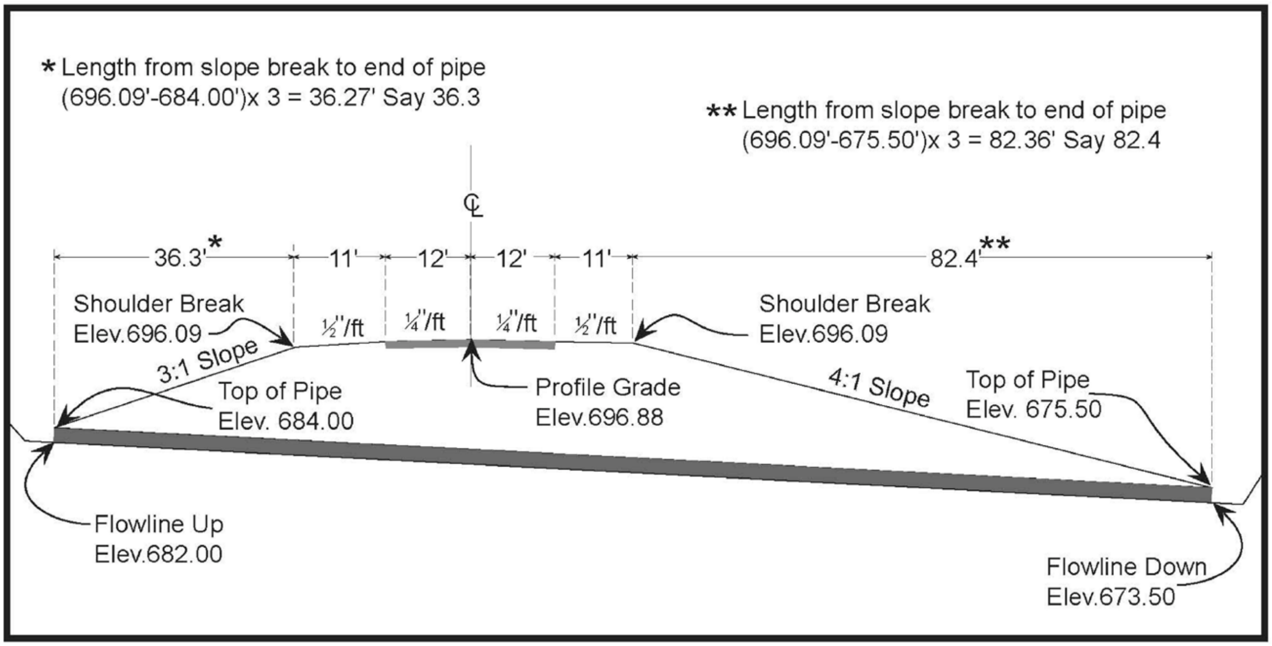


Figure 8-2 Pipe Cross Section View

SKEW

Sometimes structures are placed on a skew rather than right angles to centerline. This placement adds another adjustment to the structure length computations.

Using the typical section in ***Figure 8-3***, the effect of a skew on the structure is indicated below.

The length of pipe may be computed using trigonometric functions. In this example, the length is C / Cosine of the skew angle:

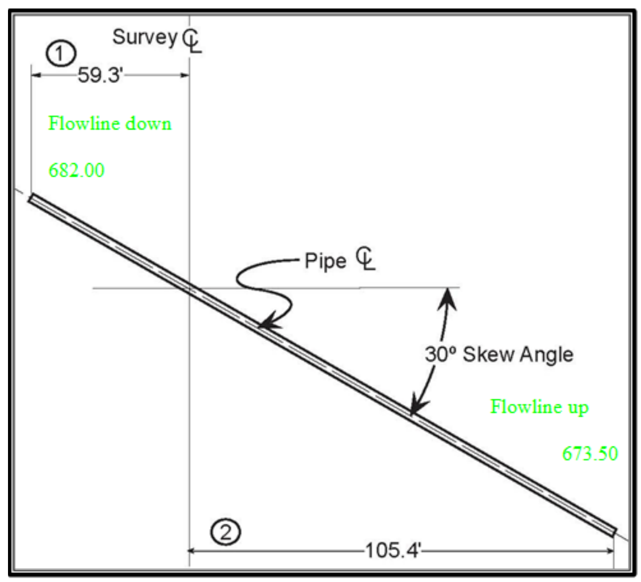


Figure 8-3 Skew

1) 59.3 ft / Cosine 30° = 68.47 ft (Say 68.5 ft)

2) 105.4 ft / Cosine 30° = 121.7 ft (Say 121.7 ft) Skew length = 190.2 ft

3) Adjustment for flowline fall:

Adjustment for flowline fall: $\sqrt{((8.5)^2 + (190.2)^2)} = 190.39$ ft – Say 190.4 ft

BASIS OF USE FOR PIPE MATERIALS

Pipe materials shall be in accordance with Standard Specifications Sections **715**, **907**, **908**, and other applicable sections. Different types of pipe materials have different requirements.

For all pipe materials, regardless of whether or not it is required to be furnished from a manufacturer on the QPL, a Buy America or Build America certification, whichever is applicable, shall be provided for the metal in accordance with Section **916** or as stated herein.

THERMOPLASTIC PIPE

In accordance with Section **907.16**, a QPL of Thermoplastic Pipe and Liner Pipe Sources will be maintained by the Department. The QPL will specify the manufacturer and thermoplastic pipe designation in accordance with Sections **907.16** and **907.24**.

Pipe requirements are shown in the table, *Summary of Thermoplastic Pipe Specification Requirements*, in Section **907.16**, which includes references to Standard Specifications, AASHTO, ASTM, ITMs, and others. Only materials meeting these requirements and supplied by qualified manufacturers will be accepted.

The manufacturer shall become qualified by establishing a history of satisfactory quality control of these materials as evidenced by the test results performed by the manufacturer's testing laboratory. For any pipe materials not listed in the table, refer to the Standard Specification sections listed above as applicable.

METAL PIPE

In accordance with Section **908.01**, a QPL of Metal Pipe Sources will be maintained by the Department. The QPL will specify the manufacturer and pipe designation.

The manufacturer is defined as the plant which produces the metal pipe or pipe-arch. Pipe material required, and not required, to be furnished from a manufacturer on the QPL are listed in the table, *Summary Of Metal Pipe Specification Requirements*, in Section **908.01**. References to Standard Specifications, AASHTO, ASTM, ITM, and other requirements are listed in the table.

The manufacturer shall establish and maintain a history of satisfactory quality control of these materials. This history will be based on achieving and maintaining a "Compliant" status with the AASHTO PEAS program in accordance with **ITM 806**, **Procedure O**.

For any pipe materials not listed in the table, refer to the Standard Specification sections listed above as applicable. See Section **908** for material requirements. For all pipe materials, regardless of whether or not it is required to be furnished from a manufacturer on the QPL, a Build America, Buy America (BABA) Certification, whichever is applicable, shall be provided for the metal in accordance with Section **916** or as stated herein.

For metal end sections and structural plate pipe, pipe-arches, and arches, aluminum alloy and steel, the fabricator's certification-other shall contain the information listed in Section **908.05**.

CONCRETE PIPE

Precast concrete units shall be from a source listed on the QPL of Certified Precast Concrete Producers, in accordance with **ITM 813**. Precast concrete products shall be marked with the *date of manufacturing*, *Department identification number*, and one of the following *certification identification markings*: *ACPA*, *NPCA*, or *PCI*.

- **ACPA** - "QCast" emblem or "ACPA Certified Product"
- **NPCA** - "NPCA Certified Product"
- **PCI** - "PCI certification" emblem or "PCI Certified Product"

CONCRETE END SECTIONS (AND ANCHORS)

Precast reinforced concrete end sections shall be in accordance with Section **905.06**.

OTHER ITEMS

Precast concrete GBES shall be from a source listed on the QPL of Certified Precast Concrete Producers, in accordance with **ITM 813** the same as for concrete pipe.

Chapter Nine: PIPE PLACEMENT

EXCAVATION

Unless otherwise directed the trench cross sectional dimensions are required to be as indicated on the plans. The trench bottom gives full support to the pipe. Recesses are cut to receive any projecting hubs or bells on concrete pipe.

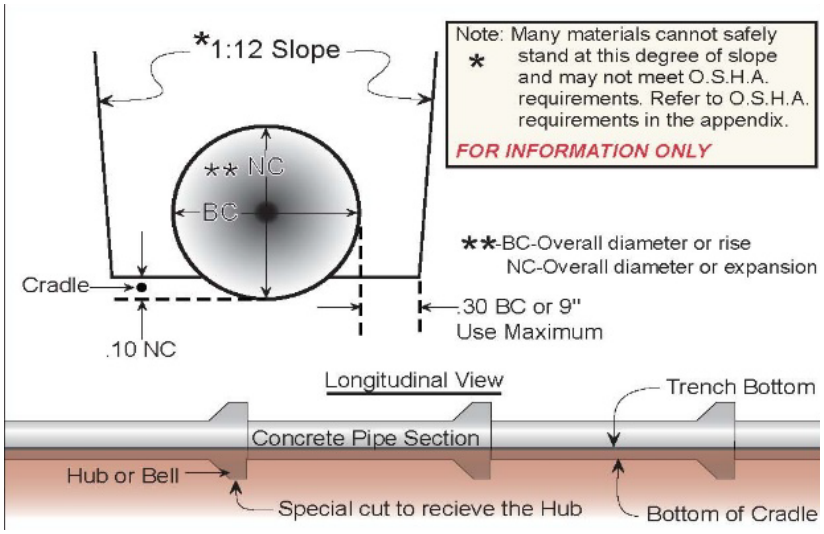


Figure 9-1 Pipe Excavation

Figure 9-1 indicates some basic trench requirements. These are also indicated on Standard Drawings **E 715-BKFL-01 through E 715 BKFL-10**. Construction details shall be in accordance with Section **715.04**.

Pipes trenches in fill areas are excavated only after the fill elevation is to a height equal to the top of the pipe plus the minimum cover on the pipe.

- NC & BC measurements can be found on the pipe manufacturer's website.
- NC & BC should be measured to the outside of the pipe.

Consider whether the pipe has corrugations or a thick wall that might not be included in the item description. A 12 in. pipe might actually have a 12.75 in. outside diameter when determining the needed backfill amount.

For structures for which the plans show pipes of differing sizes for either smooth, semi-smooth or corrugated interiors, and either the semi-smooth corrugated interior alternate is installed, measurement and payment pipe backfill, structure backfill or flowable backfill will be based on the neat line dimensions shown on the plans for the smooth interior alternate.

Designers may utilize '*Pipe-Backfill Calculation Software*' on INDOT's website located at:
https://www.in.gov/dot/div/contracts/standards/

The software can be used to determine the Planned backfill amount for culvert cross pipes. Trench pipes for storm drains require the calculations per neat lines as shown in the standard drawing series **E 715-BKFL**.

Inspectors need to consider the Standard Drawings and what Backfill Method is required, while also using INDOTs software on the website to determine the actual placed backfill amount. *Refer to Chapter 12 for additional information on Backfill.*

ROCK EXCAVATION

When rock or boulder formation is encountered during trench excavation for the pipe at or above the required trench bottom elevation, the rock shall be removed to at least 8 in. below the proposed grade, backfilled with structure backfill to bring the pipe to the proper flowline, and compacted in accordance with Section **211.04**.

UNSUITABLE MATERIAL

If soft or unstable material is encountered at the required flowline elevation (***Figure 9-2***), such material is required to be removed and replaced with suitable material, typically B-Borrow, compacted, and properly shaped to produce a uniform and stable foundation along the entire length of the pipe.

Figure 9-2 Figure 9-2 Removing Unsuitable Material

EXCESS EXCAVATION PAYMENT

Cut volumes and B borrow for replacing soft areas are required to be recorded. If a pipe structure is lowered, relocated, or if unsuitable material is encountered so that additional excavation is necessary over and above that shown on the plans at the original location, such additional excavation will be paid for at three times the contract unit price for the class of excavation involved.

