CHAPTER 5

SUPPLEMENTAL DATA

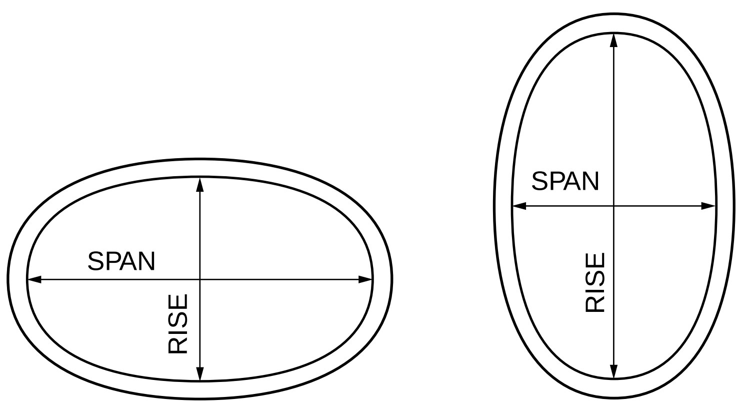
CIRCULAR CONCRETE PIPE

Illustration 5.2 includes tables of dimensions and approximate weights of most frequently used types of circular concrete pipe. Weights are based on concrete weighing 150 pounds per cubic foot. Concrete pipe may be produced which conforms to the requirements of the respective specifications but with increased wall thickness and different concrete density.

ELLIPTICAL CONCRETE PIPE

Elliptical pipe, shown in Illustration 5.1, installed with the major axis horizontal or vertical, represents two different products from the stand-point of structural strength, hydraulic characteristics and type of application. Illustration 5.3 includes the dimensions and approximate weights of elliptical concrete pipe.

Illustration 5.1 Typical Cross Sections of Horizontal Elliptical and Vertical Elliptical Pipe



Horizontal Elliptical (HE) Pipe. Horizontal elliptical concrete pipe is installed with the major axis horizontal and is extensively used for minimum cover conditions or where vertical clearance is limited by existing structures. It offers the hydraulic advantage of greater capacity for the same depth of flow than most other structures of equivalent water-way area. Under most embankment conditions, its wide span results in greater earth loadings for the same height of cover than for the equivalent size circular pipe and, at the same time, there is a reduction in effective lateral support due to the smaller vertical dimension of the section. Earth loadings are normally greater than for the equivalent circular pipe in

Illustration 5.2 Dimensions and Approximate Weights of Concrete Pipe

ASTM C 14 - Nonreinforced Sewer and Culvert Pipe, Bell and Spigot Joint.						
	CLASS 1		CLASS 2		CLASS 3	
Internal Diameter, inches	Minimum Wall Thickness, inches	Approx. Weight, pounds per foot	Minimum Wall Thickness, inches	Approx. Weight, pounds per foot	Minimum Wall Thickness, inches	Approx. Weight, pounds per foot
4	5/8	9.5	3/4	13	7/8	15
6	5/8	17	3/4	20	1	24
8	3/4	27	7/8	31	1 1/8	36
10	7/8	37	1	42	1 1/4	50
12	1	50	1 3/8	68	1 3/4	90
15	1 1/4	80	1 5/8	100	1 7/8	120
18	1 1/2	110	2	160	2 1/4	170
21	1 3/4	160	2 1/4	210	2 3/4	260
24	2 1/8	200	3	320	3 3/8	350
27	3 1/4	390	3 3/4	450	3 3/4	450
30	3 1/2	450	4 1/4	540	4 1/4	540
33	3 3/4	520	4 1/2	620	4 1/2	620
36	4	580	4 3/4	700	4 3/4	700

ASTM C 76 - Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, Bell and Spigot Joint.				
WALL A			WALL B	
Internal Diameter, inches	Minimum Wall Thickness inches	Approximate Weight, pounds per foot	Minimum Wall Thickness, inches	Approximate Weight,pounds per foot
12	1 3/4	90	2	110
15	1 7/8	120	2 1/4	150
18	2	160	2 1/2	200
21	2 1/4	210	2 3/4	260
24	2 1/2	270	3	330
27	2 5/8	310	3 1/4	390
30	2 3/4	360	3 1/2	450

These tables are based on concrete weighing 150 pounds per cubic foot and will vary with heavier or lighter weight concrete.

Illustration 5.2 (Continued) Dimensions and Approximate Weights of Concrete Pipe

ASTM C 76 - Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, Tongue and Groove Joints						
	WALL A		WALL B		WALL C	
Internal Diameter inches	Minimum Wall Thickness, inches	Approximate Weight, pounds per foot	Minimum Wall Thickness, inches	Approximate Weight, pounds per foot	Minimum Wall Thickness, inches	Approximate Weight, pounds per foot
12	1 3/4	79	2	93	—	—
15	1 7/8	103	2 1/4	127	—	—
18	2	131	2 1/2	168	—	—
21	2 1/4	171	2 3/4	214	—	—
24	2 1/2	217	3	264	3 3/4	366
27	2 5/8	255	3 1/4	322	4	420
30	2 3/4	295	3 1/2	384	4 1/4	476
33	2 7/8	336	3 3/4	451	4 1/2	552
36	3	383	4	524	4 3/4	654
42	3 1/2	520	4 1/2	686	5 1/4	811
48	4	683	5	867	5 3/4	1011
54	4 1/2	864	5 1/2	1068	6 1/4	1208
60	5	1064	6	1295	6 3/4	1473
66	5 1/2	1287	6 1/2	1542	7 1/4	1735
72	6	1532	7	1811	7 3/4	2015
78	6 1/2	1797	7 1/2	2100	8 1/4	2410
84	7	2085	8	2409	8 3/4	2660
90	7 1/2	2395	8 1/2	2740	9 1/4	3020
96	8	2710	9	3090	9 3/4	3355
102	8 1/2	3078	9 1/2	3480	10 1/4	3760
108	9	3446	10	3865	10 3/4	4160

Illustration 5.2 (Continued) Dimensions and Approximate Weights of Concrete Pipe

Large Sizes of Pipe Tongue and Groove Joint			
Internal Diameter Inches	**Internal Diameter Feet**	**Wall Thickness Inches**	**Approximate Weight, pounds per foot**
114	9 1/2	9 1/2	3840
120	10	10	4263
126	10 1/2	10 1/2	4690
132	11	11	5148
138	11 1/2	11 1/2	5627
144	12	12	6126
150	12 1/2	12 1/2	6647
156	13	13	7190
162	13 1/2	13 1/2	7754
168	14	14	8339
174	14 1/2	14 1/2	8945
180	15	15	9572

These tables are based on concrete weighing 150 pounds per cubic foot and will vary with heavier or lighter weight concrete.

the trench condition, since a greater trench width is usually required for HE pipe. For shallow cover, where live load requirements control the design, loading is almost identical to that for an equivalent size circular pipe with the same invert elevation.

Vertical Elliptical (VE) Pipe. Vertical elliptical concrete pipe is installed with the major axis vertical and is useful where minimum horizontal clearances are encountered or where unusual strength characteristics are desired. Hydraulically, it provides higher flushing velocities under minimum flow conditions and carries equal flow at a greater depth than equivalent HE or circular pipe. For trench conditions the smaller span requires less excavation than an equivalent size circular pipe and the pipe is subjected to less vertical earth load due to the narrower trench. The structural advantages of VE pipe are particularly applicable in the embankment condition where the greater height of the section increases the effective lateral support while the vertical load is reduced due to the smaller span.

