## CONCRETE PIPE

## USE MANUAL



Prepared By
The Illinois Concrete Pipe Association

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## I. INTRODUCTION

Concrete pipe has been used successfully for sewers and culverts in Illinois for over a century. By its very nature, concrete pipe is an ideal drainage product that has the inherent advantage of hydraulic efficiency, structural versatility, local availability, proven durability, construction adaptability, and economic superiority.

National specifications have been issued by the American Society for Testing and Materials, American Association of State Highway and Transportation Officials, American Society of Civil Engineers and the Federal Government for the purpose of ensuring uniform high quality products meeting specific physical requirements.

Concrete pipe is the modern manufactured conduit material with the longest history of excellent service and widest acceptance. New processes, concrete mixes, designs, and unique features are constantly being introduced to make it an even better engineered product for the future.

The purpose of this Manual is to provide information on concrete products available, specification designations, and proper application in the sewer and culvert field. Although liability cannot be assumed, the technical data presented here are considered reliable.

## II. STORM SEWERS \& CULVERTS

## INTRODUCTION

Storm sewers carry rainwater, surface water, ground water, cooling water, or other similar flows to a point of safe discharge. They help protect much of the land we use for agriculture, industry, transportation, residences, and recreation.

Concrete pipe, with its impressive record of strength and durability, is the most economical and reliable choice of materials available today. Storm sewers require that pipe meet the strength requirements of any depth of fill and live load, are hydraulically efficient, are non-combustible, and provide resistance to abrasion.

Culverts provide for the free passage of surface drainage water under a highway, railroad, canal, or other embankment. Proper culvert design prevents the hazards and concurrent expenses of washouts, erosion, flooding, and inundation of adjacent land.

Concrete pipe has been used for culverts in Illinois since the 1800 s and much of it is still serving reliably. Culverts must be strong to meet the embankment and traffic loads, durable, resistant to abrasion and combustion, and available in a variety of shapes.

## APPLICABLE SPECIFICATIONS AND RECOMMENDED USE

## CIRCULAR PIPE

## ASTM C14 Concrete Sewer, Storm Drain, and Culvert Pipe (Non-Reinforced)

C14 pipe is currently not in general use in Illinois. If desired, it may be used for sizes 12 in . through 36 in. diameter with the provision that C76 pipe of comparable strength also be specified. Joints provided for most storm sewer construction employ cement mortar or mastic compound. For installations with internal or external head condition, joints may be provided meeting the requirements of ASTM C443 utilizing a rubber gasket.

## ASTM C76 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

C76 pipe is used for sizes 12 in . through 144 in . diameter and is available with bell and spigot or tongue and groove ends utilizing cement mortar or mastic compound joints. These joints are adequate for most culvert and drainage installations. For the special condition of internal or external heads, joints may be provided meeting the requirements of ASTM C443 or ASTM C361 utilizing a rubber gasket. ASTM C76 pipe is the most commonly used storm sewer pipe because of its excellent hydraulic capacity, resistance to abrasion and combustion, capabilities in meeting any variety of load conditions, and availability with a number of related appurtenances.

## ASTM C655 Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe

C655 pipe is used for sizes 12 in . through 144 in . diameter designed for a specific D-load strength. Joints provided for most culvert and drainage employ cement mortar or mastic compound. The properties of the pipe are similar to ASTM C76 pipe except that the pipe may be designed for a specific D-load strength and the design accepted on the basis of a statistical analysis of test specimens.

## SPECIAL SHAPE PIPE AND PRECAST CONCRETE BOXES

## ASTM C506 Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe

C506 arch pipe is used for sizes 18 in . through 132 in . equivalent circular sizes and is available with tongue and groove cement mortar or mastic compound joint. This arch-shaped pipe is used for minimum cover situations or other conditions where vertical clearance problems are encountered. It offers the hydraulic advantage of greater capacity for the same depth flow than most other structures or equivalent waterway area. Loads under similar cover conditions are similar to that of circular pipe with the same span. If arch pipe is not available in a certain area, elliptical pipe may be substituted as an equivalent.

## ASTM C507 Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe

C507 horizontal elliptical pipe is used for sizes 18 in. through 144 in . equivalent circular sizes with tongue and groove cement mortar or mastic compound joint. The horizontal elliptical pipe is installed with the major axis horizontal and is used for 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 waterway area. Loads under similar cover conditions are similar to that of circular pipe with the same span.

C507 vertical elliptical pipe is used for sizes 36 in . through 144 in . equivalent circular sizes with tongue and groove cement mortar or mastic compound joint. The vertical elliptical pipe is installed with the major axis vertical and is used 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 horizontal elliptical, arch, or circular pipe. Loads under similar cover conditions are similar to that of circular pipe with the same span. Special installation techniques are required for vertical elliptical pipe.

## ASTM C1577 Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers

C1577 box sections are used in sizes of span and rise from 3 ft . by 2 ft . to 12 ft . by 12 ft . Although not specifically called out by ASTM C1577, 2 ft . by 2 ft . box sections are also locally available. The tables provide design requirements for boxes installed under earth, dead and HL-93 live load conditions, for design earth cover of 0 to 35 feet. Joints provided utilize tongue and groove type ends with cement mortar or mastic compound joints. Box sections are used where special hydraulic requirements and minimum cover are encountered. They offer the advantage of precast products over cast-in-place construction through low installation costs and minimum inconvenience of weather and traffic delay.

Box units may be used in parallel for multicell installations. Double-cell box sections are also available locally.
The following tables are provided from the Illinois Department of Transportation's "Standard Specifications for Road and Bridge Construction", April 1, 2016 edition. Please note that all applicable IDOT provisions must be adhered to when using these tables.

# CIRCULAR RCP FOR STORM SEWERS \& PIPE CULVERTS 

STRENGTH CLASS REQUIRED FOR THE RESPECTIVE DIAMETERS OF CIRCULAR PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS \& PIPE CULVERTS

|  | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 | Type 7 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nominal <br> Diameter Inches | Fill <br> Height: 3' and less with 1' minimum cover | Fill Height: <br> Greater than 3' not exceeding 10 ' | Fill Height: Greater than 10 , not exceeding 15 ' | Fill Height: Greater than 15, not exceeding 20' | Fill Height: Greater than 20' not exceeding 25' | Fill Height: Greater than 25, not exceeding $30^{\prime}$ | Fill Height: Greater than 30, not exceeding 35' |
| 10 | NA | NA | NA | NA | NA | NA | NA |
| 12 | IV | II | III | IV | IV | V | V |
| 15 | IV | II | III | IV | IV | V | V |
| 18 | IV | II | III | IV | IV | V | V |
| 21 | III | II | III | IV | IV | V | V |
| 24 | III | II | III | IV | IV | V | V |
| 27 | III | II | III | IV | IV | V | V |
| 30 | IV | II | III | IV | IV | V | V |
| 33 | III | II | III | IV | IV | V | V |
| 36 | III | II | III | IV | IV | V | V |
| 42 | II | II | III | IV | IV | V | V |
| 48 | II | II | III | IV | IV | V | V |
| 54 | II | II | III | IV | IV | V | V |
| 60 | II | II | III | IV | IV | V | V |
| 66 | II | II | III | IV | IV | V | V |
| 72 | II | II | III | IV | V | V | V |
| 78 | II | II | III | IV | 2,020 | 2,370 | 2,730 |
| 84 | II | II | III | IV | 2,020 | 2,380 | 2,740 |
| 90 | II | II | III | 1,680 | 2,030 | 2,390 | 2,750 |
| 96 | II | III | III | 1,690 | 2,040 | 2,400 | 2,750 |
| 102 | II | III | III | 1,700 | 2,050 | 2,410 | 2,760 |
| 108 | II | III | 1,360 | 1,710 | 2,060 | 2,410 | 2,770 |