If the contract does not include rock excavation or unclassified excavation, rock removal below the proposed trench bottom elevation will be paid for at three times the contract unit cost for common excavation.

In each of the above cases, such excavation will not be paid for if the additional amount involved at such structure is 10 cu yds or less.

REMOVAL OF EXISTING STRUCTURES

Removal of an existing structure is included in the cost of a new structure item unless a special item is included for the removal. This procedure consists of removal of pavement, existing pipe, end sections, anchors, headwalls, concrete collars, encasements, and disposal of surplus materials, to outside the limits of excavation for the new structure.

SAFETY

A special concern for safety is required for deep pipe trenches. The Contractor is required to have the necessary safety equipment available such as safety boxes in deep pipe or sewer cuts and/or sheeting or shoring as directed by safety requirements.

Figure 9-3 Trench Box Safety

LAYING PIPE

STRUCTURE BEARING

Each section of pipe is required to have full firm bearing throughout its length, true to the line and grade given. All pipes which settle or which are not in alignment shall be taken up and re-laid at no additional cost. Pipe shall not be laid on a frozen trench bottom.

LAYING CONCRETE OR CLAY BELL PIPE

When laying concrete or clay pipe, the hub or bell end is required to be placed up-grade with the spigot end fully inserted into the next hub and with all ends fitted together tightly. Concrete pipe shall not be laid in muck or sulphate soils.

Except for circular concrete pipe, pipe joints designed to accommodate seals or pipe joints requiring seals are sealed with approved rubber type gaskets, caulking, pipe joint sealant, electrometric material, or sealing compound. Circular concrete pipe joints shall utilize rubber type gaskets.

If infiltration of water is a factor, each joint, regardless of the type used, is required to be sealed with a compression type joint sealer in accordance with **ASTM C425** or **ASTM C443**, whichever is applicable.

THERMOPLASTIC PIPE

Joints and stub-tee connections for thermoplastic pipe shall be in accordance with the requirements of the respective material specifications for each type of pipe. Connections of thermoplastic pipe to manholes, catch basins, and inlets shall be in accordance with the manufacturer's recommendations.

METAL PIPE

Prior to placing corrugated metal pipe, the sections are required to be checked for the proper fit. Sections shall be examined closely and so fitted that they will form a true line of pipe when in place. Sections which do not fit together properly shall not be used since they could easily leak. This may be a problem on spiral pipe because some Suppliers cut sections to lengths and the end cuts are not square cut. Pipe sections are joined with approved band couplers for **AASHTO M 36 Type I** and **Type II**, and **Type 1A** and **Type IIA**, and corrugated steel pipe and pipe arches per Section **715.06**. Couplers for Type IR ribbed steel pipe shall be in accordance with **AASHTO M 36** and the manufacturer's recommendations per Section **715.06**.

When placing riveted corrugated metal pipe, the section laps are required to be placed downstream.

Figure 9-4 Corrugated Metal Pipe

JOINING PIPE WITH COLLARS

At the connection of a pipe extension to an existing structure where the joint system of the pipe extension differs from that in place, different types of pipe are connected, or if a satisfactory joint cannot be obtained between the two structures a concrete collar is required to be constructed. At the connection of two different types of pipe, if not shown on the plans, the collars are required to be at least 18 in. wide and 6 in. thick around the entire joint.

If rigid pipe connections are of lesser strength than that of the main barrel of a pipe structure, these connections shall be encased in concrete at least 6 in. thick.

STUB-TEE CONNECTIONS

At locations indicated on the plans or where directed, a stub-tee connection of the size required is furnished and connected to the pipe type specified. The pipe type may include corrugated metal pipe, corrugated metal pipe-arch, concrete pipe, reinforced concrete pipe, or reinforced concrete horizontal elliptical pipe.

METAL PIPE

The stub-tee connection to a corrugated metal pipe, ribbed metal pipe, or corrugated metal pipe-arch shall be constructed of corrugated or ribbed metal and the length of the stub shall be no less than that which readily accommodates the connecting band. It shall be made by shop welding a stub of corrugated or ribbed metal pipe to the respective corrugated metal pipe or pipe-arch or ribbed metal pipe at the time of fabrication.

Where field conditions warrant, stub-tee or other connections may be field connected by using shop fabricated saddle connectors. Welds, flame cut edges, and damaged spelter coating shall be re-galvanized or painted with zinc dust-zinc oxide paint in accordance with Federal Specification **TT-P-641**, **Type II** or **MIL-P-21035**.

Where applicable, damaged bituminous coating shall be repaired with asphalt mastic in accordance with **AASHTO M 243**. The pipe connection to the stub shall be made by means of connecting bands of required size or by means of concrete collars as directed.

CONCRETE PIPE

The stub-tee connection to concrete pipe, reinforced concrete pipe, or reinforced concrete horizontal elliptical pipe may be field constructed or factory constructed. The concrete used in the stub shall be of the same proportions as that used in the construction of such pipe. The length of the concrete stub shall be no less than 6 in. and no more than 12 in. The pipe connection to the concrete stub shall be made by means of a cement mortar bead or concrete collar or as directed.

PIPE END TREATMENTS

Pipe anchors, end sections, grated box end sections, and safety metal end sections shall be constructed as shown on the plans or as directed.

The pipe end treatments that may be used include:

1. Pipe anchors
2. Pipe end sections
3. Grated box end sections
4. Safety metal end sections

PIPE ANCHORS

Straps or hook bolts required for anchors shall be as shown on the plans *or standard drawings*. Anchor straps shall be placed at both the upstream and downstream end of each corrugated aluminum alloy, corrugated steel, structural plate pipe, or pipe-arch with a diameter or span of 42 in. or greater. Hook bolts and anchor straps shall be placed at both the upstream and downstream end of each corrugated aluminum alloy, corrugated steel, structural plate pipe, or pipe-arch with a diameter or span of 84 in. or greater.

Standard Drawing **E 715-ANCH-01** and **E 715-ANCH-02** are the Concrete anchor table. Standard Drawings **E 715-MPCA-01** and **E 715-MPCA-02**, **E 715-PAHB-01**, and **E 715-PASD-01** indicate different sizes and measurements for pipe anchors, which are mainly used on larger pipe. They prevent water flow from undermining the pipe ends, causing settlement or wash outs.

Pipe anchors are poured in place using class A concrete and are held to the pipe by either anchor bolts or straps, where required per standard drawings for metal pipe.

PIPE END SECTIONS

Standard Drawings **E 715-MPES-01** through **E 715-MPES-03** and **E 715-PCES-01** indicate different pipe end sections that are available in either metal or precast concrete. Metal pipe end sections connect to the pipe by a strap band or a ring type bolt that draws the end section tight to the pipe. These units have a toe wall that is placed in a cut trench and backfilled. This toe wall serves the same purpose as an anchor which is to keep water from undermining the pipe.

A dimpled connection band shall be used for connecting pipe end sections and safety metal end sections to ends of corrugated metal pipe whose end corrugations are not perpendicular to the centerline of the pipe.

Precast concrete end sections are designed for use on concrete pipe. The inside of the end section is grooved to accept the spigot end of the pipe. After the precast pipe end section is placed, an anchor is poured using class A concrete. The anchor has hook bolts extending through the end section floor and is secured by nuts and washers.

GRATED BOX END SECTIONS AND SAFETY METAL END SECTIONS

Grated box end sections and safety metal end sections are used to provide a safety slope over the structure opening. Safety metal end sections are detailed on Standard Drawings **E 715-SMES-01 through E 715-SMES-12**, and grated box end sections on Standard Drawings **E 715-GBTO-01 through E 715-GBTO-08,** and **E 715-GBTT-01 through E 715-GBTT-06**. There are two basic types of grated box end sections: Type I and Type II.

GBES TYPE I

Type I grated box end sections (***Figure 9-6***) are used on cross-pipes under the roadway or other structures perpendicular to the direction of traffic. These units are constructed to the same slope as the embankment they fit into and have a tubular type grating which supports vehicles traveling across them

GBES TYPE II

Type II grated box end sections (***Figure 9-5***) are used where the end of a structure is facing incoming traffic. They are built to flatter slopes and have a crossbar grating for vehicle support.

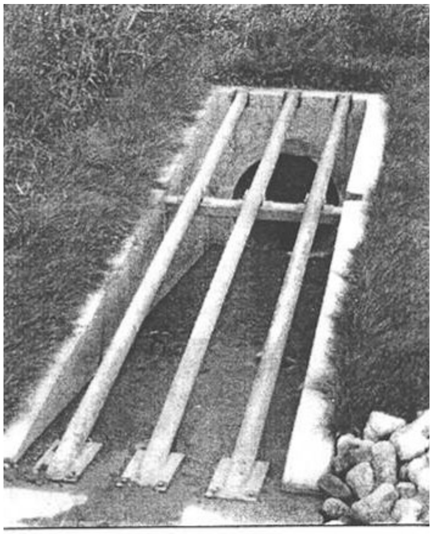


Figure 9-6 GBES Type I

Figure 9-5 GBES Type II

Both Type I and Type II units may be either precast or constructed in place. A 6 in. aggregate leveling bed is required for precast units which shall be coarse aggregate No. 8 in accordance with Section **904.03**. Per the standard drawings, weep holes are installed in sides of the structure. Hardware cloth is used to cover the weepholes which shall be plastic with 1/4 in. mesh or galvanized steel wire No. 4 mesh with a minimum wire diameter of 1/32 in. It shall be firmly anchored to the outside of the structure and shall be centered on the holes. The structure is partially Backfilled with porous aggregate. This procedure allows ground water to filter in through weepholes. Precast units have a toe wall that is poured with class A concrete. Constructed in place units are poured with class A concrete and reinforcing steel with a toe wall as designated in the Standard Drawings. If precast units are used and the adjoining pipe is to be field connected directly to the precast unit, the connection shall be made using a Class A concrete collar of 6 in. minimum longitudinal and radial thickness. Refer to the standard specifications and the standard drawings for more information.

Chapter Ten: MEASUREMENT AND PAYMENT OF PIPE ITEMS

PIPE MEASUREMENT

Pipes are paid for by the linear measurement as specified in Section **715.13** and **715.14** and measured from outside of manhole to outside of manhole. For pipes connecting to inlets and catch basins, the pipes are also measured to the outside face of the structure. The accepted quantities of pipe and pipe extensions will be paid for at the contract unit price per linear foot for pipe of the type, shape, and size specified, complete in place.

The length of beveled or skewed terminal sections of circular corrugated or ribbed metal pipe to be measured for payment will be the average of the top and bottom centerline lengths for beveled ends or of the sides for skewed ends. Measurement of deformed pipe will be made along the bottom centerline of the pipe.

Where used other than as a roadway drain extension pipe or as a bridge deck drain system, cast iron soil pipe will be measured by the pound based on the theoretical weight shown on the plans, and will be paid for at the contract unit price per pound for the specified diameter. Roadway drain extension pipe will be measured per each drain extended, and will be paid for at the contract unit price per each. Pipe used as drainage pipe through concrete masonry or pipe used for bridge deck drainage system will not be measured for payment.

Excavation above the trench bottom elevation shown on the plans will not be measured for payment. Additional excavation below the proposed trench bottom elevation required to install the pipe at a lower elevation or to remove rock or unsuitable material will be measured in accordance with Section **203.27(b)** and paid for in accordance with Section **203.28**.

Concrete used for backfill of slotted drain pipe and slotted vane drain pipe will not be measured for payment.

Video inspection for pipe will be measured by the linear foot as determined by the electronic equipment, and will be paid for at the contract unit price per linear foot completed.

TEES, STUB-TEES, AND WYES

Tee, Stub-Tee, and Wye connections are measured along the centerline of the barrel. For making the connection, an additional 5 LFT of the smaller pipe diameter is paid.