CONCRETE ARCH PIPE

Arch pipe, as shown in Illustration 5.4, is useful in minimum cover situations or other conditions where vertical clearance problems are encountered. It offers the hydraulic advantage of greater capacity for the same depth of flow than most other structures of equivalent water-way area. Structural characteristics are

Illustration 5.3 Dimensions and Approximate Weights of Elliptical Concrete Pipe

ASTM C 507-Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe					
Equivalent Round Size, inches	**Minor Axis, inches**	**Major Axis, inches**	**Minimum Wall Thickness, inches**	**Water-Way Area, square feet**	**Approximate Weight, pounds per foot**
18	14	23	2 3/4	1.8	195
24	19	30	3 1/4	3.3	300
27	22	34	3 1/2	4.1	365
30	24	38	3 3/4	5.1	430
33	27	42	3 3/4	6.3	475
36	29	45	4 1/2	7.4	625
39	32	49	4 3/4	8.8	720
42	34	53	5	10.2	815
48	38	60	5 1/2	12.9	1000
54	43	68	6	16.6	1235
60	48	76	6 1/2	20.5	1475
66	53	83	7	24.8	1745
72	58	91	7 1/2	29.5	2040
78	63	98	8	34.6	2350
84	68	106	8 1/2	40.1	2680
90	72	113	9	46.1	3050
96	77	121	9 1/2	52.4	3420
102	82	128	9 3/4	59.2	3725
108	87	136	10	66.4	4050
114	92	143	10 1/2	74.0	4470
120	97	151	11	82.0	4930
132	106	166	12	99.2	5900
144	116	180	13	118.6	7000

similar to those of horizontal elliptical pipe in that under similar cover conditions it is subject to the same field load as a round pipe with the same span. For minimum cover conditions where live load requirements control the design, the loading to which arch pipe is subjected is almost identical to that for an equivalent size circular pipe with the same invert elevation. Illustration 5.5 includes the dimensions and approximate weights of concrete arch pipe.

Illustration 5.4 Typical Cross Section of Arch Pipe

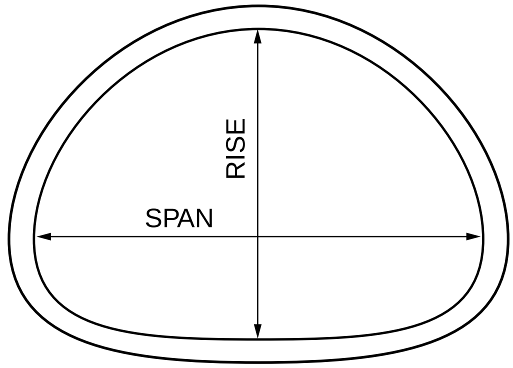
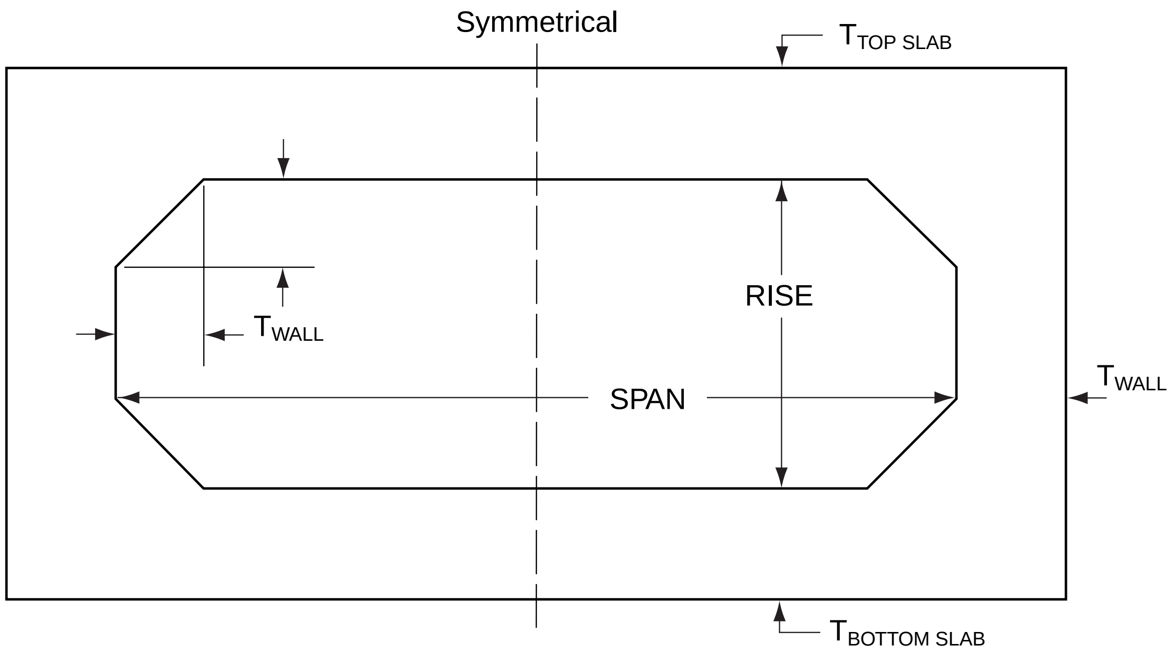


Illustration 5.5 Dimensions and Approximate Weights of Concrete Arch Pipe

ASTM C 506 - Reinforced Concrete Arch Culvert, Storm Drain and Sewer Pipe					
Equivalent Round Size, inches	**Minimum Rise, inches**	**Minimum Span, inches**	**Minimum Wall Thickness, inches**	**Water-Way Area, square feet**	**Approximate Weight, pounds per foot**
15	11	18	2 1/4	1.1	—
18	13 1/2	22	2 1/2	1.65	170
21	15 1/2	26	2 3/4	2.2	225
24	18	28 1/2	3	2.8	320
30	22 1/2	36 1/4	3 1/2	4.4	450
36	26 5/8	43 3/4	4	6.4	595
42	31 5/16	51 1/8	4 1/2	8.8	740
48	36	58 1/2	5	11.4	880
54	40	65	5 1/2	14.3	1090
60	45	73	6	17.7	1320
72	54	88	7	25.6	1840
84	62	102	8	34.6	2520
90	72	115	8 1/2	44.5	2750
96	77 1/4	122	9	51.7	3110
108	87 1/8	138	10	66.0	3850
120	96 7/8	154	11	81.8	5040
132	106 1/2	168 3/4	10	99.1	5220

Illustration 5.6 Typical Cross Section of Precast Concrete Box Sections



CONCRETE BOX SECTIONS

Precast concrete box sections, as shown in Illustration 5.6, are useful in minimum cover and width situations or other conditions where clearance problems are encountered, for special waterway requirements, or designer preference. Illustration 5.7 includes the dimensions and approximate weights of standard precast concrete box sections. Special design precast concrete box sections may be produced which conform to the requirements of the respective specifications but in different size and cover conditions.

Illustration 5.7 Dimensions and Approximate Weights of Concrete Box Sections

ASTM C1433 - PRECAST REINFORCED CONCRETE BOX SECTIONS						
		Thickness (in.)			Waterway Area	Approx. Weigh†
Span (Ft.)	Rise (Ft.)	Top Slab	Bot. Slab	Wall	(Sq. Feet)	(lbs/ft)
3	2	7	6	4	5.8	830
3	3	7	6	4	8.8	930
4	2	7 1/2	6	5	7.7	1120
4	3	7 1/2	6	5	11.7	1240
4	4	7 1/2	6	5	15.7	1370
5	3	8	7	6	14.5	1650
5	4	8	7	6	19.5	1800
5	5	8	7	6	24.5	1950
6	3	8	7	7	17.3	1970
6	4	8	7	7	23.3	2150
6	5	8	7	7	29.3	2320
6	6	8	7	7	35.3	2500
7	4	8	8	8	27.1	2600
7	5	8	8	8	34.1	2800
7	6	8	8	8	41.1	3000
7	7	8	8	8	48.1	3200
8	4	8	8	8	31.1	2800
8	5	8	8	8	39.1	3000
8	6	8	8	8	47.1	3200
8	7	8	8	8	55.1	3400
8	8	8	8	8	63.1	3600
9	5	9	9	9	43.9	3660
9	6	9	9	9	52.9	3880
9	7	9	9	9	61.9	4110
9	8	9	9	9	70.9	4330
9	9	9	9	9	79.9	4560
10	5	10	10	10	48.6	4380
10	6	10	10	10	58.6	4630
10	7	10	10	10	68.6	4880
10	8	10	10	10	78.6	5130
10	9	10	10	10	88.6	5380
10	10	10	10	10	98.6	5630
11	4	11	11	11	42.3	4880
11	6	11	11	11	64.3	5430
11	8	11	11	11	86.3	5980
11	10	11	11	11	108.3	6530
11	11	11	11	11	119.3	6810
12	4	12	12	12	46.0	5700
12	6	12	12	12	70.0	6300
12	8	12	12	12	94.5	6900
12	10	12	12	12	118.0	7500
12	12	12	12	12	142.0	8100

SPECIAL SECTIONS

Precast Concrete Manhole Sections. Precast manholes offer significant savings in installed cost over cast-in-place concrete, masonry or brick manholes and are universally accepted for use in sanitary or storm sewers. Precast, reinforced concrete manhole sections are available throughout the United States and Canada, and are generally manufactured in accordance with the provisions of American Society for Testing and Materials Standard C 478.