Notes: A number indicates the D-Load for the diameter and depth of fill and that a special design is required.
Design assumptions: Water filled pipe, Type 2 bedding and Class C walls

# ELLIPTICAL RCP FOR STORM SEWERS \& PIPE CULVERTS <br> STRENGTH CLASS REQUIRED FOR ELLIPTICAL REINFORCED CONCRETE PIPE OF THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE 

| Equivalent Round Size, inches | Reinforced Concrete Elliptical Pipe, inches |  | Minimum <br> Fill <br> Height | Type 1 <br> Fill Height: <br> Not exceeding 3' | Type 2 <br> Fill Height: Greater than 3 ' not exceeding $10^{\prime}$ | Type 3 <br> Fill Height: <br> Greater than 10 ' not exceeding 15 , |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |
|  | Span | Rise |  |  |  |  |
| 15 | 23 | 14 | 1'-0" | HE-III | HE-III | HE-IV |
| 18 | 23 | 14 | $1^{\prime}-0$ " | HE-III | HE-III | HE-IV |
| 21 | 30 | 19 | 1'-0" | HE-III | HE-III | HE-IV |
| 24 | 30 | 19 | $1^{\prime}-0$ " | HE-III | HE-III | HE-IV |
| 27 | 34 | 22 | $1^{\prime}-0$ " | HE-III | HE-III | HE-IV |
| 30 | 38 | 24 | $1^{\prime}-0$ " | HE-III | HE-III | HE-IV |
| 36 | 45 | 29 | $1^{\prime}-0$ " | HE-II | HE-III | HE-IV |
| 42 | 53 | 34 | $1^{\prime}-0$ " | HE-I | HE-III | HE-IV |
| 48 | 60 | 38 | 1'-0" | HE-I | HE-III | 1,460 |
| 54 | 68 | 43 | 1'-0" | HE-I | HE-III | 1,460 |
| 60 | 76 | 48 | 1'-0" | HE-I | HE-III | 1,460 |
| 66 | 83 | 53 | 1'-0" | HE-I | HE-III | 1,470 |
| 72 | 91 | 58 | 1'-0" | HE-I | HE-III | 1,470 |

Notes: A number indicates the D-Load for the diameter and depth of fill and that a special design is required.

Design assumptions: Water filled pipe, Type 2 bedding and Class C walls

## III. SANITARY SEWERS

## INTRODUCTION

Sanitary sewers are conduits that carry liquid and water-carried wastes from homes, commercial facilities, industrial plants and institutions to a treatment plant for the express purpose of protecting our environment, safeguarding health, and improving our comforts and quality of life.

Concrete pipe is the most widely used and accepted permanent product of all sanitary sewer materials. It makes up the greater portion of the sanitary sewer system in most major cities in the United States. Sanitary sewers require that pipe meet infiltration limits, meet the strength conditions of any depth of backfill and superimposed load, and provide resistance to the effects of sewage.

## RECOMMENDED STANDARD SPECIFICATION

## 1. SCOPE

1.1-This specification covers reinforced concrete pipe intended to be used for the conveyance of waste water.

## 2. REFERENCED DOCUMENTS

2.1 ASTM Standards:

C76 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
C361 Reinforced Concrete Low-Head Pressure Pipe
C443 Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets
C655 Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe
C822 Definitions of Concrete Pipe and Related Products
C969 Infiltration and Exfiltration Acceptance Testing
C1103 Joint Acceptance Testing of Installed Pre-cast Concrete Pipe Sewer Lines

## 3. TERMINOLOGY

3.1 Definitions - For definitions of terms relating to concrete pipe, see Definitions C822.

## 4. MATERIALS

4.1 Reinforced Concrete Pipe - Reinforced concrete pipe shall be manufactured in accordance with ASTM C76 or ASTM C655. The manufacturer of the reinforced concrete pipe shall be on the Illinois Department of Transportation's "List of Certified Plants."
4.2 Pipe Class - The class of pipe shall be as shown on the plans.
4.3 Lift Holes - Lift holes shall not be permitted.
4.4 Joints - Joints shall conform to ASTM C443 or C361.
4.5 Gaskets - The gaskets shall be installed in accordance with the manufacturer's recommendations. Prior to commencing installation, the contractor shall submit to the engineer:
4.5.1 - Manufacturer's literature on the type of gasket to be used.
4.5.2 - Manufacturer's literature on the type of lubricant to be used.
4.5.3 - Manufacturer's recommended installation procedures, including equalization techniques.
4.6 Fittings - Fittings shall conform to the strength and water-tightness requirements placed upon mainline pipe.

## 5. EXCAVATION

5.1 Trench Depth - The trench shall be excavated to a firm foundation at least 4 inches below the bottom of the pipe so that the flow line of the finished sewer will be at the depth and grade specified by the engineer.
5.2 Trench Width - For trench depths of less than 5 ft . and when sheeting or shoring is not required, the trench shall be excavated 18 inches wider than the external diameter of the pipe. For trench depths of 5 ft . or more and when sheeting or shoring is required, the trench width shall be 3 ft . wider than the external diameter of the pipe.

## 6. BEDDING

6.1 - Bedding material (pea gravel, crushed stone or washed gravel with at least $95 \%$ passing the 1 " sieve) shall be placed at least $4 "$ thick on the bottom of the trench. If any unyielding foundation is encountered, the minimum thickness shall be increased to $8 "$.

## 7. INSTALLATION

7.1 Handling - The contractor shall handle the pipe with care and avoid chipping or cracking the pipe.
7.2 Laying Pipe - The contractor shall keep the trench free from water during installation. The laying of pipe shall proceed upgrade, with spigot or tongue ends pointing in the direction of flow. The ends of the pipe shall be carefully cleaned before they are lowered into the trench. Each pipe shall be carefully aligned horizontally and vertically with the previous pipe and the joint pulled home. Care shall be taken to assure the gasket remains in its intended position.

## 8. BACKFILLING

8.1 Haunch - As soon as possible the entire width of the trench shall be backfilled with pea gravel, crushed stone or washed gravel (with at least $95 \%$ passing the 1 " sieve) to the pipe springline. Special care shall be taken to completely fill the space under the pipe. A flowable backfill mixture, described as controlled low strength material (CLSM), may be used.
8.2 Backfill - The remainder of the trench shall be backfilled to the natural grade or finished surface. This material may consist of material excavated from the trench. Care shall be taken to avoid disturbing the pipe.
8.3 Special Considerations - In areas where the trench will be under pavements, curbs, shoulders, sidewalks or other structures, granular material will be used to fill the entire trench. The granular material will be placed and compacted to the satisfaction of the engineer. A flowable CLSM may be used when high relative densities are desired.

## 9. ACCEPTANCE TESTING

9.1 Types of Testing - Testing for acceptance of reinforced concrete pipe shall be conducted by one of the following methods:

### 9.1.1 - Water exfiltration, ASTM C969

9.1.2 - Water infiltration, ASTM C969
9.1.3 - Joint testing, ASTM C1103
9.2 Test Sections - Unless otherwise specified or directed by the engineer, the first 1200 feet (or the entire length if the project is less than 1200 feet) shall be tested before additional excavation is permitted. If the initial section does not pass, it shall be repaired and retested until a satisfactory result is obtained. Excavation shall not proceed beyond the first 1200 -foot section until satisfactory results are obtained.