ELBOWS

Elbow connections are measured along the centerline of the elbow. An additional payment of 2 LFT of pipe of the same diameter as that of the elbow will be included for each elbow connection.

OTHER CONNECTIONS

Other connections, such as size increasers or reducers, are measured for length and paid for as the larger diameter pipe size specified.

ANCHORS

Pipe anchors are measured and paid by the number of units of each size installed, at the contract unit price per each for the size specified, complete in place. The size will be considered as the nominal diameter of the pipe to which they are attached. A concrete anchor attached at one end of twin pipes will be measured and paid for as two concrete anchors. A concrete anchor attached at one end of triple pipes will be measured and paid for as three concrete anchors.

Reinforcing bars, straps, and hook bolts used in anchors will not be measured for payment. They are included in other costs.

PIPE END SECTIONS AND SAFETY METAL END SECTIONS

Pipe end sections, metal or precast concrete, and safety metal end sections are measured and paid for by the number of units of each size installed, at the contract unit price per each for the size specified, complete in place. The size will be considered as the nominal diameter of the pipe to which they are attached. As an example, 15 in. metal end sections are required to fit a 12 in. concrete pipe.

GRATED BOX END SECTIONS

Grated box end sections are paid for each, by the pipe size, surface slope, and type specified.

COMPUTING STRUCTURE LENGTH USING ELBOWS

Sometimes structures use elbows or bends to decrease the depth of cut in large fills. The following example displays the proper method for computing pipe lengths when bends or elbows are used.

[See an example on the following page.]

EXAMPLE

E-7 Inlet inside measure = 2.5 ft/2 = 1.25 ft on ℄ to end of pipe

If elbows = 4 ft measured along ℄:

Section (1)	= 36 ft + 4 ft + 12 ft + 12 ft + 11 ft
	= 75 ft
Section (2)	= 54 ft
Section (3)	= 26 ft
Add Sections	= 75 ft + 54 ft + 26 ft
	= 155 ft
Elbow Length	= 2 elbows @ 4 ft each + 2 connections @ 2 ft each
	= 12 ft
Total Length	= 155 ft + 12 ft
	= 167 ft

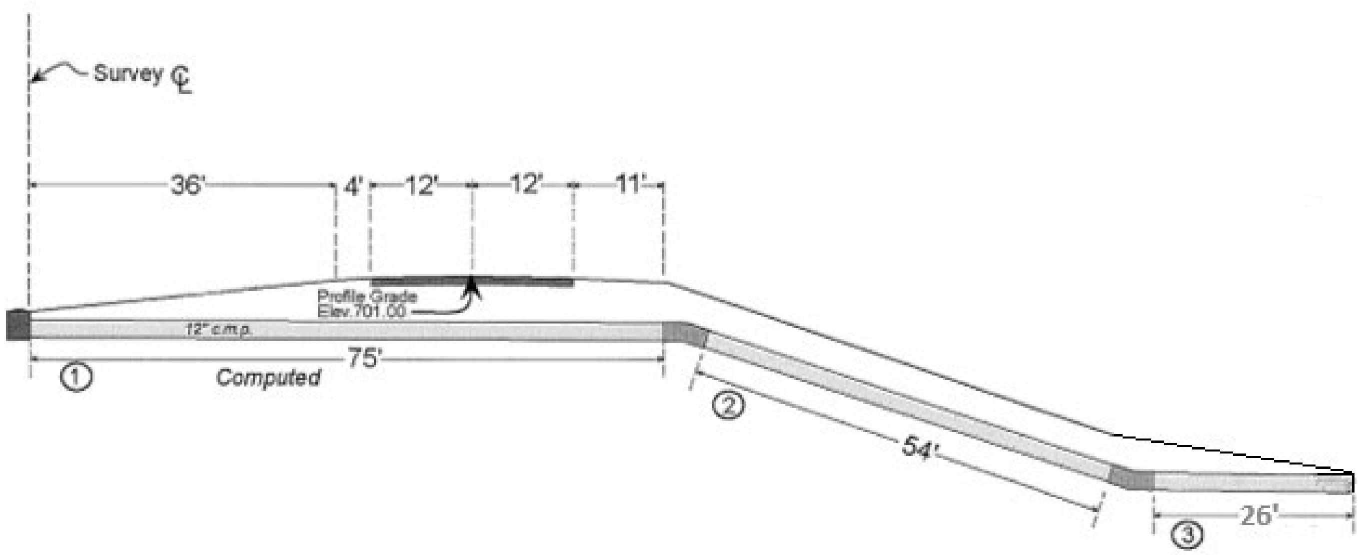


Figure 10-1 Structure with Elbows or Bends

Chapter Eleven: Manholes, Inlets, and Catch Basins

There are numerous types of manholes, inlets and catch basins. Diagrams for each type of structure are shown in Standard Drawings **E 720-CBST-01 through E 720-CBST-09, E 720-CBCA-01, E 720-ICCA-01, E 720-INST-01, E -720-INCA-01 through E 720-INCA-10, E 720-MHCA-01 through MHCA-03**, **E 720-EDCA-01** and **E 720-MHST-01 through E 720-MHST-10** contain diagrams for each type of structure**.** Construction details shall be in accordance with Section **720**.

STRUCTURES

The letter prefix listed in the Standard Drawings for Catch Basins, Inlets, and Manholes as found in the plans represents the structure type such as A, B, C. The number suffix represents the casting type such as 5, 8, 10.

MATERIAL REQUIREMENTS

CONCRETE

Concrete construction is required to be in accordance with Section **702** and reinforcing steel in accordance with Section **910.01**.

Preformed expansion joint material shall be in accordance with Section **906.01**.

BRICK OR BLOCK

Clay or shale brick is required to be in accordance with Section **905.01**. Concrete brick is required to be in accordance with Section **905.02** and concrete masonry block is required to be in accordance with Section **905.03**. Joint filler is required to be in accordance with Section **906.01** and joint mortar is required to be in accordance with Section **901.08** and Section **907.12**.

PRECAST

Precast concrete manholes, inlets, and catch basins are required to be in accordance with Section **907.04**.

CASTINGS

Castings are required to be in accordance with Section **910.05**.

GENERAL REQUIREMENTS

Several types of construction methods are designated for manholes, inlets, or catch basins. Some units may be constructed from brick, block, concrete class A, or precast, when allowed. The materials that are used for each type of structure are noted on the applicable Standard Drawing.

When constructing manholes, inlets, or catch basins in the field, the excavation for the floor slab is required be on firm, stable soil. If soft or yielding spots are encountered at this elevation, they shall be removed, backfilled with suitable material, and tamped into place. If rock is encountered, the rock is required to be removed 6 in. below the bottom elevation and backfilled with approved material tamped to the required elevation.

The manhole bottom shall be constructed of a precast bottom section, or of Class A concrete formed in place. A precast cover shall be placed on a manhole in which headroom is limited.

Material excavated for the structure shall, if suitable, be utilized as backfill. If the excavated material is in excess for use in the work, the excess shall be used in embankment where locations are available or otherwise disposed of as directed. If the excavated material is unsuitable, it shall be disposed of in accordance with Section **201.03**.

Concrete construction shall be in accordance with the requirements for structural concrete. Masonry shall be in accordance with the requirements for the respective type. Exposed corners of concrete shall be rounded to a 1/4 in. radius. Air-entrained concrete will not be required in the precast portions of concrete manholes or catch basins.

BRICK OR BLOCK

Brick or other masonry units are required to be laid with joints not exceeding ⅜ in. If brick is used, at least every 7th course is required to be laid as a header course (***Figure 11-1***).

In the header course, the bricks are turned so that the mortar joint does not run continuously from the top to the bottom of the structure.

Brick or block structures are required to have a ½ in. mortar plaster coat on the inside and outside of the structure, as designated.

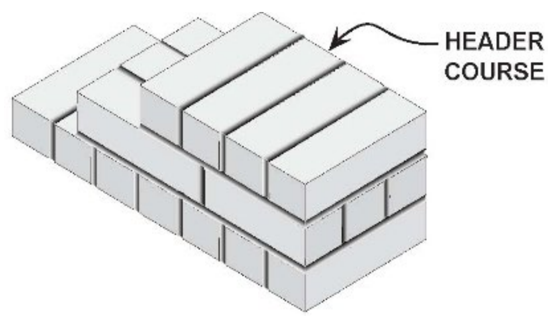


Figure 11-1 Brick Manhole, Inlet or Catch Basin

FRAMES FOR CASTING AND BEARING PLATES FOR MANHOLES

Frames for castings and bearing plates for manholes shall be set in full mortar beds and secured as shown on the plans or as otherwise approved.

GRATES AND CURB BOXES

Grates shall be placed with the maximum dimension of the rectangular opening parallel to the direction of flow. The surface of the grate shall be flush with the top edge of the frame, wingwall, and headwall. The frame shall be galvanized and anchored into concrete. The frame shall be factory assembled with all joints fully welded.

Adjusting slots for curb boxes shall be of the dimensions shown on the plans. One slot shall be located at each end of the curb box, and one slot shall be located at the approximate centerline on the back of the curb box. Galvanized or stainless steel 3/8 in. UNC x 3 1/2 in. round head, square shoulder bolts with one flat washer, one lock washer, and one nut each shall be used in each slot to anchor the curb box to the frame such that the top of the curb box is flush with the top of the curb. Bolts shall be torqued to a minimum of 120 ft lb.

Steel grating Type 12 shall be a galvanized grating which shall be of sufficient strength to support a 12,000 lb wheel load with a maximum fiber stress of 20,000 lb/sq in. The grating shall seat firmly in, but shall not be secured to, the frame. The length and width of the grating shall leave no more than 3/8 in. clearance on each side when placed in the frame. The grating shall be cut so all riveted or welded connections are left intact.

STRUCTURES IN PAVEMENT AREA

When manhole castings are surrounded by concrete pavement, the casting is required to be the same thickness as the concrete pavement and a bearing plate for such casting will also be required. Adjusting rings or steps of alternate types to those shown on the plans may be used subject to approval. Where castings are adjacent to or surrounded by concrete pavement, they are separated from the concrete pavement by using a ⅜ in. minimum thickness preformed joint filler.

If the completed structure is partially or completely under or at its nearest point is within 5 ft of pavement, sidewalks, curbs, gutters, or similar miscellaneous existing or proposed structures, the excavated space not occupied by the newly completed structure shall be filled to the required subgrade elevation with material in accordance with Section **211.02**. Placement of this material shall be in accordance with Section **211.04**.

STRUCTURES OUTSIDE OF THE PAVEMENT AREA

If a manhole is constructed outside the proposed pavement area and outside an area that may be paved at some future date, the height of the casting used shall be at least 7 in. and a bearing plate for such casing will not be required.

If the completed structure is not located partially or completely under or at its nearest point is within 5 ft of pavement, sidewalks, curbs, gutters, or similar miscellaneous existing or proposed structures as set out above for structures in the pavement area, the backfill shall be with approved material which, when compacted, shall meet the required subgrade density.

HOODS FOR CATCH BASINS

Cast iron hoods for catch basins are to be installed in the walls of the structure as shown on the plans or in the Standard Drawings. These are to be placed so that a 6 in. seal is formed. Joints between castings and the structure are required to be made gas tight.

MORTAR MIXTURE

Mortar for laying brick or block is required to be 1 part masonry cement and 2 parts mortar sand. The mortar for plastering a brick or block structure may be the same or may be made using 1 part Portland cement, 1 part hydrated lime and 2 parts mortar sand. The lime should not exceed 10% of the cement.