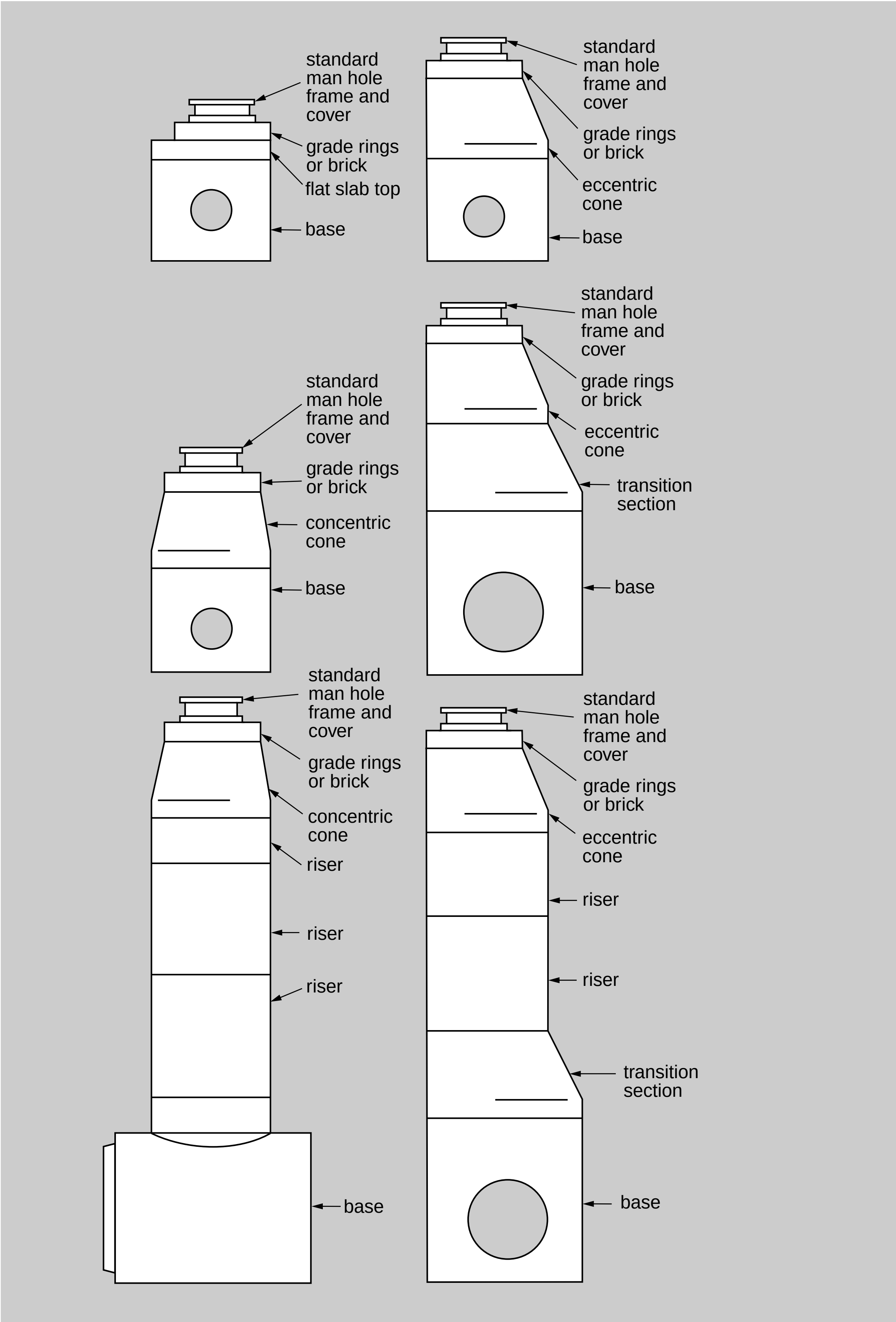
The typical precast concrete manhole as shown in Illustration 5.8 consists of riser sections, a top section and grade rings and, in many cases, precast base sections or tee sections. The riser sections are usually 48 inches in diameter, but are available from 36 inches up to 72 inches and larger. They are of circular cross section, and a number of sections may be joined vertically on top of the base or junction chamber. Most precast manholes employ an eccentric or a concentric cone section instead of a slab top. These reinforced cone sections affect the transition from the inside diameter of the riser sections to the specified size of the top opening. Flat slab tops are normally used for very shallow manholes and consist of a reinforced circular slab at least 6-inches thick for risers up to 48 inches in diameter and 8-inches thick for larger riser sizes. The slab which rests on top of the riser sections is cast with an access opening.

Precast grade rings, which are placed on top of either the cone or flat slab top section, are used for close adjustment of top elevation. Cast iron manhole cover assemblies are normally placed on top of the grade rings.

The manhole assembly may be furnished with or without steps inserted into the walls of the sections. Reinforcement required by ASTM Standard C 478 is primarily designed to resist handling stresses incurred before and during installation, and is more than adequate for that purpose. Such stresses are more severe than those encountered in the vertically installed manhole. In normal installations, the intensity of the earth loads transmitted to the manhole risers is only a fraction of the intensity of the vertical pressure.

The maximum allowable depth of a typical precast concrete manhole with regard to lateral earth pressures is in excess of 300 feet or, for all practical purposes, unlimited, Because of this, the critical or limiting factor for manhole depth is the supporting strength of the base structure or the resistance to crushing of the ends of the riser section. This phenomena, being largely dependent on the relative settlement of the adjacent soil mass, does not lend itself to precise analysis. Even with extremely conservative values for soil weights, lateral pressure and friction coefficients, it may be concluded several hundred feet can be safely supported by the riser sections without end crushing, based on the assumption that provision is made for uniform bearing at the ends of the riser sections and the elimination of localized stress concentrations.

Illustration 5.8 Typical Configuration of Precast Manhole Sections



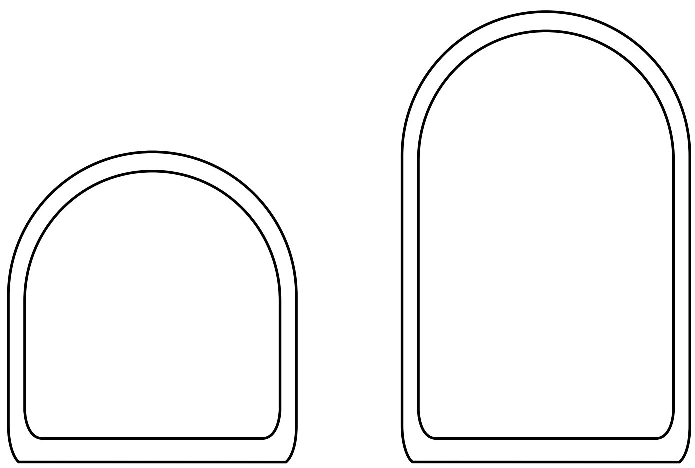
When confronted with manhole depths greater than those commonly encountered, there may be a tendency to specify additional circumferential reinforcement in the manhole riser sections. Such requirements are completely unnecessary and only result in increasing the cost of the manhole structure.

A number of joint types may be used for manhole risers and tops, including mortar, mastic, rubber gaskets or combinations of these three basic types for sealing purposes. Consideration should be given to manhole depth, the presence of groundwater and the minimum allowable leakage rates in the selection of specific joint requirements.

Flat Base Pipe. Flat base pipe as shown in Illustration 5.9 has been used as cattle passes, pedestrian underpasses and utility tunnels. It is normally furnished with joints designed for use with mortar or mastic fillers and may be installed by the conventional open trenching method or by jacking.

Although not covered by any existing national specification, standard designs have been developed by various manufacturers which are appropriate for a wide range of loading conditions.