In the event the first 1200 -foot section did not pass the test on the first trial, the next section of sanitary sewer approximately 1200 feet long shall also be tested, repaired if necessary, and restored until a satisfactory result is obtained. Additional excavation shall not be started until this section has passed.

When favorable test results are obtained on the first trial for a full 1200-foot section, the engineer may designate additional sections for testing. The engineer reserves the right to select the location and lengths of additional test sections. All testing will be performed within 30 days of backfilling.
9.3 Water Exfiltration - The test shall be conducted in accordance with ASTM C969.
9.4 Water Infiltration - The test shall be conducted in accordance with ASTM C969.
9.5 Joint Acceptance Testing - The test shall be conducted in accordance with ASTM C1103.

## PLANT TESTING - LEAKAGE ALLOWANCE

Most manufacturers are willing to test sewer pipe in their yard prior to shipment to ensure that the barrels of the pipe will not leak. Random vacuum testing of an assembly of two or more sections of pipe can also be performed at the place of manufacture to assure the integrity of the pipe joints.

## FIELD TESTING - LEAKAGE ALLOWED

Infiltration should be held to a minimum in sanitary sewers since it reduces the carrying capacity of the sewer, keeps associated sewer system treatment costs at a minimum, and eliminates maintenance and operating costs arising from soil fines entering the system under infiltration situations. Acceptable infiltration limits have varied widely over the years but the trend in recent years has been to require sewers to meet low infiltration limits. Low leakage requirements can be met with well-made concrete gravity sewer pipe and rubber gasket joints. It should be recognized by the engineer, however, that field performance represents the sum of the manufactured joint characteristics and the contractor's installation practices.

In making the joint on rubber gasket sewer pipe, the pipe being installed should be held by the lifting device straight to line and grade with the pipe in the ground. The pipe must not be held at an angle when entry is started to avoid the gasket being pinched between the shoulder of the spigot and bell at the bottom of the pipe. With the spigot carefully aligned at the entrance to the bell and with the pipe to be installed held in line with the previously laid pipe, the joint should be pulled home slowly.

To check on whether reasonable workmanship was realized during the construction phase, maximum limits of allowable leakage in terms of water infiltration or exfiltration are usually included in project specifications. They should be stated in terms of both maximum allowable rate per test section and maximum allowable average rate for the total project. These project acceptance tests evaluate the quality of the contractor's work.

There are many opinions, but not much hard data, upon which to base infiltration requirements that are generally cost-effective. There will always be at least a small increment of infiltration which is not costeffective to eliminate. The expense of the pipe and increases in construction and inspection costs fix the lower limit for infiltration allowance.

Current information indicates that the 200 gallons/mile/inch-diameter/day can normally be achieved in manhole to manhole tests with minimum to no effect on construction cost. A higher allowable leakage limit should be used for an exfiltration test over that used for an infiltration test. This is because the exfiltration test is performed with a definite internal pressure head, and the exfiltration of clear water out of the pipe is less likely to be reduced than the infiltration of ground water mixed with soil fines into the pipe.

A ready reference for information on construction leakage allowances in sewers and methods of test is provided in the EPA "Manual of Practice, Sewer System Evaluation, Rehabilitation and New Construction."

## PROTECTIVE LINING PRODUCTS

Present design methodology for sanitary sewers gives the designer the ability to predict the potential for hydrogen sulfide production. Available references include EPA's "Design Manual on Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants" and ACPA's "Design Manual, Sulfide and Corrosion Prediction and Control." If the potential for hydrogen sulfide production is determined to be significant, linings or coatings may be used to protect the inner pipe surface from corrosion.

Available liners consist of a sheet of plasticized PVC with T-shaped keys running longitudinally along one face. The keys are cast into the concrete pipe during manufacture. PVC liners have been used very successfully for over 30 years.

Available coatings may consist of coal tar/epoxy, polyethylene or polyurethane. Coal tar/epoxy coatings are applied by spraying either during or after manufacture of the concrete pipe in varying thicknesses. These coatings have proven to be effective providing adequate surface preparation is performed, adequate thickness is applied and adequate quality control procedures are followed.

## IV. JOINTS

## INTRODUCTION

Joint configurations include bell and spigot, tongue and groove and modified tongue and groove. Joint gaskets and sealants fall into the general categories of cement mortar or mastic sealants, rubber gaskets, external sealing bands, steel end rings, and butyl or bitumen rope. Although the primary considerations in joint quality are permissible infiltration and exfiltration rates, other important performance requirements include: resistance to infiltration of backfill material, control of leakage due to internal or external pressure, flexibility to accommodate lateral deflection of longitudinal movement, pipeline continuity and smooth flow line, infiltration of groundwater for subsurface drainage, and ease of installation.

## CEMENT MORTAR AND MASTIC COMPOUND

Circular pipe, special shapes and boxes are available with tongue and groove joints that may be packed with cement mortar, filled with a preformed butyl or bitumen gasket sealing compound or a trowel applied mastic compound. Such joints have a successful experience record and are generally used for storm sewer construction. Properly applied mastic joint fillers provide flexibility and help to keep fines out of the pipe.

ASTM C443 Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets
Joints recommended for circular sewers where infiltration or exfiltration is a factor in design are the following flexible watertight joints using compression type rubber gaskets for sealing the joints. C443 joints are intended for use with pipe manufactured to meet the requirements of ASTM C76 and may be used with either bell and spigot or tongue and groove pipe. The joint is made up of concrete surfaces, with a compression type rubber gasket. O-ring type joints will also meet the performance requirements of C443.

## ASTM C361 Reinforced Concrete Low-Head Pressure Pipe

Although ASTM C361 covers both low-head pressure pipe and the joint requirements for this type of pipe, it is referenced here for special conditions of internal or external head. C361 joints can be supplied for use with pipe manufactured to meet the requirements of ASTM C76. The joint is made up of concrete surfaces with a groove on the spigot for an O-ring rubber gasket (also referred to as a confined O-ring type joint). Provisions are made in Section 8 for an alternative joint as approved by the owner. These joints are normally used in gravity sewers where exceptional tightness is required. This type of joint meets all the joint requirements of ASTM C443. Steel end rings may also be used for the special condition of pressure flow.

## ASTM C877 External Sealing Bands for Non-Circular Concrete Sewer, Storm Drain and Culvert Pipe

For special conditions where an effective rubber seal is desired for jointing non-circular concrete pipe (arch, elliptical and box shapes), an external sealing band is available meeting the requirements of ASTM C877. These sealing bands are generally limited to non-circular pipe with tongue and groove configurations. ASTM C877 describes specific types of external sealing bands. Other types of sealing bands with adequate results may also be specified.

ASTM C990 Joints for Concrete Pipe, Manholes and Precast Box Sections Using Preformed Flexible Joint Sealants

C990 joints are intended for use with circular pipe, elliptical pipe or precast box sections and may be used with either bell and spigot or tongue and groove pipe. The joint is made up of concrete surfaces, with a preformed bitumen or butyl rubber sealant and is also referred to as bitumen or butyl rubber rope.

## V. MANHOLES/CATCH BASINS/INLETS

## INTRODUCTION

Manholes and certain appurtenances are necessary for the proper functioning of a complete sewer and culvert system. They may include manholes, inverted syphons, catch basins and inlets, flared end sections, and fittings such as bends, tees, and wyes. The concrete pipe industry has developed most of the common appurtenances and specials necessary for efficient and economical performance of the complete system.