PRECAST STRUCTURES

The Contractor may precast inlets, catch basins, or manholes, subject to approval. If precast concrete inlets, catch basins, or manholes are used, a layer of structure backfill of minimum thickness of 4 in. shall be used under each unit for ease in positioning. If holes are formed or field cut in precast inlets or catch basins to receive the pipe structures, the pipes shall be connected directly to the precast unit, by means of a Class A concrete collar of a minimum longitudinal and radial thickness of 6 in. When using precast components for a manhole and there is a need in the field to add a pipe opening to the precast component, a new hole shall be cut in the required location. Holes formed or cut in the wrong place shall be plugged satisfactorily with a Class A concrete mixture.

Horizontal joints may be used in the construction of precast catch basins. The Contractor or Supplier is required to submit drawings showing the location of the joints, type of joints, and types of sealers to be used for approval prior to the construction of these units. No joint may be closer than 3 in. above standing water for those catch basins requiring hoods.

Grade and location adjustments to precast inlets and catch basins caused by unforeseen conditions shall be handled as if the units were being cast-in-place. All additional adjustments required due to precasting will not be paid for directly, but the cost thereof shall be included in the cost of the inlet or catch basin.

GRADE ADJUSTMENT TO EXISTING STRUCTURES

ADJUSTING EXISTING STRUCTURES

When grade adjustments of existing structures is specified, the casting frame, covers, or gratings shall be removed and the walls of the structure reconstructed as required. The cleaned frames shall be reset at the required elevation. If an existing casting is unfit for re-use, the casting is replaced with the type specified. If so specified or if it is determined that the existing casting and supporting walls are in good condition, and is of the type required, an approved devise, such as riser or adjusting rings, may be used to adjust the manhole casting cover to the correct grade without reconstructing the walls or resetting the frame. Excavation and backfill shall be done in accordance with Section **720.03**.

REPLACING CASTINGS

If an existing casting is unfit for further use, a new casting shall be furnished with payment at the contract unit price per each for castings of the type specified, furnished and adjusted to the required grade. This payment shall include furnishing the new casting, placing and adjusting it to grade including any necessary removal, construction, or reconstruction not to exceed 12 in. average height of the upper portion of the masonry. This is to include cleaning of the existing structure and keeping the structure clean until the final acceptance of the work.

RECONSTRUCTED STRUCTURES

That portion of a reconstructed structure which exceeds 12 in. in average height will be paid for at the contract unit price per linear foot, for structure, of the type specified, reconstruct, complete in place.

CASTINGS IN PAVEMENT AREA

When manholes, catch basins and inlet castings are adjusted to grade and are to abut existing concrete construction the castings shall be entirely separated from the adjacent concrete by a preformed expansion joint no less than ⅜ in. in thickness. The cost of furnishing and placing the preformed expansion joint material shall be included in the payment for reconstructed catch basin, or reconstructed inlet, or castings furnished and adjusted to grade.

ADJUSTMENT ON RESURFACE CONTRACTS

On resurface contracts the castings shall, unless otherwise directed, be adjusted to grade after the last binder course has been laid and before placing the surface course.

MEASUREMENT AND PAYMENT

Manholes, inlets, spring boxes, and catch basins, both new and reconstructed as applicable, will be measured per each unit, complete in place. Payment, by each, is made for the placed quantity and type specified of manholes, inlets, or catch basins. Castings are paid as each, for the type specified. Castings furnished and adjusted to grade (not exceeding 12" or masonry work) are paid as each for the type specified. The portion of masonry work necessary above a 12 in. average height is paid for by the linear foot and the type of structure specified.

MISCELLANEOUS REQUIREMENTS

Excavation, backfill, reinforcing steel, replacing pavement, and other miscellaneous items necessary to complete the work are not paid for directly, but are included in the cost of the other items.

Chapter Twelve: Structure Backfill and Inspection of Pipes

PIPE TRENCH BACKFILL REQUIREMENTS

The trench for a pipe must be backfilled as indicated on the plans or Standard Drawings with structural backfill or coarse aggregate (Section **211.02**) or flowable backfill (Section **213.02**).

BASIS OF USE

STRUCTURE BACKFILL

The Contractor has the option of providing structure backfill from an established CAPP source (Certified Aggregate Producer Program) or from a local site with the establishment of a CAPP Producer Yard in accordance with Section **917** or using a CAPP Certified Aggregate Technician or consultant on the Department's list of Qualified Geotechnical Consultants for Gradation Control Testing. For material excavated within the project limits, gradation control testing will be performed by the Department if the Contractor is directed to use the material as structure backfill.

The frequency of gradation control testing shall be one test per 2,000 t based on production samples into a stockpile or by over the scales measurement, with a minimum of two tests per contract, one in the beginning and one near the mid-point. The sampling and testing of these materials shall be in accordance with applicable requirements of Section **904** for fine and coarse aggregates.

Structure backfill nominal sizes 2 in. and 1 1/2 in. shall not be used as pipe backfill on any pipe with exterior ribs, corrugations, or other profile.

FLOWABLE BACKFILL

If flowable backfill is to be used, the Contractor may either design their own flowable backfill mix or may choose to use one of the four standard mix designs shown in Section **213.03(a)**. For flowable backfill being placed around a pipe, the mix shall contain a minimum of 150 lb/cu yd of coal ash.

If one of the four standard flowable backfill mix designs in Section **213.03(a)** is used, a trial batch will not be required. The Contractor may still choose to perform a trial batch in accordance with Section **213.05(b)**, if desired.

Per Section **213,04 a, b & c**, in order to produce a workable mixture, flowable backfill mix criteria include a flow consistency measurement in accordance with **ASTM D 6103**, a lightweight dynamic cone penetrometer blow count number in accordance with **ITM 216**, and a removability modulus (RM) test.

To conduct the flow consistency test, a 3 in. diameter by a 6 in. cylinder is placed on a smooth level surface and filled to the top with the flowable backfill. The cylinder is quickly pulled straight up and the mortar spread measured. The diameter of the mortar spread is required to be at least 8 in.

The lightweight dynamic cone penetrometer (DCP) test requires determination of the blow count penetration resistance of flowable backfill, after a 3 day cure, to assess the strength of the material. Removable flowable backfill shall have a penetration resistance blow count of not less than 12 nor greater than 30. Non-removable flowable backfill mixes shall have an average penetration resistance blow count greater than 30.

The removability modulus test is used to calculate the removability modulus (RM) of the flowable backfill. If the RM is calculated at 1.0 or less, the flowable backfill is classified as removable.

After all test results have been reviewed for compliance with the specifications, a mixture number will be assigned by the DTE.

Per Section **213.07**, flowable backfill is not to be placed on frozen ground and is required to be protected from freezing for 72 hours. Flowable backfill may not be loaded or disturbed by construction until the above DCP test requirements have been met.

BACKFILL METHODS

There are different methods of required backfill, depending on where the pipe structure is located and what the purpose of the structure is. These are indicated on Standard Drawings **E 715-BKFL-01 through E 715-BKFL-10.**

TRENCH DETAILS

The basic trench details are indicated on Standard Drawings **E 715-BKFL-01 through E 715-BKFL-10.**

ROCK

When rock or boulder formation is encountered during excavation for the pipe at or above the proposed trench bottom elevation, the rock shall be removed at least 8 in. below the proposed grade, backfilled with structure backfill to bring the pipe to the proper flowline, and compacted in accordance with Section 211.04.

BEDDING DETAILS

All of the details use structure backfill or flowable backfill bedding for pipe (where pipe is bedded in a soil cradle cut). On Standard Drawings **E 715-BKFL-01 through E 715-BKFL-10** the proper limits and dimensions for backfilling with structural or flowable backfill are indicated.

BACKFILL PLACEMENT

Per Section **715.09**, if a pipe is to be backfilled using one of the flowable backfill options, design calculations shall be submitted in accordance with Section **105.02**, either proving the pipe will not float or detailing the methods that will be taken to prevent the pipe from floating during installation of the flowable backfill.

Structure backfill material is required to be placed in no greater than 12 in. loose lifts and compacted with mechanical compactors to the required density. When compacting structure backfill, the material is required to be within the allowable range of moisture content to obtain the required density. Types 1 through 5 structural backfill are covered in Section **211.03** and compaction requirements are covered in Section **211.04**.

Flowable backfill is required to be uniformly placed up to the fill line as indicated on the plans or Standard Drawing. Before flowable backfill is placed in a trench, all standing water is required to be removed. If removal of water is not possible, structural backfill is required to be used up to an elevation of 2 ft above the ground water.

Figure 12-12-1 Flowable Backfill for Box

METHOD 1 BACKFILL

When a pipe is placed under mainline pavement or under public road approaches, or it is within 5 ft or less of pavement, sidewalk, curbs or gutters, Method 1 Backfill is used. Method 1 requires that flowable backfill or structure backfill be used as backfill for the width of the pavement + 5 ft on each side of the pavement. Method 1 is also used for a distance required to maintain a 2:1 slope from the determined width to the bottom of the pipe structure. Method 1 Backfill for a fill section is indicated on Standard Drawings **E 715-BKFL-01 and E 715-BKFL-02.** Existing trench cut section is indicated in Standard Drawings **E 715-BKFL-03 through E 715-BKFL-05, and E-715-BKFL-09** for a median installation embankment. Proper elevation of backfill material is maintained as indicated in the Standard Drawings. The remaining area may be backfilled with suitable materials in layers of not more than 6 in. when inside the slope stake area.

METHOD 2 BACKFILL

When a pipe is placed under commercial or private drive approaches, Method 2 Backfill is used. Method 2 requires that backfill be placed at a height as indicated as indicated on the Standard Drawings, in addition to heights shown on the **715-PHCL** series. The length of the backfill material is the same as Method 1 Backfill. Method 2 Backfill for cut and a fill sections are indicated on Standard Drawings **715-BKFL-06** and **715-BKFL-07**. The remaining area may be backfilled with suitable materials in layers of not more than 6 in. when inside the slope stake area.

METHOD 3 BACKFILL

When a pipe is placed in an existing median trench, Method 3 Backfill is used per Standard Drawing **E 715-BKFL-08**.

OTHER BACKFILL

Where other than special backfill material is required, the material is required to be easily compacted and free of large stones for the portions around and 6 in. above the pipe (***Figure 12-2***).

Figure 12-2 Structural Backfill

BACKFILLING OUTSIDE BACKFILL SPECIFIED LIMITS

If the structure is outside the aforementioned areas, the pipe may be backfilled with suitable material. Where material other than structure backfill is allowed and used for backfilling, it shall be of such a nature that it compacts readily. The portion around and for 6 in. above the top of the pipe shall be free from large stones. The material shall be placed in layers not exceeding 6 in. loose measurement, and each layer shall be compacted thoroughly by means of mechanical tamps.

COVER LIMITS

The proper cover is required to be maintained for heavy equipment to cross pipe structures during construction. The cover requirements are:

1. Up to and including 18 in diameter (Bc) or equal.................................1' - 6" cover
2. Greater than 18 in diameter (Bc) up to and including 54 in diameter (Bc) or equal ....3' - 0" cover
3. Greater than 54 in diameter (Bc) or equal ....4' - 0" cover

In addition to these cover requirements, INDOT Standard Drawing series **715-PHCL** should be reviewed for appropriate height of cover depths with regard to specific pipe types.

RAMPS OVER STRUCTURE FOR PROTECTION

If the minimum amount of cover is not available, the Contractor is required to ramp over with soil to provide the coverage needed to prevent structure damage.

POST-INSTALLATION INSPECTION

After a period of no less than 30 days following backfilling, all pipes except underdrains will be visually or video inspected (***Figure 12-4***). If the pipe cannot be visually inspected, video inspection shall be performed in accordance with Section **715.09** using equipment described in Section **718.07**. The Contractor shall provide project personnel with the inspection video prior to acceptance of the pipe. If mandrel testing is required, the video shall be provided prior to mandrel testing. Mandrel testing is also covered by Section **715.09**. Type 3 pipes in accordance with Section **715.02(c**) are excluded from the mandrel testing and video inspection requirements.