Illustration 5.9 Typical Cross Sections of Flat Base Pipe



STANDARD SPECIFICATIONS FOR CONCRETE PIPE

Nationally accepted specifications covering concrete pipe along with the applicable size ranges and scopes of the individual specifications are included in the following list.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM C 14 Concrete Sewer, Storm Drain and Culvert Pipe: Covers nonreinforced concrete pipe intended to be used for the conveyance of sewage, industrial wastes, storm water, and for the construction of culverts in sizes from 4 inches through 36 inches in diameter.

ASTM C 76	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe: Covers reinforced concrete pipe intended to be used for the conveyance of sewage, industrial wastes, and storm waters, and for the construction of culverts. Class I - 60 inches through 144 inches in diameter; Class II, III, IV and V - 12 inches through 144 inches in diameter. Larger sizes and higher classes are available as special designs.
ASTM C 118	Concrete Pipe for Irrigation or Drainage: Covers concrete pipe intended to be used for the conveyance of irrigation water under low hydrostatic heads, generally not exceeding 25 feet, and for use in drainage in sizes from 4 inches through 24 inches in diameter.
ASTM C 361	Reinforced Concrete Low-Head Pressure Pipe: Covers reinforced concrete pipe intended to be used for the construction of pressure conduits with low internal hydrostatic heads generally not exceeding 125 feet in sizes from 12 inches through 108 inches in diameter.
ASTM C 412	Concrete Drain Tile: Covers nonreinforced concrete drain tile with internal diameters from 4 inches to 24 inches for Standard Quality, and 4 inches to 36 inches for Extra-Quality, Heavy-Duty Extra-Quality and Special Quality Concrete Drain Tile.
ASTM C 443	Joints for Circular Concrete Sewer and Culvert Pipe, with Rubber Gaskets: Covers joints where infiltration or exfiltration is a factor in the design, including the design of joints and the requirements for rubber gaskets to be used therewith for pipe conforming in all other respects to ASTM C 14 or ASTM C 76.
ASTM C 444	Perforated Concrete Pipe: Covers perforated concrete pipe intended to be used for underdrainage in sizes 4 inches and larger.
ASTM C 478	Precast Reinforced Concrete Manhole Sections: Covers precast reinforced concrete manhole risers, grade rings and tops to be used to construct manholes for storm and sanitary sewers.
ASTM C 497	Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile: Covers procedures for testing concrete pipe and tile.
ASTM C 505	Nonreinforced Concrete Irrigation Pipe With Rubber Gasket Joints: Covers pipe to be used for the conveyance of irrigation water with working pressures, including hydraulic transients, of up to 30 feet of head. Higher pressures may be used up to a maximum of 50 feet for 6 inch through 12 inch diameters, and 40 feet for 15 inch through 18 inch diameters by increasing the strength of the pipe.

ASTM C 506 Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe: Covers pipe to be used for the conveyance of sewage, industrial waste, and storm water and for the construction of culverts in sizes from 15 inch through 132 inch equivalent circular diameter. Larger sizes are available as special designs.

ASTM C 507 Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe: Covers reinforced elliptically shaped concrete pipe to be used for the conveyance of sewage, industrial waste and storm water, and for the construction of culverts. Five standard classes of horizontal elliptical, 18 inches through 144 inches in equivalent circular diameter and five standard classes of vertical elliptical, 36 inches through 144 inches in equivalent circular diameter are included. Larger sizes are available as special designs.

ASTM C 655 Reinforced Concrete D-load Culvert, Storm Drain and Sewer Pipe: Covers acceptance of pipe design and production pipe based upon the D-load concept and statistical sampling techniques for concrete pipe to be used for the conveyance of sewage, industrial waste and storm water and construction of culverts.

ASTM C 822 Standard Definitions and Terms Relating to Concrete Pipe and Related Products: Covers words and terms used in concrete pipe standards.

ASTM C 877 External Sealing Bands for NonCircular Concrete Sewer, Storm Drain and Culvert Pipe: Covers external sealing bands to be used for noncircular pipe conforming to ASTM C 506, C 507, C 789 and C 850.

ASTM C 923 Resilient Connectors Between Reinforced Concrete Manhole Structures and Pipes: Covers the minimum performance and material requirements for resilient connections between pipe and reinforced concrete manholes conforming to ASTM C 478.

ASTM C 924 Testing Concrete Pipe Sewer Lines by Low-Pressure Air Test Method: Covers procedures for testing concrete pipe sewer lines when using the low-pressure air test method to demonstrate the integrity of the installed material and construction procedures.

ASTM C 969 Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines: Covers procedures for testing installed precast concrete pipe sewer lines using either water infiltration or exfiltration acceptance limits to demonstrate the integrity of the installed materials and construction procedure.

ASTM C 985 Nonreinforced Concrete Specified Strength Culvert, Storm Drain, and Sewer Pipe: Covers nonreinforced concrete pipe designed for specified strengths and intended to be used for the conveyance of sewage, industrial wastes, storm water, and for the construction of culverts.

ASTM C 990 Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Sealants: Covers joints for precast concrete pipe, box, and other sections using preformed flexible joint sealants for use in storm sewers and culverts which are not intended to operate under internal pressure, or are not subject to infiltration or exfiltration limits.

ASTM C 1103 Joint Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines: Covers procedures for testing the joints of installed precast concrete pipe sewer lines, when using either air or water under low pressure to demonstrate the integrity of the joint and construction procedure.

ASTM C 1131 Least Cost (Life Cycle) Analysis of Concrete Culvert, Storm Sewer, and Sanitary Sewer Systems: Covers procedures for least cost (life cycle) analysis (LCA) of materials, systems, or structures proposed for use in the construction of concrete culvert, storm sewer and sanitary sewer systems.

ASTM C 1214 Test Method for Concrete Pipe Sewerlines by Negative Air Pressure (Vacuum) Test Method: Covers procedures for testing concrete pipe sewerlines, when using the negative air pressure (vacuum) test method to demonstrate the integrity of the installed material and the construction procedures.

ASTM C 1244 Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) Test: Covers procedures for testing precast concrete manhole sections when using the vacuum test method to demonstrate the integrity of the installed materials and the construction procedures.

ASTM C 1417 Manufacture of Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design: Covers the manufacture and acceptance of precast concrete pipe designed to conform to the owner’s design requirements and to ASCE 15-93 (Direct Design Standard) or an equivalent design specification.

ASTM C 1433 Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers: Covers single-cell precast reinforced concrete box sections intended to be used for the construction of culverts for the conveyance of storm water and industrial wastes and sewage.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO M 86 Concrete Sewer, Storm Drain, and Culvert Pipe: Similar to ASTM C 14.

AASHTO M 170 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe: Similar to ASTM C 76.

AASHTO M 175 Perforated Concrete Pipe: Similar to ASTM C 444.

AASHTO M 178 Concrete Drain Tile: Similar to ASTM C 412.

AASHTO M 198 Joints for Circular Concrete Sewer and Culvert Pipe, Using Flexible Watertight Gaskets: Similar to ASTM C 990.

AASHTO M 199 Precast Reinforced Concrete Manhole Sections: Similar to ASTM C 478.

AASHTO M 206 Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe: Similar to ASTM C 506.

AASHTO M 207 Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe: Similar to ASTM C 507.

AASHTO M 242 Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe: Similar to ASTM C 655.

AASHTO M 259 Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewers: Similar to ASTM C 789.

AASHTO M 262 Concrete Pipe and Related Products: Similar to ASTM C 882.

AASHTO M 273 Precast Reinforced Box Section for Culverts, Storm Drains, and Sewers with less than 2 feet of Cover Subject to Highway Loadings: Similar to ASTM C 850.

AASHTO T 280 Methods of Testing Concrete Pipe, Sections, or Tile: Similar to ASTM C 497.

AASHTO M 315 Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets: Similar to ASTM C 443.

PIPE JOINTS

Pipe joints perform a variety of functions depending upon the type of pipe and its application. To select a proper joint, determine which of the following characteristics are pertinent and what degree of performance is acceptable.