## MANHOLES

## ASTM C478 Precast Reinforced Concrete Manhole Sections

C478 manhole sections including risers, base sections, and appurtenances, such as grade rings and flat slab tops, are used in sizes 36 in. and larger diameters. Also available for large sewers over 3 or 4 ft . in diameter are precast base tees. The riser sections are of circular cross section and may employ an eccentric, concentric cone section or a flat slab top. Cone sections affect the transition from the inside diameter of the riser sections to the top opening. Flat slab tops are normally used for very shallow manholes.

Precast barrel sections (riser sections) are available locally in the following sizes:
I.D./O.D.: $36 " / 44 ", 48 " / 58 ", 60 " / 72 ", 72 " / 86 ", 84 " / 100 ", 96 " / 114 "$

Lengths: 12", 16", 24 ", 32 ", 36 ", 42 ", $48^{\prime \prime}, 60$ ", 72 ", 84 ", $96^{\prime \prime}$ (depending on diameter) Bottoms are available cast in or loose.

Precast cone sections, eccentric or concentric, are available locally in the following sizes:

$$
\begin{aligned}
& 36 " \text { I.D. } / 18 " \text { long } \\
& 48 " \text { I.D. } / 24 ", 30 ", 36 ", 38 ", 48 ", 52 ", 54 " \text { long } \\
& 60 " \text { I.D. } / 42 ", 48 " \text { long }
\end{aligned}
$$

Flattops are available locally in the following sizes:

$$
\begin{aligned}
& 36 " \text { I.D. } / 6 " \text { " thick } \\
& 48^{\prime \prime} \text { I.D. } / 6 ", 8 " \text { thick } \\
& 60 " \text { I.D. } / 8 " \text { thick } \\
& 72 " \text { I.D. } / 8 " \text { thick } \\
& 84 " \text { I.D. } / 8 " \text { thick } \\
& 96 " \text { I.D. } / 8 ", 10 ", 12 " \text { thick }
\end{aligned}
$$

The manhole assembly may be furnished with or without steps inserted into the walls of the sections. Steps are cast, mortared or attached by mechanical means into the wall of the section and may be made of plastic encapsulated steel, aluminum, or cast iron. Inverts are available for $36 ", 48^{\prime \prime}, 60$ " and $72^{\prime \prime}$ precast barrels. A number of joints are used for manhole risers and cones including cement mortar, mastic compound, and rubber gaskets for sealing purposes. Asphalt or coal tar epoxy coatings can also be furnished. Manhole adjusting rings (spacers) are available in thicknesses of $2 ", 4 "$ and $6^{\prime \prime}$. Precast concrete headwalls (IDOT Standard \#1976) are available for $8 ", 10 ", 12 ", 15 ", 18 ", 21 ", 24 ", 27 ", 30 ", 36 ", 42 "$ and $48^{\prime \prime}$ diameter pipe.

ASTM C923 Resilient Connectors between Reinforced Concrete Manhole Structures and Pipes
C923 Resilient Connectors are available for special conditions of internal or external head, providing a water resistant connection between the manhole and pipe. These connections are generally used only for sanitary sewer applications. They are locally available for $3 ", 4 ", 6 ", 8 ", 10^{\prime \prime}, 12^{\prime \prime}, 14^{\prime \prime}, 15^{\prime \prime}$, $16 ", 18 ", 20^{\prime \prime}, 21 ", 24 ", 27 ", 30$ ", and $36 "$ diameter pipes.

## CATCH BASINS AND INLETS

Catch basins are available in 2 ft . through 5 ft . diameters in variable lengths. Inlets are available in 2 ft . diameters in various lengths. Catch basins and inlets may be manufactured with precast bottom sections. Special precast inlet boxes are also manufactured for use in highway median sloped ditch checks.


## VI. FLARED END SECTIONS/FITTINGS

## FLARED END SECTIONS

Precast flared end sections for circular concrete pipe are manufactured in diameters of 12 in . through 84 in . and in sizes of 14 " $\times 23^{\prime \prime}$ to $48^{\prime \prime} \times 76$ " and $58^{\prime \prime} \times 91$ " for elliptical pipe with the groove end on the outlet and tongue end on the inlet section. Precast flared end sections are also available for many sizes of elliptical pipe and precast box sections. Steel grates are available for all types of flared end sections. Toe blocks may be employed to support the outlet of flared end sections. Various examples of flared end sections are pictured below.


FLARED END SECTIONS


FLARED END SECTION W/ GRATE


STEEL GRATES

## FITTINGS - BENDS

Bends are furnished in standard ranges of 15 degree angular deflections although specials can be manufactured to meet any required deflection. The bend is formed by cutting the pipe barrel to the desired bevel, spot welding, or tying together the exposed reinforcing, and packing the seams with cement mortar. Pipe bends should be equal in design strength to the abutting pipe. Bends are locally available for circular and elliptical pipe in the following sizes and angles:

## Circular Pipe

| Pipe Diameter (in.) | Bend Angle $\left({ }^{\circ}\right)$ |  |
| :---: | :---: | :---: |
| 96 |  | 5 to 45 |
| 84 | 5 to 45 |  |
| 72 |  | 5 to 45 |
| 66 |  | 5 to 45 |
| 60 | 5 to 90 |  |
| 54 | 5 to 90 |  |
| 48 | 5 to 90 |  |
| 42 | 5 to 90 |  |
| 36 | 5 to 90 |  |
| 30 | 5 to 90 |  |
| 27 | 5 to 90 |  |
| 24 | 5 to 90 |  |
| 21 | 5 to 90 |  |
| 18 | 5 to 90 |  |
| 15 | 5 to 90 |  |
| 12 | 5 to 90 |  |
| 10 | 5 to 90 |  |
| 8 | 5 to 90 |  |



## Elliptical Pipe

| Mainline Pipe Size (in.) | Equivalent Round Size (in.) | Bend Angle $\left({ }^{\circ}\right)$ <br> $63 \times 98$ |
| :---: | :---: | :---: |
| $58 \times 91$ | 78 | 5 to 45 |
| $53 \times 83$ | 72 | 5 to 45 |
| $48 \times 76$ | 60 | 5 to 45 |
| $43 \times 68$ | 54 | 5 to 60 |
| $38 \times 60$ | 48 | 5 to 90 |
| $34 \times 53$ | 42 | 5 to 90 |
| $29 \times 45$ | 36 | 5 to 90 |
| $24 \times 38$ | 30 | 5 to 90 |
| $19 \times 30$ | 24 | 5 to 90 |
| $14 \times 23$ | 18 | 5 to 90 |
|  |  | 5 to 90 |



Note: Generally, a manhole riser may be added to a bend, providing the riser is smaller in diameter than the mainline pipe.