PIPES REQUIRING MANDREL TESTING	
Pipe Material	**Standard Specifications**
Corrugated Polyethylene Pipe*	907.17(b)
Corrugated Polypropylene Pipe	907.19
Profile Wall PVC Pipe*	907.22
* When used as underdrain pipe, mandrel testing will not be required.	

Figure 12-3

Figure 12-4 Van with Video Inspection Equipment

PAYMENT FOR BACKFILL

STRUCTURE BACKFILL

When the contract contains an item for structure backfill, the material is measured and paid for by the cubic yard as computed from the neat lines limits shown on the plans. Standard Drawings **E 715-BKFL** & the method of backfill should be consulted. The backfill calculator available on INDOT's website at www.in.gov/dot/div/contracts/standards or other INDOT approved calculator can be used to determine both planned amounts, and the neat line amount for culvert cross pipes only. Section **715-BKFL-04** is used for storm drain backfill amounts. If neat line limits are not specified for measurement of volume for the material, measurement will be based on the cubic yard at the loading point in truck beds which have been measured, stenciled, and approved.

FLOWABLE BACKFILL

When the contract contains an item for flowable backfill, this material is measured and paid for by the cubic yard as computed from the neat line limits shown on the plans for the type specified. If no neat lines are shown, the cubic yard will be determined based on the batched ticketed amount as delivered to the job.

OTHER ITEMS

Pavement replacement and subbase necessary due to structure placement under an existing pavement will be measured to the neat lines shown on the plans, and will be paid for at the contract unit price per ton of HMA for structure installation of the type specified and per square yard for PCCP for structure installation. Subbase will be paid for in accordance with Section **302.09**. Geotextile used for backfill material will not be measured for payment.

Video inspections for pipe will be measured and paid for at the contract unit price per linear foot completed.

Chapter Thirteen: SLIP LINING OF EXISTING PIPE STRUCTURES

A method of reconditioning existing structures, by which an existing structure is relined with a thermoplastic pipeliner is currently being used. This method consists of installing pipes underground using construction techniques that eliminate open cutting of the pavement or of the ground.

Pipe liners are used for relining existing in-place concrete, vitrified clay, or metal culvert pipe. For pipe liners, the annular space between the liner and the existing culvert is filled with cellular grout. The Contractor is required to furnish and install the liner and grout in accordance with Sections **105.03** and **725**.

Using the methods described above saves costly disruption to traffic, especially in areas where a structure has a high fill over the pipe.

MATERIALS

Where circular liner pipe is shown on the plans, the pipe structure shall be lined with solid wall HDPE liner pipe, profile wall HDPE liner pipe, or profile wall PVC liner pipe. Where deformed liner pipe is shown on the plans, the pipe structure shall be lined with solid wall HDPE liner pipe or profile wall HDPE liner pipe. The maximum number of joints and corresponding maximum length of each section of liner pipe used in each pipe structure to be lined shall be as shown on the plans.

Each type of liner pipe shall either be selected from those shown on the QPL of Thermoplastic Pipe and Liner Pipe Sources or shall be accompanied by a certification in accordance with Section **916**. If the liner pipe is not on the QPL of Thermoplastic Pipe and Liner Pipe Sources, then the certification shall be furnished. The results of the tests listed in **ITM 804** shall be shown in the certification. Liner pipe shall be submitted to the Engineer for review and approval prior to installation.

FREQUENCY MANUAL

Acceptance information for pipe liners is included under Reference 63, INSTALLATION Sub Reference 09 of 12 of the Frequency Manual.

SOLID WALL HDPE LINER PIPE

Solid wall HDPE Liner Pipe shall be in accordance with **ASTM F 714**. Solid wall HDPE liner pipe shall either be selected from a source listed on the QPL of Thermoplastic Pipe and Liner Pipe Sources or a Type A certification in accordance with Section **916**, with the results of the tests listed in ITM 804 shown on the certification, shall be provided for the liner pipe. Solid Wall HDPE Liner Pipe will be considered for inclusion on the QPL by completing the requirements of **ITM 806**, **Procedure Q**. Solid Wall HDPE liner pipe joined using butt fusion shall be in accordance with **ASTM F2620**. Solid wall HDPE liner pipe is a black plastic material. The black appearance is due to the specification requirement that carbon black be used to provide UV resistance. The liner pipe is generally smooth on both interior and exterior.

The liner is also required to have a Standard Dimension Ratio (SDR) equal to 32.5. *SDR* is defined as the ratio of the liner outside diameter to the minimum thickness of the wall of the liner and may be expressed mathematically as:

$$SDR = \frac{D}{T}$$

where:

D = liner outside diameter in inches
T = minimum liner wall thickness in inches

The smaller the dimension, the thicker the wall and generally, the stronger the pipe. Section **907.25(a)** requires a minimum dimension ratio (DR) of 30.0 in accordance with **ASTM F 412** to prevent a wall thickness that reduces the hydraulic capacity. See specifications for further requirements.

A 12 in. section of the liner is required to show no evidence of splitting, cracking, or breaking when compressed between parallel plates to 40 percent of its outside diameter within 2 to 5 minutes. The liner is required to have sufficient rigidity to withstand being placed by either pulling or pushing and exhibit a minimum amount of distortion.

MARKINGS

The print line on Solid Wall HDPE liner pipe should appear every 5 ft or less. The markings include the manufacturer, size, dimension ratio, specification designation, plant code and date of manufacture (***Figure 13-1***).

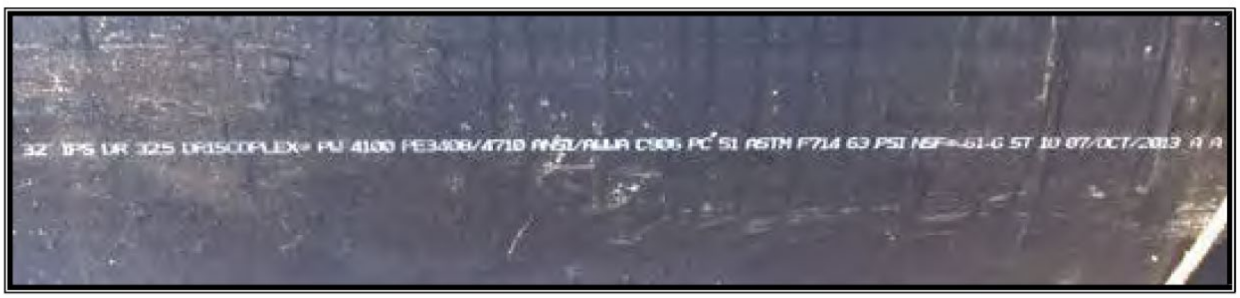


Figure 13-1 Markings on Solid Wall HDPE liner pipe

PROFILE WALL HDPE LINER PIPE

Profile wall HDPE liner pipe is required to be in accordance with **ASTM F 894**. A Type A certification in accordance with Section **916**, with the results of the tests listed in ITM 804 shown on the certification, shall be provided for the liner pipe. The minimum liner ring stiffness constant, RSC, shall be a value of 160 for circular installations and 250 for deformed installations.

Where a deformed HDPE liner pipe is specified, the liner pipe shall be made deformed by using equipment specifically designed to take a circular liner pipe and deform it without causing damage to the liner pipe. The equipment and method used to deform the liner pipe shall be described in the QCP. See QCP requirements under General Requirements.

Once the liner pipe has been deformed, it shall be structurally reinforced in the horizontal and vertical planes. Structural reinforcement shall be spaced at a maximum distance of 3 ft on centers. Structural reinforcement shall not be removed until the installation of the liner pipe and cellular concrete grout at that structure has been completed.

MARKINGS

The print line on Profile Wall HDPE liner pipe should appear every 10 ft or less. The markings include the manufacturer, size, dimension ratio, specification designation, plant code and date of manufacture.

Manufacturer's Name or Trademark	Pipe Diameter, Diameter Basis, and DR/SDR	PE Material Type; indicated by Material Designation or cell classification	Product Standard(s), may include Pressure Rating or Pressure Class	Production Date may also include lot number, footage, and/or Package number	Other Markings can include Resin Codes, 3rd Party Certification codes,

Figure 13-2 Thermoplastic Pipe & Liner Markings

PROFILE WALL PVC LINER

Profile wall PVC liner pipe is required to be in accordance with **ASTM F 949**. A Type A certification in accordance with Section **916**, with the results of the tests listed in ITM 804 shown on the certification, shall be provided for the liner pipe.

CELLULAR CONCRETE GROUT

The cellular concrete grout shall be designed in accordance with **ASTM C869** except as modified by the standard specifications. Section **725.07** includes the procedures for placement and testing of cellular concrete grout. The equipment used to produce the grout and all equipment used in the mixing, pumping and placing is certified as to suitability by the Supplier of the foam concentrate.

The Contractor supplying and placing the grout is certified by the foam concentrate Supplier and is required to be capable of developing a mix design, batching, handling, pumping and placing grout under the contract conditions.

The materials used to manufacture the cellular concrete grout are required to be in accordance with the following:

Fine Aggregate **904.02**
Coal Ash **901.02**
Foaming Agent............................... **ASTM C 869 & 912.05**
Water **913.01**

Admixtures, retarders, and plasticizers used are required to be in accordance with the foam concentrate Supplier's specifications. Portland cement is required to be in accordance with Section **901.01 (b)**, except Type II cement is not allowed.

The grout shall be made using the preformed foam process using generating equipment calibrated by the manufacturer to produce a precise and predictable volume of foam. The foam concentrate shall be certified by the manufacturer to have specific liquid/foam expansion ratio at a constant dilution ratio with water.

The specific job mix is submitted to the engineer by either the foam concentrate supplier or the certified or licensed grouting contractor for approval prior to use on the contract. The mix is required to have a minimum 28-day compressive strength of 150 psi. The mix shall be tested by a laboratory qualified by the Department or shall be approved based on prior acceptable performance on Department contracts.

The cellular concrete grout pump gauges shall be calibrated at a minimum of once per month in the presence of the Engineer by the method described in the QCP. See QCP requirements under General Requirements.

Grout mixed off site shall be delivered to the job site in a truck mixer in accordance with Section **702.09**, filled to half of its capacity. The foaming agent shall then be added to the cement mix in the truck and mixed to a uniform consistency. Grout mixed on site shall be batched in a deck mate or a similar device. Small batches of approximately 1 cu yd shall be mixed and pumped in a continuous operation. For each day worked or for each 100 cu yds placed, four test cylinders measuring 3 in. by 6 in. are cast at the point of placement of the grout. Sampling, molding, curing, and compressive strength testing of the cylinders shall be in accordance with **ASTM C495** except as modified by the standard specifications.

The test specimens shall be handled, and subsequently tested at 28 days in accordance with Section **725.07**, and **ASTM C495**.

A Type A Certification in accordance with Section **916** shall be provided for the cellular concrete grout with the result of the compressive strength test shown on the certification. A Type C certification in accordance with Section **916** shall be provided for the foaming agent.

INSTALLATION

Pipe liner installation is required to be in accordance with Section **725.** Bedding and backfill shall be in accordance with the standard drawings and Section **715.09** with appropriate aggregate material coming from CAPP sources.

RIGHT OF ENTRIES

If the Contractor desires more working room than the right-of-way provides, the Contractor may elect to pursue rights-of-entry from all necessary adjacent property owners in accordance with Section **107.14**. A temporary fence shall be installed as required to prevent encroachment of the public or livestock into the work area. Upon completion of the work, disturbed areas on private property shall be restored in accordance with Section **107.14**.

JOINTS

If the Contractor has obtained the necessary right-of-entry from all affected property owners and all necessary new permits or amendments to existing permits to enable work in areas accessible via Contractor-obtained right-of-entry, the Department will consider a written request by the Contractor to use liner pipe sections which exceed the maximum length shown on the plans. A corresponding reduction in the maximum allowable number of joints shall be included with the written proposal. The Contractor shall not install longer sections of liner pipe until written approval has been received from the Engineer.