Joints are designed to provide:

1. Resistance to infiltration of ground water and/or backfill material.
2. Resistance to exfiltration of sewage or storm water.
3. Control of leakage from internal or external heads.
4. Flexibility to accommodate lateral deflection or longitudinal movement without creating leakage problems.
5. Resistance to shear stresses between adjacent pipe sections without creating leakage problems.
6. Hydraulic continuity and a smooth flow line.
7. Controlled infiltration of ground water for subsurface drainage.
8. Ease of installation.

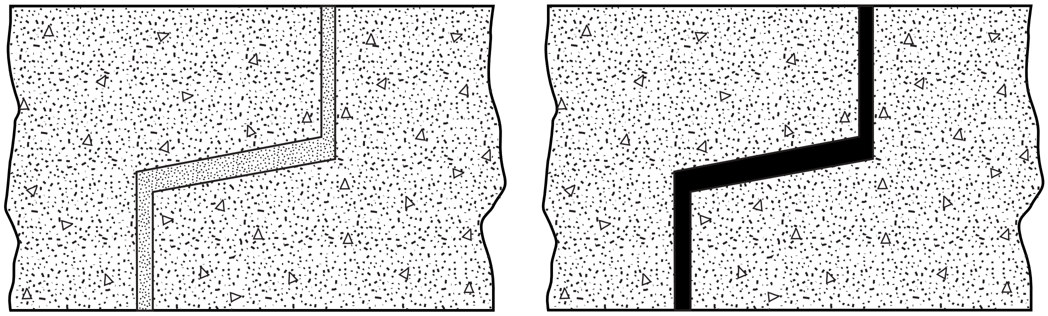
The actual field performance of any pipe joint depends primarily upon the inherent performance characteristics of the joint itself, the severity of the conditions of service, and the care with which it is installed.

Since economy is important, it is usually necessary to compare the installed cost of several types of joints against pumping and treatment costs resulting from increased or decreased amounts of infiltration.

The concrete pipe industry utilizes a number of different joints, listed below, to satisfy a broad range of performance requirements. These joints vary in cost, as well as in inherent performance characteristics. The field performance of all is dependent upon proper installation procedures.

- Concrete surfaces, either bell and spigot or tongue and groove, with some packing such as cement mortar, a preformed mastic compound, or a trowel applied mastic compound, as shown in Illustration 5.10. These joints have no inherent watertightness but depend exclusively upon the workmanship of the contractor. Field poured concrete diapers or collars are sometimes used with these joints to improve performance. Joints employing mortar joint fillers are rigid, and any deflection or movement after installation will cause cracks permitting leakage. If properly applied, mastic joint fillers provide a degree of flexibility without impairing watertightness. These joints are not generally recommended for any internal or external head conditions if leakage is an important consideration. Another jointing system used with this type joint is the external sealing band type rubber gasket conforming to ASTM C 877. Generally limited to straight wall and modified tongue and groove configurations, this jointing system has given good results in resisting external heads of the magnitude normally encountered in sewer construction.

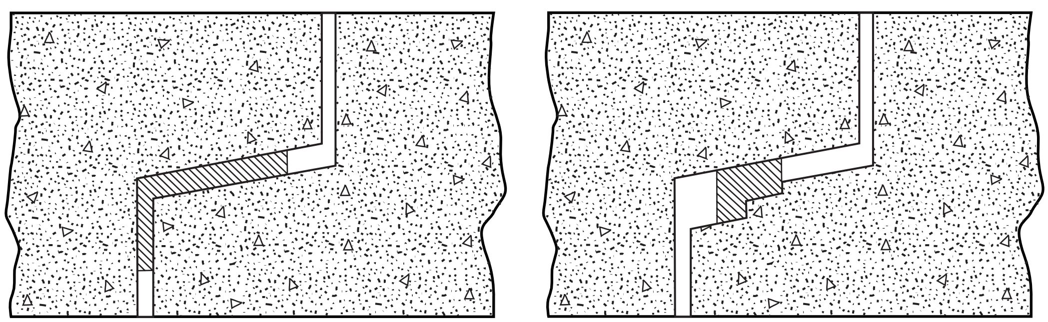
Illustration 5.10 Typical Cross Sections of Joints With Mortar or Mastic Packing



MORTOR PACKING MASTIC PACKING

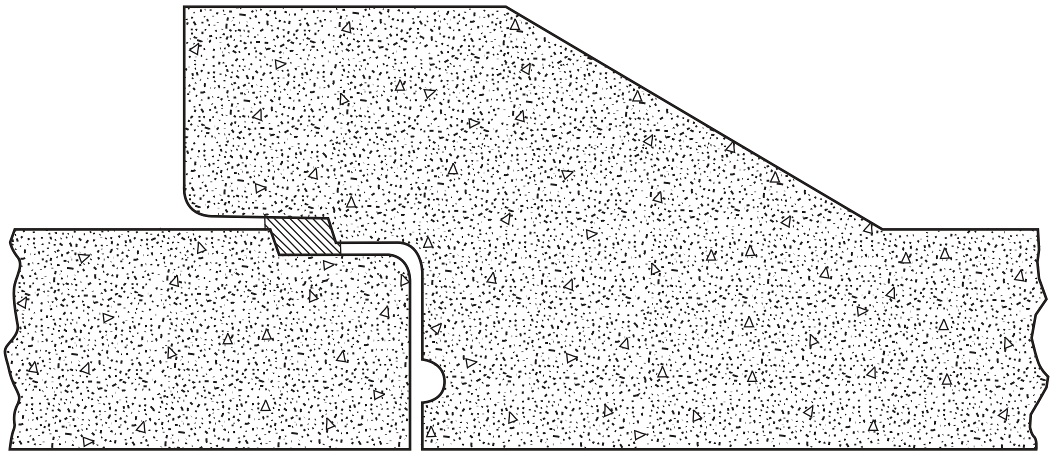
- Concrete surfaces, with or without shoulders on the tongue or the groove, with a compression type rubber gasket as shown in Illustration 5.11. Although there is wide variation in joint dimensions and gasket cross section for this type joint, most are manufactured in conformity with ASTM C 443. This type joint is primarily intended for use with pipe manufactured to meet the requirements of ASTM C 14 or ASTM C 76 and may be used with either bell and spigot or tongue and groove pipe.

Illustration 5.11 Typical Cross Sections of Basic Compression Type Rubber Gasket Joints



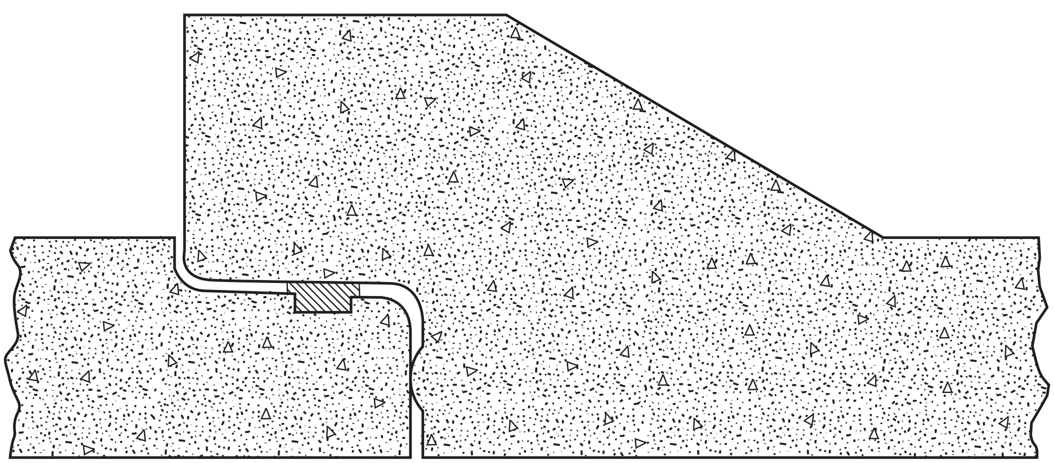
- Concrete surfaces with opposing shoulders on both the bell and spigot for use with an 0-ring, or circular cross section, rubber gasket as shown in Illustration 5.12. Basically designed for low pressure capability, these joints are frequently used for irrigation lines, waterlines, sewer force mains, and gravity or low head sewer lines where infiltration or exfiltration is a factor in the design. Meeting all of the requirements of ASTM C 443, these type joints are also employed with pipe meeting the requirements of ASTM C 361. They provide good inherent watertightness in both the straight and deflected positions, which can be demonstrated by plant tests.