## FITTINGS - TEES

Tees are special fittings for which the intersecting pipe (branch or lateral) enters the base pipe perpendicular to, and intersects the centerline of, the base pipe and are available with all joint types of the connecting pipe. Branches terminate in bells or grooves, and the branch will be of sufficient length to permit making a proper joint when the connecting pipe is inserted into the branch bell or groove. Tees are locally available for circular and elliptical pipe in the following sizes:

## Circular Pipe

| Mainline Pipe <br> Size (in.) | Lateral Pipe <br> Size (in.) |
| :---: | :---: |
| 96 | 8 to 72 |
| 84 | 8 to 72 |
| 72 | 8 to 72 |
| 66 | 8 to 66 |
| 60 | 8 to 60 |
| 54 | 8 to 54 |
| 48 | 8 to 48 |
| 42 | 8 to 42 |
| 36 | 8 to 36 |
| 30 | 8 to 30 |
| 27 | 8 to 27 |
| 24 | 8 to 24 |
| 21 | 8 to 18 |
| 18 | 8 to 15 |
| 15 | 8 to 12 |
| 12 | 8,10 |



## FITTINGS - MANHOLE TEES

Manhole tees (or manhole base tees) can eliminate costly cast-in-place or precast manhole structures, and can be manufactured with either a concentric or offset riser section. Manhole tees are locally available for circular and elliptical pipe in the following sizes:

## Circular Pipe

| Mainline Pipe <br> Size (in.) | Riser Size (in.) |
| :--- | :--- |
| 96 | $24,36,48,60,72$ |
| 84 | $24,36,48,60,72$ |
| 72 | $24,36,48,60,72$ |
| 66 | $24,36,48,60$ |
| 60 | $24,36,48,60$ |
| 54 | $24,36,48$ |
| 48 | $24,36,48$ |
| 42 | 24,36 |
| 36 | 24,36 |
| 30 | 24 |
| 27 | 24 |
| 24 | 24 |

## Elliptical Pipe

| Mainline Pipe <br> Size (in.) | Equiv. Round <br> Size (in.) |  |
| :---: | :---: | :---: |
| $63 \times 98$ | 78 | $\frac{\text { Riser Size (in.) }}{24,36,48}$ |
| $58 \times 91$ | 72 | $24,36,48$ |
| $53 \times 83$ | 66 | $24,36,48$ |
| $48 \times 76$ | 60 | $24,36,48$ |
| $43 \times 68$ | 54 | $24,36,48$ |
| $38 \times 60$ | 48 | $24,36,48$ |
| $34 \times 53$ | 42 | $24,36,48$ |
| $29 \times 45$ | 36 | 24,36 |
| $24 \times 38$ | 30 | 24,36 |
| $19 \times 30$ | 24 | 24 |
| $14 \times 23$ | 18 | 24 |



Note: Generally, manhole tees can accommodate a lateral connection as well.

## FITTINGS - WYES

Wyes are similar to tees, except the centerline of the intersecting pipe intersects the centerline of the base pipe at an acute angle. Manhole tees are locally available for circular and elliptical pipe in the following sizes:

## Circular Pipe

| Mainline Pipe <br> Size (in.) | Lateral Pipe <br> Size (in.) |
| :---: | :---: |
| 96 | 8 to 72 |
| 84 | 8 to 72 |
| 72 | 8 to 72 |
| 66 | 8 to 66 |
| 60 | 8 to 60 |
| 54 | 8 to 54 |
| 48 | 8 to 48 |
| 42 | 8 to 42 |
| 36 | 8 to 36 |
| 30 | 8 to 30 |
| 27 | 8 to 27 |
| 24 | 8 to 24 |
| 21 | 8 to 21 |
| 18 | 8 to 18 |
| 15 | 8 to 15 |
| 12 | 8 to 12 |
| 10 | 8,10 |
| 8 | 8 |



## Elliptical Pipe

| Mainline Pipe <br> Size (in.) | Equiv. Round <br> $\frac{\text { Size (in.) }}{}$ | Lateral Pipe <br> Size (in.) |
| :---: | :---: | :---: |
| $53 \times 98$ | 78 | 8 to 36 |
| $58 \times 91$ | 72 | 8 to 36 |
| $53 \times 83$ | 66 | 8 to 36 |
| $48 \times 76$ | 60 | 8 to 36 |
| $43 \times 68$ | 54 | 8 to 36 |
| $38 \times 60$ | 48 | 8 to 36 |
| $34 \times 53$ | 42 | 8 to 30 |
| $29 \times 45$ | 36 | 8 to 27 |
| $24 \times 38$ | 30 | 8 to 24 |
| $19 \times 30$ | 24 | 8 to 18 |
| $14 \times 23$ | 18 | 8 to 12 |



## FITTINGS - TRANSITIONS

Special transition pipe sections can be manufactured to accommodate connecting circular pipe of different diameters and circular to elliptical pipe, saving the added expense of using manholes whenever there is a change in pipe diameter or shape. Transitions are locally available for circular to circular and elliptical to circular pipe in the following sizes.

## Circular Pipe

| Larger Pipe | Smaller Pipe |
| :---: | :---: |
| Size (in.) | Size (in.) |
| 96 | 36 to 72 |
| 84 | 36 to 72 |
| 72 | 36 to 66 |
| 66 | 30 to 60 |
| 60 | 30 to 54 |
| 54 | 27 to 48 |
| 48 | 24 to 42 |
| 42 | 21 to 36 |
| 36 | 18 to 30 |
| 30 | 15 to 27 |
| 27 | 12 to 24 |
| 24 | 12 to 21 |
| 21 | 10 to 18 |
| 18 | 8 to 15 |
| 15 | 8 to 12 |
| 12 | 8, 10 |
| 10 | 8 |

## Elliptical Pipe to Circular Pipe

| Elliptical Pipe <br> Size (in.) | Equiv. Round <br> Size (in.) | Circular Pipe <br> Size (in.) |
| :---: | :---: | :---: |
| $63 \times 98$ | 78 | 36 to 72 |
| $58 \times 91$ | 72 | 30 to 72 |
| $53 \times 83$ | 66 | 27 to 72 |
| $48 \times 76$ | 60 | 24 to 72 |
| $43 \times 68$ | 54 | 21 to 72 |
| $38 \times 60$ | 48 | 18 to 72 |
| $34 \times 53$ | 42 | 18 to 66 |
| $29 \times 45$ | 36 | 15 to 60 |
| $24 \times 38$ | 30 | 12 to 48 |
| $19 \times 30$ | 24 | 10 to 36 |
| $14 \times 23$ | 18 | 8 to 30 |



## FITTINGS - BULKHEADS

Bulkheads include both caps, for sealing the spigot end of a pipe, and plugs, for sealing the bell end of a pipe. Bulkheads are generally available for circular pipe of diameters 8 " to 96 " and elliptical pipe of sizes 14 " x 23 " to $63 "$ x 98 ". Pipe plugs offer an alternative method of making a transition. This is accomplished by making an opening for the smaller diameter pipe in the plug for the larger pipe. An example is pictured below.

Curves in concrete pipelines may be achieved by opening up one side of a pipe joint while the other side remains in the home position affecting an angular deflection of the axis of the pipe. The maximum permissible opening of the joint varies for different joint configurations and should be obtained from the pipe manufacturer. The radius of curvature which may be obtained by this method is a function of deflection angle per joint and length of pipe section.

In general, the dimensions of all fittings and manhole base tees conform to the dimensions as given in the appropriate ASTM pipe specifications. Thus wall thicknesses along with the general requirements will be the same as the standard concrete pipe requirements.

In many cases, a fitting can be made with a combination of a bend, wye, tee, transition, bulkhead, etc. It is important to check with local manufacturers for prices and availability of fittings.


## VII. TESTING

## PLANT TESTING

Quality control testing is routinely employed in the concrete pipe plant to ensure the pipe produced meets all applicable project specifications. Concrete pipe plants certified by the Illinois Department of Transportation must adhere to rigorous testing requirements. Quality control tests in all concrete pipe plants are performed in accordance with ASTM C497.

ASTM C497 Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile

ASTM C497 specifies the three-edge bearing test as the method of determining the maximum D-load of the pipe. In the three-edge bearing test, a piece of pipe, chosen at random, is supported on two lower bearing strips and loaded from above through an upper bearing block. The pipe is loaded until a crack is produced having a width of 0.01 inch throughout a continuous length of 1 foot.