There are several types of joints typically used with pipe liners. These joints include bell and spigot, screw type, grooved press on, butt fusion, extrusion welded, or other joints as recommended by the liner pipe manufacturer. Each liner pipe joint shall be welded, fused, or joined according to the manufacturer's recommended methods. Elastomeric seals for joining plastic pipe shall be in accordance with Section **907.27**, and **ASTM F477**. Jointing is required to provide water tight integrity for all joints and not interrupt the flow characteristics of the pipe. The Contractor shall propose and describe in the QCP a destructive test such as but not limited to a bend strap test, to demonstrate that an operator can produce an extrusion welded joint that will not fail as per Section **725.06**. See QCP requirements under General Requirements.

Welded liner pipe joints shall be welded with a continuous weld for the circumference of the liner pipe both inside and outside. Welded liner pipe joints shall have weld beads that are smooth and shall not project further than 3/8 in. into the inside of the liner pipe and shall not reduce the hydraulic capacity of the liner pipe. The ends of liner pipe that are to be welded or butt fused shall be at the same temperature ±5º F.

All liner pipe joints shall have sufficient mechanical strength to withstand the liner pipe installation and cellular concrete grouting operations without affecting the joint's integrity.

Figure 13-3 Jointing a Liner

Certification

Welding, butt fusing, or joining shall be performed by an operator trained and certified by either the manufacturer of the liner pipe or the manufacturer of the joining equipment as required by the standard specifications.

A Type B certification in accordance with Section **916** shall be provided for elastomeric seals used for joining plastic pipe. The testing limits from the table in Section **907.27** shall be shown on the certification.

Grooved Press-on

Typical grooved press-on joints feature male and female joint ends. Opposing ends of the liner pipe have grooves cut on the interior and exterior of the pipe, respectively. The ends of the liner pipe may also be beveled to allow the edges to slip past one another. Once joined, the liner pipe joint is virtually smooth both inside and out.

Butt Fusion

Liner pipe sections that are butt fused undergo a three-step joining process. The meeting ends of the sections are shaved or planed to ensure perfectly smooth and perpendicular surfaces. The ends are then simultaneously heated to soften the plastic so that the ends may be re- bonded. The sections are then pressed together while the thermoplastic cools, creating a permanent joint between the sections. The resulting interface may project a slight double-bead on both the interior and exterior of the liner pipe.

Extrusion Weld

An extrusion welded joint on solid wall HDPE & Profile Wall liner pipe incorporates a bead of plastic material to join two sections of liner pipe. Polyethylene material is extruded at the interface of the two sections to bond them together. The welding process results in an external weld bead at the joint.

Figure 13-5 Pulling Pipe Liner

Figure 13-4 Pushing Pipe Liner over Water

GENERAL REQUIREMENTS

A QCP shall be submitted in accordance with **ITM 803**. No work on the pipe lining operation shall begin until written notice has been received that the QCP has been accepted by the Engineer. Acceptance of the QCP in no way relieves the Contractor of the responsibility for installation procedures and testing requirements.

As shown and approved in the QCP, all equipment necessary for the satisfactory performance of relining existing pipes is required to be approved by the PEMS. The equipment includes all machinery necessary for the installation of the liner and the reworking of the temporary easements.

A QC representative shall be present at the jobsite for the initial testing of the first welding or fusing at each liner pipe installation location and for the joining, welding, or fusing of the liner pipe at each location.

The cross-sectional area of the liner pipe shall be as shown on the plans. Prior to commencing the liner pipe installation operation, all liner sizes are required to be approved by the PEMS. Steps shall be taken to verify that a liner pipe meeting the required cross-sectional area can be successfully placed inside the existing pipe. If it is discovered prior to installation that a liner pipe with the required opening area cannot fit, the inside and outside diameters of a substitute liner pipe shall be submitted to the Engineer for approval.

Prior to liner pipe installation, all existing jagged pipe edges or other deformities shall be repaired. All debris and foreign material shall be removed from the existing pipe and disposed of in accordance with Section **203.08**. A visual walk-through inspection shall be performed after all debris and foreign material has been removed from the existing pipe to assess the condition of the pipe. If visual inspection is not possible, a video inspection of the existing pipe shall be performed. A copy of the video inspection shall be provided to the Engineer.

The Contractor is required to re-establish flow lines of any eroded inverts, with cellular concrete grout meeting the Specifications. The Contractor is required to maintain a positive flowline in the liner. Any obvious cavities outside the existing pipe shall be filled with non-removable flowable backfill in accordance with Section **213** prior to the liner pipe installation or with cellular concrete grout placed in conjunction with the grouting operation after the liner pipe is installed.

After the liner pipe insertion is made, installation is complete, and the liner pipe has been inspected by the PEMS, the liner pipe shall be cut so that each end is 8 in. outside of the end of the existing pipe. In some applications, the liner pipe may have been exposed to the sun prior to insertion into the existing pipe, resulting in a temperature increase of the liner pipe. For all applications, the liner pipe shall be allowed to cool to the temperature of the existing pipe before proceeding with the grouting operation.

The cellular concrete grout injected within the annular space between the existing pipe and the liner pipe shall be contained by the bulkheads constructed at each end of the structure in accordance with Section 725.08. A 2 in. vent hole at the crown and a 1 in. hole at the invert are placed in the downstream bulkhead. An access hole, sized to facilitate the method of grout input, and a 2 in. air vent are placed at the crown in the upstream bulkhead. The grout is placed from the upstream end of the culvert where practical (***Figure 13-6***). The vent holes in the downstream bulkhead are plugged as soon as grout begins to flow out each hole. The 2 in. air vent in the upstream bulkhead is kept clear until grout begins to flow out of the vent.

Figure 13-6 Grouting Pipe Liner

The cellular concrete grout is injected to completely fill all voids within the annular space without causing deformation of the liner and extends for the full length of the pipe. Injection of the cellular concrete grout in lifts, use of spacers, or other safeguards shall be taken to keep the liner pipe in position and prevent it from floating. The pressure developed in the annular space between the liner pipe and the existing pipe shall not exceed the liner pipe manufacturer's recommended maximum value.

All existing culverts, storm drains, underdrain pipes, drain tile, or other pipes that are directly connected to the lined structure shall be perpetuated. Cellular concrete grout shall not leak through the liner pipe at these connections.

Liner storage areas are required to be approved by the PEMS. All drainage structures and ditches are required to remain open at all times, and traffic control is required to be in accordance with the MUTCD or as directed.

All incidental work, such as brush removal, flowline adjustments, etc., is done by the Contractor. Where required, and practical, a bull nose device is pulled through the existing culvert to facilitate the liner installation. The bull nose device is of appropriate diameter to permit the installation of the intended liner size. Any restoration of right of entry areas, acquiring all necessary new permits or amendments are at no added cost to the Department.

POST INSTALLATION INSPECTION

A visual inspection will be conducted for acceptance of all liner pipe joined by methods other than by welding or fusing joints. All joints that do not pass visual inspection shall be removed, shall have a new joint fabricated, and will be re-inspected.

MEASUREMENT AND PAYMENT

All thermoplastic liner pipe will be measured and paid for by the linear foot, for the shape and cross-sectional area of the liner pipe, complete in place. The cost of repairing, trimming, or cutting jagged edges or deformities to existing pipe, filling cavities around the existing pipe with cellular concrete grout, acquisition and restoration of right-of-entry areas, acquiring all necessary new permits or amendments to existing permits to work in areas accessible via Contractor-obtained right-of-entry, erection, maintenance, and removal of temporary fence, removal and disposal of debris and foreign material from the existing pipe, visual or video inspection of the existing pipe, deforming a circular liner pipe, supplying and constructing bulkheads, grouting the annular space between the existing pipe and the liner pipe, and other incidentals will not be paid separately, but shall be included in the cost of the pay items in Section **725.10**.

The cost of liner pipe joints other incidentals necessary to join sections of liner pipe in accordance with the manufacturer's recommendations, and all test sections of liner pipe and test sections of HDPE sheet stock shall be included in the cost of the pay items in Section **725.10**.

See Sections **725.09** & **725.10** for additional requirements.

Chapter Fourteen: CURED-IN-PLACE PIPE LINER, CIPP

Construction shall consist of the fabrication, installation, and curing of a tight-fitting, resin-impregnated fabric called Cured in Place Pipe Liner, CIPP, into existing circular or deformed pipe structures.

Figure 14-1 Cured in Place Pipe Liner

MATERIALS

CIPP shall be in accordance with **ASTM D5813**, Type III, grade 1, 2, or 3 and shall be UV and abrasion resistant. The Manufacturer shall determine the proper grade of the CIPP to be used under the installation and operating conditions that will exist for the location where the liner is placed. CIPP shall be designed in accordance with **ASTM F1216** and **Appendix X1** for a fully deteriorated condition.

RIGHT OF ENTRY

If the Contractor desires more working room than the right-of-way provides, the Contractor may elect to pursue rights-of-entry from all necessary adjacent property owners in accordance with Section **107.14**. A temporary fence is required to prevent encroachment of the public or livestock into the work area. Upon completion of the work, disturbed areas on private property shall be restored in accordance with Section **107.14**.

QC/QA PROCEDURES

A Type A certification in accordance with Section **916** and a test report in accordance with **ASTM D5813, Section 7.3**, shall be provided for each existing structure to be lined.

An independent laboratory shall test field cured samples from each CIPP installation. Appropriate documentation for the independent laboratory shall be provided prior to installation of the CIPP. Testing results shall be provided to the Department within seven days.

At each structure to be lined, two flat plate samples shall be field cured and submitted for testing. The samples shall be taken from the wet-out tube, clamped between flat plates and cured in the downstream end of the tube. Alternatively, two restrained end samples may be used for CIPPs installed in pipes between 8 in. and 18 in. in diameter, or equivalent. The samples shall be submitted to the laboratory within three days of the completion of the installation. Field-cured samples shall be conditioned, prepared, and tested in accordance with **ASTM D5813**. The wall thickness and flexural tests need only be performed on the structural portion of the CIPP only.

MAINTENANCE OF DRAINAGE

Drainage shall be maintained during the installation and curing operations in a manner that does not damage adjacent property.

PRE-INSTALLATION REQUIREMENTS

Three copies of design calculations shall be submitted in accordance with Section **105.02** and shall certify:

(a) Proposed CIPP thickness determined in accordance with **ASTM F1216**,
(b) Required curing pressure,
(c) The proposed waterway opening,
(d) The minimum required temperature for initial cure,
(e) The minimum required temperature and duration for the post cure, and
(f) The temperature profile and time required for cool down.

The Contractor shall submit a Water Collection Plan to the Engineer for review and acceptance that includes phasing and implementation of the effluent collection process, storage, accidental spill procedure, transportation and disposal of effluent generated during the curing or washing process a minimum of 14 days prior to site operations. The Contractor shall provide to the Engineer proof of disposal of effluent and documentation from a State authorized facility receiving the effluent. Copies of any test results required by the disposal site shall be submitted to the Engineer. An **IC 203 form** shall be submitted to cover the disposal site, in accordance with Section **203.08**.

Prior to installing the CIPP, a video inspection of the structure shall be performed. This inspection is to identify cavities in the structure that need repair, and the connecting structures that shall be perpetuated. The video shall become the property of the Department. Cavities adjacent to the existing structure shall be filled in accordance with Section **725.05**. Existing jagged edges or other deformities that impact the CIPP operation or function shall be repaired in accordance with the manufacturer's recommended procedures. All foreign material shall be removed from the existing structure in accordance with the ASTM specifications for the installation method and disposed of in accordance with Section **203.10**.

INSTALLATION REQUIREMENTS

The CIPP shall be installed by the inversion method or the pulled in-place method. Inversion installation of the CIPP liner shall be in accordance with **ASTM F1216**. Pulled-in-place installation of the CIPP liner shall be in accordance with **ASTM F1743**.