Illustration 5.12 Typical Cross Sections of Opposing Shoulder Type Joint With 0-ring Gasket



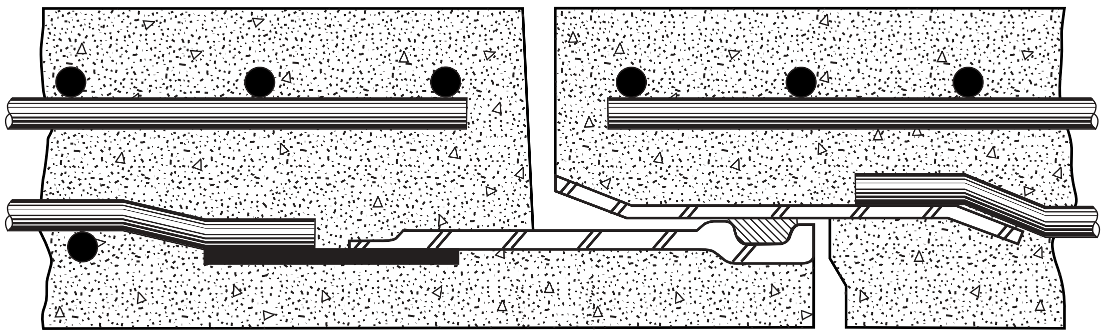
- Concrete surfaces with a groove on the spigot for an 0-ring rubber gasket, as shown in Illustration 5.13. Also referred to as a confined 0-ring type joint, these are designed for low pressure capabilities and are used for irrigation lines, water lines, sewer force mains, and sewers where infiltration or exfiltration is a factor in the design. This type joint, which provides excellent inherent watertightness in both the straight and deflected positions, may be employed to meet the joint requirements of ASTM C 443 and ASTM C 361.

Illustration 5.13 Typical Cross Section of Spigot Groove Type Joint With 0-ring Gasket



- Steel bell and spigot rings with a groove on the spigot for an 0-ring rubber gasket, as shown in Illustration 5.14. Basically a high pressure joint designed for use in water transmission and distribution lines, these are also used for irrigation lines, sewer force mains, and sewers where infiltration or exfiltration is a factor in the design. This type of joint will meet the joint requirements of ASTM C 443 and ASTM C 361. Combining great shear strength and excellent inherent watertightness and flexibility, this type joint is the least subject to damage during installation.

Illustration 5.14 Typical Cross Section of Steel End Ring Joint With Spigot Groove and 0-ring Gasket



Since both field construction practices and conditions of service are subject to variation, it is impossible to precisely define the field performance characteristics of each of the joint types. Consultation with local concrete pipe manufacturers will provide information on the availability and cost of the various joints. Based on this information and an evaluation of groundwater conditions, the specifications should define allowable infiltration or exfiltration rates and/or the joint types which are acceptable.

JACKING CONCRETE PIPE

Concrete pipelines were first jacked in place by the Northern Pacific Railroad between 1896 and 1900. In more recent years, this technique has been applied to sewer construction where intermediate shafts along the line of the sewer are used as jacking stations.

Reinforced concrete pipe as small as 18-inch inside diameter and as large as 132-inch inside diameter have been installed by jacking.

Required Characteristics of Concrete Jacking Pipe. Two types of loading conditions are imposed on concrete pipe installed by the jacking method; the axial load due to the jacking pressures applied during installation, and the earth loading due to the overburden, with some possible influence from live loadings, which will generally become effective only after installation is completed.

It is necessary to provide for relatively uniform distribution of the axial load around the periphery of the pipe to prevent localized stress concentrations. This is accomplished by keeping the pipe ends parallel within the tolerances prescribed by ASTM C 76, by using a cushion material, such as plywood or hardboard, between the pipe sections, and by care on the part of the contractor to insure that the jacking force is properly distributed through the jacking frame to the pipe and parallel with the axis of the pipe. The cross sectional area of the concrete pipe wall is more than adequate to resist pressures encountered in any normal jacking operation. For projects where extreme jacking pressures are anticipated due to long jacking distances or excessive unit frictional forces, higher concrete compressive strength may be required, along with greater care to avoid bearing stress concentrations. Little or no gain in axial crushing resistance is provided by specifying a higher class of pipe.

For a comprehensive treatment of earth loads on jacked pipe see Chapter 4. The earth loads on jacked pipe are similar to loads on a pipe installed in a trench with the same width as the bore with one significant difference. In a jacked pipe installation the cohesive forces within the soil mass in most instances are appreciable and tend to reduce the total vertical load on the pipe. Thus the vertical load on a jacked pipe will always be less than on a pipe in a trench installation with the same cover and, unless noncohesive materials are encountered, can be substantially less.

With the proper analysis of loadings and selection of the appropriate strength class of pipe, few additional characteristics of standard concrete pipe need be considered. Pipe with a straight wall, without any increase in outside diameter at the bell or groove, obviously offers fewer problems and minimizes the required excavation. Considerable quantities of modified tongue and groove pipe have been jacked, however, and presented no unusual problems.

The Jacking Method. The usual procedure in jacking concrete pipe is to equip the leading edge with a cutter, or shoe, to protect the pipe. As succeeding lengths of pipe are added between the lead pipe and the jacks, and the pipe jacked forward, soil is excavated and removed through the pipe. Material is trimmed with care and excavation does not precede the jacking operation more than necessary. Such a procedure usually results in minimum disturbance of the natural soils adjacent to the pipe.

Contractors occasionally find it desirable to coat the outside of the pipe with a lubricant, such as bentonite, to reduce the frictional resistance. In some instances, this lubricant has been pumped through special fittings installed in the wall of the pipe.

Because of the tendency of jacked pipe to “set” when forward movement is interrupted for as long as a few hours, resulting in significantly increased frictional resistance, it is desirable to continue jacking operations until completed.

In all jacking operations it is important that the direction of jacking be carefully established prior to beginning the operation. This requires the erection of guide rails in the bottom of the jacking pit or shaft. In the case of large pipe, it is desirable to have such rails carefully set in a concrete slab. The number and capacity of the jacks required depend primarily upon the size and length of the pipe to be jacked and the type of soil encountered.

Illustration 5.15 Steps in Jacking Concrete Pipe

1. Pits are excavated on each side. The jacks will bear against the back of the left pit so a steel or wood abutment is added for reinforcement. A simple track is added to guide the concrete pipe section. The jack(s) are positioned in place on supports.