If so desired, the actual compressive strength of the concrete can be determined by performing a compressive strength test on a core removed from the pipe.

If the pipe for a particular project must meet the requirements of C 443 , a hydrostatic test may be performed to ensure joint integrity. This test is performed by subjecting the joint between two pipes to an internal hydrostatic pressure of 13 psi for 10 minutes in both straight and deflected alignment.

## FIELD TESTING

In special circumstances, when infiltration or exfiltration rates are a concern, one of the following field tests may be performed to demonstrate the integrity of the sewer line.

ASTM C969 Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines
C969 covers procedures for testing installed precast concrete sewer lines using either water infiltration or exfiltration acceptance limits to demonstrate the integrity of the installed materials and construction procedure.

ASTM C1103 Joint Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines
C1103 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 the construction procedures. This practice is used for testing 27" and larger diameter precast concrete sewer lines utilizing rubber gasket sealed joints. Smaller diameter sewer lines are typically tested by infiltration and exfiltration tests (ASTM C969).

## VIII. SPECIAL CONSIDERATIONS

## SEWERS AND CULVERTS

Sewers and culverts are designed to carry the design flow and provide sufficient strength to support imposed loads at an economical cost. Hydraulic design requires determination of system type, determination of design flow, selection of pipe size, and determination of flow velocity. Design for safe supporting strength requires determination of earth and live load, selection of bedding, determination of load factor, application of factor of safety, and selection of pipe strength.

Design information is presented in the "Concrete Pipe Design Manual", American Concrete Pipe Association; WPCF and ASCE "Manual of Practice on Design and Construction of Sanitary and Storm Sewers"; EPA "Manual of Practice on Sewer System Evaluation, Rehabilitation, and New Construction"; and Design Aids listed on pages 33 through 34 of this booklet.

## HYDRAULIC COEFFICIENTS OF FLOW

Flow through sewers and culverts is primarily dependent upon the size and slope of the line and the roughness of the pipe wall. By determining these factors in hydraulic equations, engineers are able to design a sewer or culvert to carry the proposed flow.

The most important single factor affecting the hydraulic design of sewers or culverts is the roughness of the pipe wall. Therefore, the selection of the friction factor is of great importance. Roughness has a retarding effect and reduces the velocity of flow in the pipe. Friction effects are commonly evaluated by means of the friction factor " n ", used in the Manning equation for flow in open channels. Increased friction losses are indicated by high values of " n ". Therefore, a pipe with an interior surface which results in a minimum of frictional resistance is necessary for hydraulic efficiency.

It has been definitely established by authoritative tests that the roughness coefficient of concrete pipe is equal to or better hydraulically than other pipe materials. Laboratory results indicated the only differences were between smooth wall and rough wall pipes. Rough wall or corrugated pipe have relatively high " n " values that are approximately 2.5 to 3 times those of smooth wall pipe. Test programs have established values of the roughness coefficient for concrete pipe from 0.009 to 0.011 . An evaluation of " $n$ " values for different pipe materials is given in the Design Data No. 14 listed on page 33.

Recommended values for the roughness coefficient " $n$ " for concrete pipe in different types of pipe systems are as follows:

Sanitary Sewers: "n" values of 0.012 to 0.013 are used to account for the possibility of slime or grease build-up and minor head losses due to obstructions such as fittings and manholes.

Storm Sewers: " n " values of 0.010 to 0.012 are used to account for foreign debris and minor obstructions in storm sewers.

Culverts: " n " values of 0.010 to 0.012 are used to provide for reasonable margin of safety.

## INDUSTRIAL WASTES

Certain liquid wastes from industrial processes may have various objectionable effects on materials of construction used for sewers, pumping stations, treatment plant equipment and structures, and sewage treatment processes. Obviously, such wastes should not be allowed in the sewer except after such pretreatment as will prevent objectionable conditions. The practice is widely established of enforcing regulations against discharge to the sewer of improper wastes.

Generally, the only waste that directly damages concrete pipe is acid. A common requirement in sewer pollution control regulations is that the pH of a waste discharged to a sewer shall not be lower (more strongly acid) than 5.5. Authorities state that concrete pipe can carry liquid with a pH as low as 4 without harm. Highly alkaline sewage has no adverse effect on concrete pipe.

Sewer acid conditions are common to industries using pickling or other acids in plant processes. Such places should be required to neutralize the acid wastes or a protective lining should be provided on the carrier pipe. Such linings should be as recommended by the pipe manufacturer. Manufacturers in most areas can supply concrete pipe with epoxy coatings.

Concrete pipe in any well-designed sanitary sewer system will withstand the action of domestic sewage. In sanitary sewers carrying industrial wastes, the dilution of any concentrated acid waste is in general sufficient enough to raise the pH of the mixture so that it will not affect the concrete pipe.

## HYDROGEN SULFIDE IN SEWERS

Much has been said and numerous studies have been done regarding the presence of hydrogen sulfide in sewers. The great attention given to hydrogen sulfide is because of its highly objectionable odor, its toxicity, interference with treatment plant operation, and its ability when oxidized to cause corrosion of various materials used in sewer construction.

Hydrogen sulfide in amounts sufficient to cause damage is not common in sewers, and even when it is found it is present for only part of the time. Its formation is possible only when certain factors which influence its formation exist, such as conditions which permit sewage to become septic with little or no dissolved oxygen. In the northern half of the United States, sewer failures from sulfide corrosion are almost unknown except in a few cases where damage resulted from discharges from force mains. Sewage temperatures are lower than in more southerly climates, so significant amounts of sulfide are rarely formed in the gravity sewers.

Sulfide control is now a well-developed technology. Engineers who are faced with sulfide problems may apply control procedures that will overcome sulfide producing tendencies in existing systems and provide proper design to minimize problems in the future. Sources of information for sulfide control are provided in the ACPA's publication "Design Manual, Sulfide and Corrosion Prediction and Control."

## LOAD CARRYING CAPACITY

The strength of a reinforced concrete pipe is stated in terms of D-load, which is the load in pounds per lineal foot per foot of internal diameter. The strength test requirements under the three-edge-bearing method are classified according to the D-load that produces a 0.01 in . crack and the D-load that produces the ultimate load. ASTM or equivalent specifications for reinforced concrete circular, arch, or elliptical pipe have design tables of different strength classifications that give the diameter, wall thickness, compressive strength of the concrete, and the amount of reinforcement required.

When concrete pipe is subjected to external loading, resisting stresses induced in the pipe wall are flexural, axial, and diagonal tension. Tensile stresses are developed in the wall on the inside at the crown and invert and on the outside at the springline. Concurrently, compressive stresses are developed in the walls opposite to the tensile stresses. The reinforcing of a concrete pipe basically consists of the placement of steel reinforcement in those zones of the pipe wall where tension stresses exist. Reinforcement in the pipe wall where compression stresses exist is not required but it is used in various methods of reinforcing for ease of placement.

When the load carrying capacity of the pipe is controlled by diagonal tension stresses, a common method of resisting these stresses is in the form of stirrups placed radially within the pipe wall at the crown and invert zones of the pipe. Structurally, stirrups resist radial tension and diagonal shear stresses in the concrete pipe wall. Care should be taken when using elliptical, quadrant, or stirrup reinforcement to properly mark the top and bottom of pipe as designated in the appropriate ASTM specifications.