If the Contractor elects to use polyester resin, all condensate water and water in contact with the inside or outside of the CIPP during the curing and cleanup process requires collected. If the Contractor washes the inside of the CIPP after curing has occurred, then that water also requires collection.

The Contractor shall monitor and record temperatures during initial cure, post cure and cool down periods. Remote temperature sensors shall be placed between the existing pipe and the liner in the bottom of the existing pipe at locations as directed by the Engineer. A continuous monitoring system utilizing a fiber optic cable sensing system may be used in lieu of individual sensors. The minimum curing time is the sum of the initial and post curing times. Post-curing time shall be added for any deviations from the recommended post-curing temperature levels. A copy of these records shall be provided to the Engineer.

All CIPP installations shall be performed in dry conditions.

Prior to the liner installation, the Contractor shall place an approved impermeable catchment immediately upstream and downstream of the existing pipe which shall work in conjunction with cofferdams to create an impermeable basin to trap contaminated effluent. Any spillage of raw resin during the installation shall also be captured.

The Liner shall be one continuous run of material with no over-laps and be leak-free. The Contractor shall ensure there is no loss of impermeability of the inner and outer plastic films or pre-liner during the installation. Any pinholes, gaps and tears in the plastic film or pre-liner shall be properly repaired before proceeding with the liner installation. Where damaged areas cannot be repaired, the Contractor shall promptly replace the impermeable plastic films or pre-liner before proceeding with the installation. Cofferdams shall remain in place until wastewater collection processes are complete and secured.

Cured CIPP shall be inspected and videotaped for workmanship. Defects in workmanship as defined in **ASTM D5813 Section 6.2** shall be repaired or the CIPP shall be replaced so it meets the requirements of these specifications. The repaired or replaced CIPP shall be re-videotaped. The video tape shall become the property of the Department.

The installed CIPP shall be tested for delamination in accordance with the appropriate ASTM specification. The cured CIPP shall be cut within 6 in. of the ends of the existing structure. Where beveled inlets are required, the details shown on the plans shall be followed. Existing connections, including underdrains or another pipe structure, to the structure that was lined shall be perpetuated through the CIPP.

The CIPP shall be permanently marked with a stainless-steel label with a minimum thickness of 0.080 in. located above the structure low water elevation and within 6 in. of the structure end. The information shown on the label shall be at least 1/2 in. tall and shall include the month and year of installation, the CIPP source, and the ASTM material specifications.

WARRANTY

The CIPP shall be warranted, for a period of five years, against all defects which may adversely affect the integrity or strength of the liner. The Contractor shall repair or replace, at no additional cost to the Department, such defects in a manner mutually agreed upon by the Department and the Contractor.

MEASUREMENT AND PAYMENT

CIPP will be measured and paid for at the contract unit price per linear foot, for the area or diameter specified, complete in place.

No measurement will be made for debris removal, filling existing voids, or trimming, cutting, jacking, or other corrective measures performed on jagged edges or other deformities of the existing pipe in order to facilitate installation of the CIPP.

The cost of repairing jagged edge or deformities to existing pipe, filling cavities around the existing pipe with flowable backfill or grout, cleaning and surface preparation of existing pipe, acquisition and restoration of required right-of-entry areas, erection, maintenance, and removal of temporary fence, removal and reattachment of end sections for access, removing foreign material from the existing pipe, maintaining existing water flow, perpetuation of connections to the structure to be lined, warranties and all other incidentals shall be included in the cost of the pay item. Visual or video inspection of the existing pipe and new CIPP will not be measured.

The cost of developing the Water Collection Plan and the collection, storage, transportation, and disposal of water produced by the curing or washout process shall be included in the cost of the pay item.

Chapter Fifteen: TRENCHLESS PIPE INSTALLATION

This work shall consist of installing pipes underground using construction techniques that eliminate open cutting of the pavement or of the ground in accordance with Section 105.03. This addresses auger boring, guided boring, horizontal directional drilling using a reamer diameter up to and including 24 in., pipe jacking, and pipe ramming.

Installations by means of directional drilling which require a reamer larger than 24 in., microtunneling, or other tunneling methods, may be utilized if approved by the Engineer. The Contractor shall submit a detailed proposal prepared by a professional engineer for installations other than auger boring, guided boring, horizontal directional drilling using a reamer diameter less than 24 in., pipe jacking, and pipe ramming.

DEFINITIONS

AUGER BORING - Technique for forming a bore by jacking a steel casing from a drive shaft to a reception shaft by means of a rotating cutting head. Spoil is removed back to the Drive Shaft for removal by helically wound auger flights rotating within the steel casing.

GUIDED BORING - A trenchless tunneling method that utilizes small diameter pilot tubes that are installed and steered through the ground utilizing a slanted face at the cutting head containing a target with light emitting diodes, LEDs, and a camera mounted theodolite located in the shaft to achieve high accuracy in line and grade. The hole is enlarged to the same outside diameter of the final product pipe after the installation of the pilot tubes, which is then jacked into place.

HORIZONTAL DIRECTIONAL DRILLING - A steerable system for the installation of pipes, conduits, or cables in a shallow arc using a surface launched drilling rig.

PIPE JACKING - A system of directly installing pipes behind a shield machine by means of hydraulic jacking from a drive shaft such that the pipes form a continuous string in the ground. This may consist of pushing the pipe through or under the ground or embankment.

MICROTUNNELING - A remote-controlled trenchless construction method that simultaneously installs pipes as the soil is excavated. This method provides continuous support of the excavation face with slurry pressure to balance groundwater and earth pressures.

PIPE RAMMING - A non-steerable system of forming a bore by driving an open-ended steel casing using a percussive hammer from a drive shaft. The soil may be removed from the casing by augering, jetting, or compressed air.

CARRIER PIPE - The tube which carries the product being transported and which may pass through casings at highway or railroad crossings. It may be made of steel, concrete, clay, thermoplastic, ductile iron, or other materials.

CASING PIPE - A pipe installed as external protection to a carrier pipe.

DRIVE SHAFT - Excavation from which trenchless technology equipment is launched. It may incorporate a thrust wall to spread reaction loads to the soil.

RECEPTION SHAFT - Excavation into which trenchless technology equipment is driven and recovered following the installation of the pipe.

RESPONSE LEVELS - Pre-established levels of instrument readings of settlement or of other monitored behavior such as lateral movement or vibrations, which trigger the implementation of mitigative measures. Response levels consist of the initial review level, at which mitigative measures must be implemented, and the alert level, at which construction must be halted and actions taken to ensure the alert level will not be exceeded in subsequent construction.

SPOILS - Earth, rock, or other materials displaced by a tunnel or casing, and removed as the tunnel or casing is installed.

MATERIALS

Materials shall be in accordance with the following per Section **716.02**:

Cellular Grout **725**
Clay Pipe, Extra Strength **907.08**
PVC Pipe .... *
Reinforced Concrete Pipe **907.02**
Smooth Wall Polyethylene Pipe .... *
Steel Pipe **908.11**
Water **913.01**

* *Thermoplastic pipes shall be from the QPL of Thermoplastic Pipe and Liner Pipe Sources in accordance with Section **907.16**. A Type C certification in accordance with Section **916** shall be provided for the smooth wall polyethylene and smooth wall PVC pipe.*

Concrete pipe is required to be in accordance with **AASHTO M 170**, which is equivalent to **ASTM C 76**. Concrete pipe shall be from the QPL of Certified Precast Concrete Producers.

Concrete pipe installed by pipe jacking shall be designed with sufficient concrete strength and steel reinforcement to resist jacking forces and shall have tongue and groove joints.

Steel pipe used as a carrier pipe shall have minimum wall thicknesses indicated in the table. Steel pipe used as a casing pipe, but not used as a carrier pipe, shall be selected by the Contractor to have minimum wall thickness sufficient to resist jacking forces. For installations where the casing is not used as a carrier but only as a casing for a carrier pipe, the thickness of the casing shall be determined by the Contractor.

Outside Diameter, in.	Wall Thickness, in.
18 or less	1/4
19 – 20	5/16
21 – 26	3/8
27 – 30	1/2
31 – 42	1/2
43 – 48	9/16

Table 15-1

GENERAL REQUIREMENTS

QUALITY CONTROL PLAN (*QCP*)

The Contractor shall submit a QCP in accordance with **ITM 803**, detailing a description of the trenchless pipe install, along with the Contractor's plan to construct, test and manage the process. The QCP shall be submitted to the Engineer for review and acceptance, at least 15 days prior to the start of trenchless pipe installation operations.

GROUNDWATER

Where groundwater is known or anticipated, and the trenchless pipe installation technique selected does not provide positive support at the trenchless excavation face, such as by slurry support in microtunneling, then trenchless pipe installation shall not proceed without first dewatering. A dewatering system capable of handling the flow shall be maintained until its operation can be safely stopped. The dewatering system shall be equipped with screens or filter media sufficient to prevent the displacement of fines.

EXPLOSIVES

When the use of explosives is necessary for the prosecution of the work, their use is required to be in accordance with Section **107.13**.

LUBRICANTS

Bentonite or other suitable lubricants may be applied to the outside surface of the pipe to reduce frictional forces. This material is applied by the use of pressure equipment which pumps the lubricant to the outside surfaces of the pipe through grout holes.

JOINTS

Joints in steel pipe shall be watertight. Where welded joints are utilized, they shall be welded in accordance with Section **711.32**.

Joints in concrete pipe or other jacking pipe materials, including clay pipe, shall be designed to withstand additional forces created in the joints during installation. The joints in concrete pipe or other pipe jacking materials shall be protected with a resilient material around the circumference of the pipe. Resilient material shall also be used between the pipe and the thrust ring.

GROUND SURFACE

Pavement or ground surface heave or settlement resulting in damage to pavement, existing utilities, or structures above the installation will not be allowed. To confirm if heave or settlement is occurring, the Contractor shall undertake surface monitoring.

BORED HOLE DIAMETER AND GROUTING

Installations shall have a bored hole the same diameter as the outside of the installed pipe. If voids develop or if the bored diameter is greater than the outside diameter of the pipe by more than 1 in., grouting is required to fill such voids.

CASING AS CARRIER PIPE – VIDEO INSPECTION

When the installation is 4 in. or larger and the casing is used as the carrier pipe, a visual or a video inspection is required using a high resolution, high sensitivity color video camera and recording equipment. The pipe shall be cleaned of debris prior to the inspection. Cleaning shall be accomplished by water jetting or other approved methods.

The camera and recording equipment shall be designed for continuous viewing and recording of detailed images of the interior wall of pipes and transitions of the specified sizes. The equipment shall include sufficient lighting to view the entire periphery of the pipe and have appropriate attachments to maintain a position in the center of the pipe and an electronic counter to continuously record the location of the equipment in the pipe. A copy of the video inspection shall be submitted to the Engineer.

CARRIER PIPE (GRAVITY FLOW) WITHIN A CASING PIPE

Where a gravity-flow carrier pipe is placed inside a casing pipe, the gravity-flow carrier pipe shall be shimmed to proper line, elevation, and grade and then the void between the two pipes shall be grouted with cellular concrete grout.

OBSTRUCTION MANAGEMENT

If an obstruction is encountered during installation which stops the forward progress of the pipe, and it becomes evident that it is impossible to advance the pipe, the Engineer shall be notified.

For installations utilizing tunnel shields or tunnel-boring machines or other methods that allow access to the face, the obstruction shall be removed in accordance with the QCP.

For installations utilizing methods that do not allow access to the face, at the direction of the Engineer, the pipe shall be abandoned in place and filled with grout or other approved materials.

BACKFILL

Upon completion of the installation of the pipe, all excavated areas not occupied by the pipe shall be backfilled and compacted with suitable material in accordance with Section **203**.