2. A section of concrete pipe is lowered into the pit.

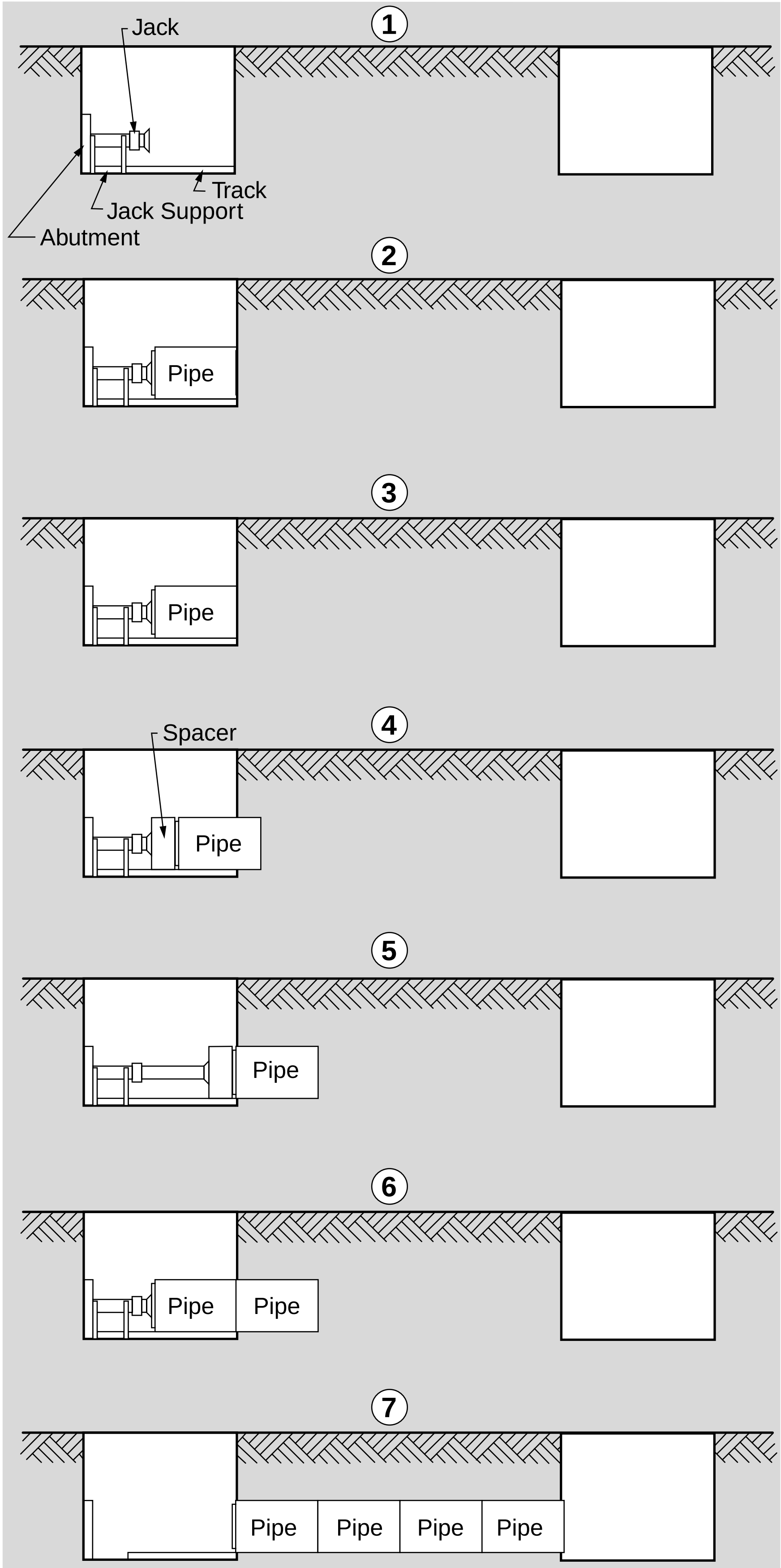
3. The jack(s) are operated pushing the pipe section forward.

4. The jack ram(s) are retracted and a “spacer” is added between the jack(s) and pipe.

5. The jack(s) are operated and the pipe is pushed forward again.

6. It may become necessary to repeat the above steps 4 and 5 several times until the pipe is pushed forward enough to allow room for the next section of pipe. It is extremely important, therefore, that the strokes of the jacks be as long as possible to reduce the number of spacers required and thereby reduce the amount of time and cost. The ideal situation would be to have the jack stroke longer than the pipe to completely eliminate the need for spacers.

7. The next section of pipe is lowered into the pit and the above steps repeated. The entire process above is repeated until the operation is complete.



Backstops for the jacks must be strong enough and large enough to distribute the maximum capacity of the jacks against the soil behind the backstops. A typical installation for jacking concrete pipe is shown in Illustration 5.15.

BENDS AND CURVES

Changes in direction of concrete pipe sewers are most commonly effected at manhole structures. This is accomplished by proper location of the inlet and outlet openings and finishing of the invert in the structure to reflect the desired angular change of direction.

In engineering both grade and alignment changes in concrete pipelines it is not always practical or feasible to restrict such changes to manhole structures. Fortunately there are a number of economical alternatives.

Deflected Straight Pipe. With concrete pipe installed in straight alignment and the joints in a home (or normal) position, the joint space, or distance between the ends of adjacent pipe sections, will be essentially uniform around the periphery of the pipe. Starting from this home position any joint may be opened up to a maximum permissible joint opening on one side while the other side remains in the home position. The difference between the home and opened joint space is generally designated as the pull. This maximum permissible opening retains some margin between it and the limit for satisfactory function of the joint. It varies for different joint configurations and is best obtained from the pipe manufacturer.

Opening a joint in this manner effects an angular deflection of the axis of the pipe, which, for any given pull is a function of the pipe diameter. Thus, given the values of any two of the three factors; pull, pipe diameter, and deflection angle, the remaining factor may be readily calculated.

The radius of curvature which may be obtained by this method is a function of the deflection angle per joint and the length of the pipe sections. Thus, longer lengths of pipe will provide a longer radius for the same pull than would be obtained with shorter lengths.The radius of curvature is computed by the equation:

$$R = \frac{L}{2(\tan 1/2 \times \frac{\Delta}{N})}$$

where:

R = Radius of curvature, feet

L = Average laid length of pipe sections measured along the centerline, feet

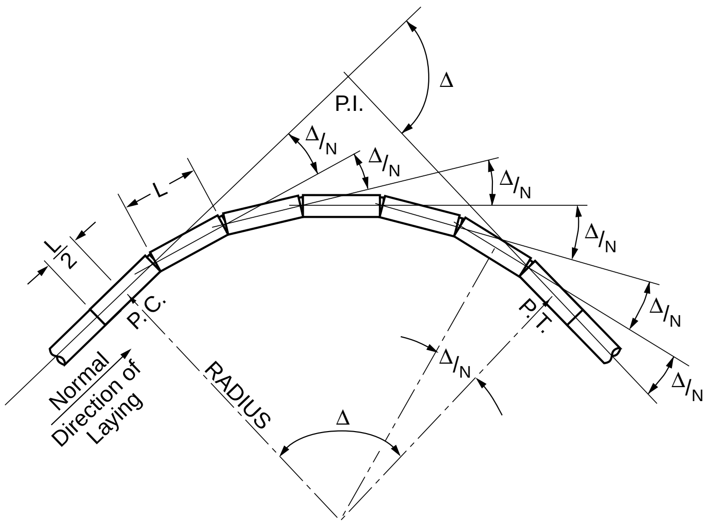
Δ = Total deflection angle of curve, degrees

N = Number of pipe with pulled joints

$\frac{\Delta}{N}$ = Total deflection of each pipe, degrees

Using the deflected straight pipe method, Illustration 5.16 shows that the P.C. (point of curve) will occur at the midpoint of the last undeflected pipe and the P.T. (point of tangent) will occur at the midpoint of the last pulled pipe.

Illustration 5.16 Curved Alignment Using Deflected Straight Pipe



Radius Pipe. Sharper curvature with correspondingly shorter radii can be accommodated with radius pipe than with deflected straight pipe. This is due to the greater deflection angle per joint which may be used. In this case the pipe is manufactured longer on one side than the other and the deflection angle is built in at the joint. Also referred to as bevelled or mitered pipe, it is similar in several respects to deflected straight pipe. Thus, shorter radii may be obtained with shorter pipe lengths; the maximum angular deflection which can be obtained at each joint is a function of both the pipe diameter and a combination of the geometric configuration of the joint and the method of manufacture.

These last two factors relate to how much shortening or drop can be applied to one side of the pipe. The maximum drop for any given pipe is best obtained from the manufacturer of the pipe since it is based on manufacturing feasibility.

The typical alignment problem is one in which the total Δ angle of the curve and the required radius of curvature have been determined. The diameter and direction of laying of the pipe are known. To be determined is whether the curve can be negotiated with radius pipe and, if so, what combination of pipe lengths and drop are required. Information required from the pipe manufacturer is the maximum permissible drop, the wall thicknesses of the pipe and the standard lengths in which the pipe is available. Any drop up to the maximum may be used as required to fit the curve.

Values obtained by the following method are approximate, but are within a range of accuracy that will permit the pipe to be readily installed to fit the required alignment.