Projects occasionally present unique conditions that require modified and/or special pipe design. Anticipated loads, stresses and size requirements exceeding those accommodated by design tables are examples where modified or special design is warranted and permitted in the ASTM specifications. Special design of any specific D-load for large quantities of a pipe size may also be a worthwhile economic consideration. Public domain software (made available through funding by the American Concrete Pipe Association and the Federal Highway Association) is now available. The user friendly programs provide structural analysis for circular pipe, elliptical pipe and box culverts. All analysis is in accordance with AASHTO Section 17.4.

## 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 are 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 subjected to variations depending upon the zeal and eyesight of the observer. The need soon became obvious for a criterion based on the measurable crack of a specified width. Eventually, the 0.01 -inch crack, as measured by a feeler gauge 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.

In summary:

- Reinforced concrete pipe is designed to crack. Cracking under load indicates that the tensile stresses have been transferred to the reinforcing steel.
- A 0.01 inch wide crack in a pipe does not indicate structural distress and such a pipe will perform successfully in the installed condition.
- Cracks much wider than 0.01 inch in corrosive environments may 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.
- Small cracks, in a normally moist atmosphere of a pipe line, will heal autogenously.


## JACKING

Where installations are deep or where surface obstructions are such that it is difficult to install pipe by conventional open excavation and backfill, it is common practice and may be more economical to install concrete pipe by means of jacking or tunneling. A critical factor in jacking and tunneling concrete pipe is consideration of the soil conditions through which the pipe is to be jacked. A thorough investigation and knowledge of soil conditions is necessary to determine the loads on the pipe, type of tunnel boring machinery, jacking equipment, and procedure of jacking.

Reinforced concrete pipe to be used for jacking generally falls in the range of 36 in . to 132 in . in diameter and should be of the required D-load class for the overburden earth loading with a minimum concrete compressive strength of 5,000 psi for axial loading.

Pipe is designed to carry the D-load as determined by the prescribed procedures in the Design Aids on page 33 of this manual. The tendency of some engineers is to require that jacking pipe be of a D-load class higher than would normally be needed. Inasmuch as thrust capacity is related to compressive strength of the concrete, increasing the D-load strength does not increase the thrust capacity of the pipe except in those cases where a higher class results in an increase in the minimum concrete compressive strength. The cross section area of the concrete pipe wall is more than adequate to resist pressures encountered in any normal jacking operation. The pipe should have straight outside walls without bell modification. Squareness of ends and spigot shoulders should be maintained within tolerances as prescribed by ASTM standards for precast concrete pipe.

Since thrust loads are transmitted through the pipe joints, it is extremely important to maintain uniform distribution of the load around the periphery of the joint. Contractors have used different methods to provide uniform loading from pipe to pipe and jacking frame head. A joint cushioning material such as $1 / 2 \mathrm{in}$. to $3 / 4 \mathrm{in}$. of plywood, hardboard or similar material is recommended to prevent concrete to concrete contact and reduce the chances of spalling. Supplemental joint reinforcing to withstand shear forces is provided by some manufacturers by means of extra bell and/or extra longitudinal steel.

In the jacking procedure, it is important that the direction of jacking be carefully established prior to the start of work. Correct alignment of the pipe guide frame, jacks, and backstop is necessary to prevent altering the directional thrust. If any part of the jacking setup is off line, forces are set up which tend to cause localized stresses or bind the pipe. Backstops in pits must be strong and large enough to distribute the maximum capacity of the jacks against the soil behind the backstops. Alignment can be best achieved by installing guide rails in the bottom of the jacking pit or shaft. In the case of a larger pipe, it is desirable to have such rails carefully set in a concrete slab. The jacks should have a greater capacity than estimated requirements. The number and capacity of jacks used depend primarily on the size and length of pipe to be placed and the soil encountered. A suitable jacking head or frame should be provided to transfer the pressure from the jacks to the concrete pipe. The jacking head will protect the end of the pipe and aid in keeping the pipe on line by distributing the pressure on the pipe joint.

Frictional resistance can be decreased by the application of bentonite or other suitable lubricant to the exterior surface of the pipe being jacked. It can be applied through pressure fittings in the pipe cutting shield or wall of pipe, or by pouring it down holes drilled from the top of ground surface to the jacked section. It has been demonstrated that jacking pressures are greatly reduced when using sufficient quantities of bentonite.

## IX. DESIGN AIDS

Design aids are available that contain technical and design information needed to assist engineers when specifying concrete pipe for sanitary sewers, storm sewers and culverts. The design aids cover data on live loads and earth loads, supporting strengths, installation, hydraulics of sewers and culverts, and supplemental design information. In selecting the type, size, and strength requirements of pipe, the following aids published by the American Concrete Pipe Association are available from the Illinois Concrete Pipe Association at minimal or no cost. Please contact the Illinois Concrete Pipe Association or one of its member pipe producers for information or these materials may be ordered directly from:

American Concrete Pipe Association, 8445 Freeport Pkwy \# 350, Irving, TX 75063
Phone: (972) 506-7216
www.concretepipe.org
ACPA DESIGN DATA SHEETS (available in hard copy or on the ACPA web site)

## Loads

Highway Live Loads on Concrete Pipe
Aircraft Loads
Railroad Loads
Jacking Concrete Pipe
Multiple Pipe Installation: Trench Condition
Loads and Supporting Strength: Elliptical and Arch Pipe
Transition Width
Three-Edge Bearing Strengths: Nonreinforced Concrete Pipe and Clay Pipe
Standard Installations Indirect Design

## Hydraulics

History of Manning's $n$
Hydraulics of Circular Sanitary Sewers
Hydraulics of Circular Storm Sewers
Hydraulics of Arch Storm Sewers
Hydraulics of Elliptical Storm Sewers
Hydraulics of Rectangular Storm Sewers
Hydraulics of Circular Culverts
Hydraulics of Arch Culverts
Hydraulics of Elliptical Culverts
Hydraulics of Rectangular Culverts

## Miscellaneous/Installations

Curved Alignment
Curved Alignment-Metric
Life Cycle Cost Analysis
Precast Concrete Manholes
Flotation of Circular Concrete Pipe
Low Pressure Air Testing
Manhole Flotation

## DESIGN AND CONSTRUCTION MANUALS

ACPA Concrete Pipe Handbook
ACPA Concrete Pipe Design Manual
ACPA Concrete Pipe Installation Manual
ACPA Concrete Pipe Technology Handbook
ACPA Design Manual for Sulfide and Corrosion Prediction and Control
WPCF \& ASCE Manual of Practice on Design and Construction of Sanitary and Storm Sewers
EPA Manual of Practice on Sewer System Evaluation, Rehabilitation and New Construction
CONCRETE PIPE INFORMATION "CP Info" (available in hard copy or on the ACPA web site)
ASTM C76 Reinforcement Design Changes and Related Research
Culvert Velocity Reduction by Internal Energy Dissipaters
Culvert Velocity Reductions with an Outlet Expansion
Precast Concrete Box Sections
Effects of Cracks in Reinforced Concrete Sanitary Sewer Pipe
Effects of Cracks in Reinforced Concrete Culvert Pipe
Life Factor Design of RCP Sewers
Significance of Cracks in Concrete Pipe
Precast Concrete Pipe Durability
Lateral Pressure and Bedding Factors

## COMPUTER SOFTWARE

Standard Installations Direct Design Software (SIDD)
Spangler and Marston Method (SAMM)
Hydrogen Sulfide (HS)
Box Culvert Analysis and Reinforcing Design (BOXCAR)
Pipe Culvert Analysis and Reinforcing Design (PIPECAR)
PipePac, which includes:
Three-Edge Bearing (3EB)
Cost Analysis Pipe Envelope (CAPE)
Least Cost (Life Cycle) Analysis (LCA)
Detention and Sewer Hydraulics (DASH)