JACKING/MICROTUNNELING

Jacking steel, reinforced concrete pipe, or other jacking pipe materials including clay pipe, consists of pushing the pipe through or under the ground or embankment. See Section **716**.

Jacking is a system of directly installing pipes behind a shield machine by means of hydraulic jacking from a drive shaft such that the pipes form a continuous string in the ground.

Jacking is a method of pushing pipe with hydraulic jacks immediately behind a tunneling (shield) machine as it advances the tunnel. Tunneling and jacking processes are simultaneous, resulting in minimal ground movement.

Microtunneling is a remote-controlled trenchless construction method that simultaneously installs pipes as the soil is excavated. This method provides continuous support of the excavation face using slurry to carry Spoils away from the tunnel to the Drive Shaft and slurry pressure to balance groundwater and earth pressures. Operators do not enter the tunnel with this method. It can install pipes to accurate line and grade tolerances from the Drive Shaft to the Reception Shaft. A remote-controlled microtunneling machine is operated from a control panel, typically located on the surface.

DRIVE SHAFT AND RECIEVING SHAFT - EXCAVATION

The Drive Shaft and Reception Shaft are excavated. The equipment is launched from the Drive Shaft which incorporates a thrust wall to spread reaction loads to the soil. The Reception Shaft is the excavation into which equipment is driven and recovered following the installation of the pipe.

The excavations are dug to a depth sufficient to form a vertical face at least 1 ft higher than the top of the pipe and large enough to provide ample working room. The size and height of the vertical face may vary; however, the roadbed and shoulders are required to always be adequately protected.

Sheeting and bracing shall be provided if the soil conditions or height of exposed faces are such as to endanger either the traveling public or the integrity of the road surface.

PIPE INSTALLATION AND THE JACKING PROCESS

Prefabricated pipe sections are assembled at the Drive Shaft. The first section is connected to the jacking equipment.

The boring equipment is equipped with hydraulic jacks which are used to apply force to push the pipe through the tunnel. As the pipe advances, additional sections are added at the rear.

Excavation is undertaken within a steel cutting edge or shield attached to the front section of pipe to form and to cut the required opening for the pipe. Excavation is not carried ahead of the pipe far enough to cause a loss of soil. When jacking in loose, granular, or running soils, the shield is required to have a means for inserting steel baffle plates and shelves for the purpose of preventing voids.

The thrust wall constructed within the Drive Shaft is required to be adequate for installation of the jacked pipe and be constructed normal to the proposed line of thrust.

The thrust load of the jacking equipment is imparted to the pipe through a suitable thrust ring which is sufficiently rigid to ensure distribution of the load without creating point loading. When necessary to prevent loss of soil at the heading, the face of the excavation is required to have an adequate bulkhead when the work is shut down at the end of the working day.

Bracing, backdrops and jacks are required to be sufficient so that jacking may progress without stoppage, except for adding lengths of pipe, until the pipe reaches the leading edge of the pavement as shown on the plans.

Jacked pipe is constructed so as to prevent leakage of any substance throughout the length of the pipe. Installation by open-trench methods is permitted only at locations indicated and is required to be in accordance with the applicable specifications for that type of installation.

The excavated soils, or Spoils, are removed from the Drive Shaft using conveyor belts or other methods.

Throughout the jacking process, the pipe’s alignment is monitored. Grout may be injected around the pipe to stabilize the surrounding soil. The pipe jacking operation terminates when the pipe reaches the Reception Shaft.

BORING

See the **Definitions** for types of Pipe Boring including Auger Boring and Guided Boring.

AUGER BORING

In general, Auger Boring consists of pushing a pipe through the ground or embankment with a boring auger rotating within the pipe to remove the spoil. Advancement of the cutting head ahead of the pipe is not allowed, except for that distance to permit the cutting head teeth to cut clearance for the pipe. If granular, loose, or unstable soil is encountered during the boring operation, the cutting head is retracted into the casting a distance that assures no voiding is taking place. The excavation by the cutting head is required to not exceed the outside diameter of the pipe by more than ½ in. The face of the cutting head is arranged to provide reasonable obstruction to the free flow of soft or porous material.

The use of water or liquids to soften or wash the face of the cutting head is not permitted. Water may be used in sticky clays to facilitate spoil removal provided the water is introduced behind the cutting head. Lubricating agents, such as bentonite, may be used to lubricate the casing and reduce friction between the casing and ground or embankment.

GUIDED BORING

Guided Boring involves a similar excavation process as traditional Auger Boring but incorporates a pilot tube that maintains the accuracy of both the line and the grade before installing the steel casing. There are several advantages to Guided Boring, including precision when guiding the steel casing. This method also helps determine geotechnical attributes of the soil and identify obstructions along the planned route.

MEASUREMENT AND PAYMENT

Pipe installed by means of trenchless installation methods will be measured by the linear foot along the center line of the pipe installed.

Pipe installed by means of trenchless installation methods will be paid for by the linear foot for pipe installation, trenchless, of the size specified, complete and in place including all incidentals.

Removal of boulders, concrete, or other obstructions will be paid in accordance with Section **104.03**.

If a partial installation must be abandoned in place and filled with grout due to the encountering of an obstruction, the abandoned work will be paid for at 75% of the contract unit price of the pipe installed.

The cost of the QCP, excavating and backfilling of the drive shaft and reception shaft, video inspection, camera and recording equipment, bentonite or other lubricant, grout, and the casing if installed shall be included in the cost of pipe installation, trenchless.

No payment will be made to repair or replace sections of pipe that have been damaged or show evidence of joint failure.

Chapter Sixteen: – STRUCTURAL PLATE PIPE, PIPE ARCHES, AND ARCHES

MATERIALS

This work shall consist of furnishing and placing structural plate pipe, pipe-arches, or arches in accordance with Section **105.03**.

Materials shall be in accordance with the following per Section **717.02**:

Concrete, Class A **702**
Flowable Backfill.. **213**
Pipe Joint Sealant **907.11**
Reinforcing Bars...**910.01**
Structural Plate Arches **908.09**
Structural Plate Pipe and Pipe Arches................................ **908.11**

Structural plate pipe and pipe-arches are part of the pipe classification system described in Section **715.02**. The minimum material thickness and required protective treatments will be determined in accordance with Section **715.02**. When metal pipe is selected, the same base metal and coating shall be used for the structure or a pipe extension.

Structural Plate Pipe, Pipe-Arches and Arches shall be constructed from individually galvanized corrugated steel plates. The individual plates shall be in accordance with **AASHTO M 167** and **AASHTO LRFD Bridge Construction Specifications**. Materials and fabrications shall be in accordance with Section **908.09**. A sheet manufacturer's certified mill report and the fabricators certification shall be provided. Standard Specifications Section **717** discusses details on construction requirements including placement, bearings, tee-connections and potential defects. Also included is relaying pipe and concrete paved invert requirements.

Requirements for metal pipe are in Section **908**. A QPL of Metal Pipe Sources for the identified pipe materials specified in the table in **908.01** will be maintained by the Department. The table shows pipe materials that are required to be furnished from a manufacturer on the QPL, and those that are not, which have other requirements per the table.

The QPL will specify the manufacturer and pipe designation. The manufacturer is defined as the plant which produces the metal pipe or pipe-arch. The manufacturer shall establish and maintain a history of satisfactory quality control of these materials. This history will be based on achieving and maintaining a "Compliant" status with the AASHTO PEAS program in accordance with **ITM 806, Procedure O**.

For all pipe materials, regardless of whether or not it is required to be furnished from a manufacturer on the QPL, a Buy America or Build America, Buy America Certification, whichever is applicable, shall be provided for the metal in accordance with Section **916** if required by the contract.

CONSTRUCTION REQUIREMENTS

Forming, punching, and assembling shall be in accordance with AASHTO LRFD Bridge Construction Specifications. The radius of the arc joining the top to the bottom shall be in accordance with Section **908.09**. Excavation shall be in accordance with the applicable requirements of Section **715** for pipe and pipe-arches and Section **206** for arches. Concrete shall be placed in accordance with Section **702** and reinforcing bars shall be placed in accordance with Section **703**.

Each side of an arch shall rest in a groove formed into the masonry or shall rest on a galvanized angle or channel securely anchored to or embedded in the structure. Where the span of the arch is greater than 14 ft, or the skew angle is more than 20°, a metal bearing surface having a width at least equal to the depth of the corrugations shall be provided.

Metal bearings may be either rolled structural or cold-formed galvanized angles or channels no less than 3/16 in. in thickness with the horizontal leg securely anchored to the substructure on 24 in. maximum centers. When the metal bearing is not embedded in a groove in the substructure, one vertical leg shall be punched to allow bolting to the bottom row of plates.

If it is necessary to make a tee-connection to a structural plate pipe, pipe-arch, or arch, a stub-tee connection of the size and at the locations shown on the plans shall be furnished and placed, and its length shall be no less than 12 in. and no more than 24 in. The stub shall be connected in the field and the stub connection bituminous coated. The stub connection to the entering pipe shall be made by means of a connecting band of the required size or by means of concrete collars, as directed.

Structures on which the spelter coating has been bruised or broken either in the shop or in shipping, or which shows defective workmanship, shall be rejected unless it can be repaired satisfactorily. This requirement applies not only to the individual plates but to the shipment on any contract as a whole for an entire contract.

The following defects are considered as poor workmanship and, if present in an individual culvert plate, will be cause for rejection:

(a) uneven laps
(b) elliptical shaping, unless specified
(c) variation from a straight centerline
(d) ragged edges
(e) loose, unevenly lined, or unevenly spaced bolts
(f) illegible brand
(g) bruised, scaled, or broken spelter coating
(h) dents or bends in the metal itself
(i) twisted so that ends do not lay on bedding satisfactorily.

Refer to Section **717.05** for Re-laid Pipe and Pipe-Arch requirements, and Section **717.07** for Concrete Paved Invert requirements.

BACKFILL

All structural plate pipe and pipe arches shall be backfilled with structure backfill or flowable backfill. Arch backfill shall be structural backfill. The amount of camber on the invert of the pipe or pipe-arch shall be varied to suit the height of fill and supporting soil, except the camber grade shall not be above level. Structure backfill shall be placed in accordance with Section **211**. Flowable backfill shall be placed in accordance with Section **213**.

An adequate earth cover shall be provided over the structure, as shown on the plans, before heavy construction equipment is operated over it. This earth cover shall be free of stones.

Where backfilling at arches before headwalls are placed, the material shall first be placed midway between the ends of the arch, forming as narrow a ramp as possible, until the top of the arch is reached. The ramp shall be built up evenly on both sides and the backfilling material compacted as it is placed. After both ramps have been built to the top of the arch, the remainder of the backfill shall be deposited in both directions from the center to the ends and evenly on both sides of the arch.

If the headwalls are built before the arch is backfilled, the backfill material shall first be placed adjacent to one headwall until the top of the arch is reached, after which the fill material shall be placed from the top of the arch towards the other headwall. The material shall be deposited evenly on both sides of the arch.

In multiple installations the above procedure shall be followed. The backfill shall be brought up evenly on both sides of each arch so that unequal pressures are avoided.

MEASUREMENT AND PAYMENT

Measurement and payment shall be in accordance with Section **717.08** and Section **717.09** respectively inclusive of structural plate pipe and pipe-arches (new, extended or re-laid), stub-tee connections, concrete for headwalls and substructures, reinforcing bars in substructures, concrete anchors, additional excavation, structural backfill, and flowable backfill.

Structural plate arches will be measured by the linear foot, complete in place. Metal bearings and other hardware required to attach the structural plate arch to its substructure will not be measured for payment. Structural plate arches will be paid for at the contract unit price for arch, structural plate, of the size specified, per LFT.

The cost of excavation, concrete field paved inverts, disposal of surplus materials, reinforcing bars, straps, and hook bolts used in anchors, and necessary incidentals shall be included in the cost of the pay item.