The tangent of the deflection angle, $\frac{\Delta}{N}$ required at each joint is computed by the equation:

$$\tan \frac{\Delta}{N} = \frac{L}{R + D/2 + t}$$

where:

Δ = Total deflection angle of curve, degrees
N = Number of radius pipe
L = The standard pipe length being used, feet
R = Radius of curvature, feet
D = Inside diameter of the pipe, feet
t = Wall thickness of the pipe, feet

The required drop in inches to provide the deflection angle, $\frac{\Delta}{N}$ computed by the equation:

$$\text{Drop} = 12(D + 2t) \tan \frac{\Delta}{N}$$

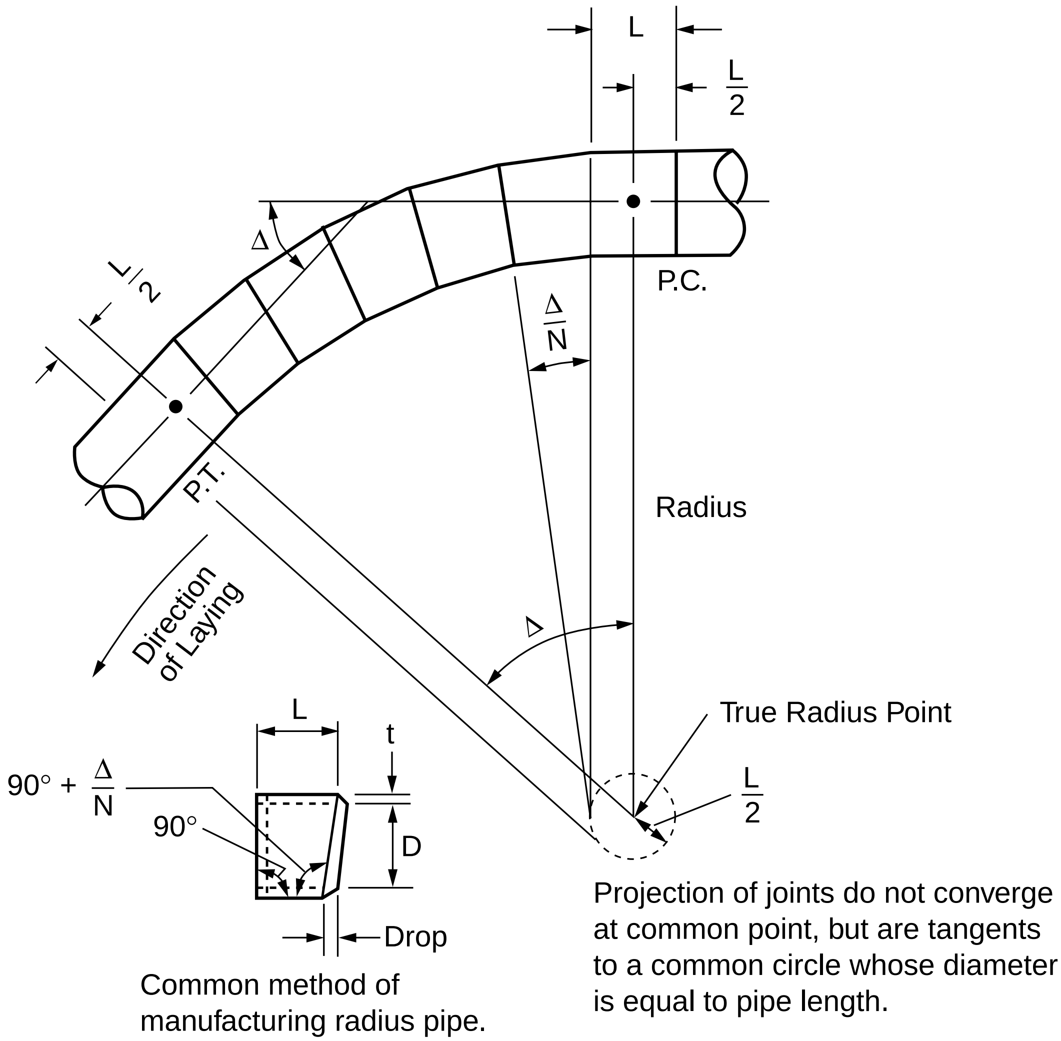
The number of pieces of radius pipe required is equal to the length of the circular curve in feet divided by the centerline length of the radius pipe (L - 1/2 Drop). Minor modifications in the radius are normally made so this quotient will be a whole number.

If the calculated drop exceeds the maximum permissible drop, it will be necessary to either increase the radius of curvature or to use shorter pipe lengths. Otherwise special fittings must be used as covered in the next section.

It is essential that radius pipe be oriented such that the plane of the dropped joint is at right angles to the theoretical circular curve. For this reason lifting holes in the pipe must be accurately located, or, if lifting holes are not provided, the top of the pipe should be clearly and accurately marked by the manufacturer so that the deflection angle is properly oriented.

It should also be noted that a reasonable amount of field adjustment is possible by pulling the radius pipe joints in the same manner as with deflected straight pipe.

Illustration 5.17 Curved Alignment Using Radius Pipe



As indicated in Illustration 5.17, the P.C. (point of curve) falls at the midpoint of the last straight pipe and the P.T. (point of tangent) falls one half of the standard pipe length back from the straight end of the last radius pipe. To assure that the P.C. will fall at the proper station it is generally necessary that a special short length of pipe be installed in the line, ahead of the P.C.

Bends and Special Sections. Extremely short radius curves cannot be negotiated with either deflected straight pipe or with conventional radius pipe. Several alternatives are available through the use of special precast sections to solve such alignment problems.

Sharper curves can be handled by using special short lengths of radius pipe rather than standard lengths. These may be computed in accordance with the methods discussed for radius pipe.

Certain types of manufacturing processes permit the use of a dropped joint on both ends of the pipe, which effectively doubles the deflection. Special bends, or elbows can be manufactured to meet any required deflection angle and some manufacturers produce standard bends which provide given angular deflection per section.

One or more of these methods may be employed to meet the most severe alignment problems. Since manufacturing processes and local standards vary, local concrete pipe manufacturers should be consulted to determine the availability and geometric configuration of special sections.

SIGNIFICANCE OF CRACKING

The occurrence, function and significance of cracks have probably been the subject of more misunderstanding and unnecessary concern by engineers than any other phenomena related to reinforced concrete pipe.

Reinforced concrete pipe, like reinforced concrete structures in general, are made of concrete reinforced with steel in such a manner that the high compressive strength of the concrete is balanced by the high tensile strength of the steel. In reinforced concrete pipe design, no value is given to the tensile strength of the concrete. The tensile strength of the concrete, however, is important since all parts of the pipe are subject to tensile forces at some time subsequent to manufacture. When concrete is subjected to tensile forces in excess of its tensile strength, it cracks.

Unlike most reinforced concrete structures, reinforced concrete sewer and culvert pipe is designed to meet a specified cracking load rather than a specified stress level in the reinforcing steel. This is both reasonable and conservative since reinforced concrete pipe may be pretested in accordance with detailed national specifications.

In the early days of the concrete pipe industry, the first visible crack observed in a three-edge bearing test was the accepted criterion for pipe performance. However, the observation of such cracks was subject to variations depending upon the zeal and eyesight of the observer. The need soon became obvious for a criterion based on a measurable crack of a specified width. Eventually the 0.01-inch crack, as measured by a feeler gage of a specified shape, became the accepted criterion for pipe performance.

The most valid basis for selection of a maximum allowable crack width is the consideration of exposure and potential corrosion of the reinforcing steel. If a crack is sufficiently wide to provide access to the steel by both moisture and oxygen, corrosion will be initiated. Oxygen is consumed by the oxidation process and in order for corrosion to be progressive there must be a constant replenishment.

Bending cracks are widest at the surface and get rapidly smaller as they approach the reinforcing steel. Unless the crack is wide enough to allow circulation of the moisture and replenishment of oxygen, corrosion is unlikely. Corrosion is even further inhibited by the alkaline environment resulting from the cement.

While cracks considerably in excess of 0.01-inch have been observed after a period of years with absolutely no evidence of corrosion, 0.01-inch is a conservative and universally accepted maximum crack width for design of reinforced concrete pipe.

- Reinforced concrete pipe is designed to crack. Cracking under load indicates that the tensile stresses have been transferred to the reinforcing steel.
- A crack 0.01-inch wide does not indicate structural distress and is not harmful.
- Cracks much wider than 0.01-inch should probably be sealed to insure protection of the reinforcing steel.
- An exception to the above occurs with pipe manufactured with greater than 1 inch cover over the reinforcing steel. In these cases acceptable crack width should be increased in proportion to the additional concrete cover.