## INFORMATIONAL VIDEOS

Long-Term Structural Integrity
Installation Success
Quality You Can Count On
Built For the Future

## X. LIST OF STANDARDS

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS
(With corresponding AASHTO Standards designations)

| Specification | Type | Size |
| :--- | :--- | :--- |
| ASTM C14 | Non-Reinforced Concrete Sewer, <br> Storm Drain and Culvert Pipe | $8 "$ through 36" |
| ASTM C76 <br> AASHTO M170 | Reinforced Concrete Culvert, Storm Drain <br> and Sewer Pipe | $12^{\prime \prime}$ through 144"" |
| ASTM C361 | Reinforced Concrete Low-Head Pressure <br> Pipe | $12^{\prime \prime}$ through 108" |
| Concrete Drain Tile | $4 "$ through 36" |  |
| ASTM C443 <br> AASHTO M198 | Joint for Circular Concrete Sewer and <br> Culvert Pipe, Using Rubber Gaskets |  |

ASTM C478
Precast Reinforced Concrete Manhole Sections

ASTM C497
Standard Methods of Testing Concrete Pipe or Tile

ASTM C506<br>AASHTO M206

Reinforced Concrete Arch, Culvert,
Equivalent Round
Storm and Sewer Pipe
18 " through 132 "

ASTM C507
AASHTO M207
Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe

Equivalent Round
$18^{\prime \prime}$ through 144 "

Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe
$12 "$ through $144 "$

| Specification | Type | Size |
| :---: | :---: | :---: |
| ASTM C1577 | Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers | Span x Rise $3^{\prime} \times 12^{\prime}$ through 12 ' $\times 12^{\prime}$ |
| ASTM C822 | Terminology Relating to Concrete Pipe and Related Products |  |
| ASTM C877 | External Sealing Bands for Non-Circular Concrete Sewer, Storm Drain and Culvert Pipe |  |
| ASTM C923 | Resilient Connectors Between Reinforced Concrete Manhole Structures and Pipes |  |
| ASTM C924 | Low-Pressure Air Test of Concrete Pipe Sewer Lines |  |
| ASTM C969 | Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines |  |
| ASTM C985 | Non-Reinforced Concrete Specified Strength Culvert, Storm Drain and Sewer Pipe Lines |  |
| ASTM C1103 | Joint Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines |  |

ASTM standards may be ordered from:
ASTM International, 100 Barr Harbor Dr., P.O. Box C700, West Conshohocken, PA 19428-2959 610-832-9585, www.astm.org

Standard Specifications for Water \& Sewer Main Construction in Illinois may be ordered from:
Illinois Society of Professional Engineers, 100 E. Washington St, Springfield, IL 62701
217-544-7424, www.illinoisengineer.com
Standard Specifications for Road and Bridge Construction may be ordered from:
Illinois Department of Transportation, 2300 S. Dirksen Parkway, Springfield, Illinois 52764
217-785-7529, www.dot.state.il.us

## Dimensions \& Approximate Weights of Circular Concrete Pipe

 English Units| ASTM C76- Reinforced Concrete Culvert, Storm Drain and Sewer Pipe |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | WALL B |  | WALL C |  |
| Internal Diameter, inches | Waterway Area, square feet | Minimum Wall Thickness, inches | Approximate Weight, lbs. per foot | Minimum Wall Thickness, inches | Approximate Weight, lbs. per foot |
| 12 | 0.8 | 2 | 93 | --- | --- |
| 15 | 1.2 | 2.25 | 127 | --- | --- |
| 18 | 1.8 | 2.5 | 168 | -- | --- |
| 21 | 2.4 | 2.75 | 214 | --- | --- |
| 24 | 3.1 | 3 | 264 | 3.75 | 365 |
| 27 | 4.0 | 3.25 | 322 | 4 | 420 |
| 30 | 4.9 | 3.5 | 384 | 4.25 | 475 |
| 33 | 5.9 | 3.75 | 451 | 4.5 | 550 |
| 36 | 7.1 | 4 | 524 | 4.75 | 655 |
| 42 | 9.6 | 4.5 | 686 | 5.25 | 810 |
| 48 | 12.6 | 5 | 867 | 5.75 | 1,010 |
| 54 | 15.9 | 5.5 | 1,068 | 6.25 | 1,210 |
| 60 | 19.6 | 6 | 1,295 | 6.75 | 1,475 |
| 66 | 23.8 | 6.5 | 1,542 | 7.25 | 1,735 |
| 72 | 28.3 | 7 | 1,811 | 7.75 | 2,015 |
| 78 | 33.2 | 7.5 | 2,100 | 8.25 | 2,410 |
| 84 | 38.5 | 8 | 2,409 | 8.75 | 2,660 |
| 90 | 44.2 | 8.5 | 2,740 | 9.25 | 3,020 |
| 96 | 50.2 | 9 | 3,090 | 9.75 | 3,355 |
| 102 | 56.7 | 9.5 | 3,480 | 10.25 | 3,760 |
| 108 | 63.6 | 10 | 3,865 | 10.75 | 4,160 |

Dimensions \& Approximate Weights of Circular Concrete Pipe English Units

| ASTM C76 - Reinforced Concrete Culvert, Storm Drain and Sewer Pipe |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Large Sizes |  |  |  |  |
| Internal <br> Diameter, <br> inches | Internal <br> Diameter, <br> feet | Wall <br> Thickness, <br> inches | Waterway <br> Area, <br> square feet | Approximate <br> Weight, lbs. <br> per foot |
|  |  |  |  |  |
| 114 | 9.5 | 9.5 | 70.8 | 3,840 |
| 120 | 10 | 10 | 78.5 | 4,265 |
| 126 | 10.5 | 10.5 | 85.6 | 4,690 |
| 132 | 11 | 11 | 95.0 | 5,150 |
| 138 | 11.5 | 11.5 | 103.8 | 5,625 |
| 144 | 12 | 12 | 113.0 | 6,125 |
| 150 | 12.5 | 12.5 | 122.7 | 6,645 |
| 156 | 13 | 13 | 132.7 | 7,190 |
| 162 | 13.5 | 13.5 | 143.1 | 7,755 |
| 168 | 14 | 14 | 153.9 | 8,340 |
| 174 | 14.5 | 14.5 | 165.0 | 8,945 |
| 180 | 15 | 15 | 176.6 | 9,570 |

Dimensions \& Approximate Weights of Elliptical Concrete Pipe English Units

| ASTM C507 Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe      |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Equivalent <br> Round Size, <br> inches | Minor Axis, <br> inches | Major Axis, <br> inches | Minimum Wall <br> Thickness, <br> inches | Waterway <br> Area, <br> square feet | Approximate <br> Weight, lbs. <br> per foot |  |
|  |  |  |  |  |  |  |
| 18 | 14 | 23 | 2.75 | 1.8 | 195 |  |
| 24 | 19 | 30 | 3.25 | 3.3 | 300 |  |
| 27 | 22 | 34 | 3.50 | 4.1 | 365 |  |
| 30 | 24 | 38 | 3.75 | 5.1 | 430 |  |
| 33 | 27 | 42 | 3.75 | 6.3 | 475 |  |
| 36 | 29 | 45 | 4.5 | 7.4 | 625 |  |
| 42 | 34 | 53 | 5 | 10.2 | 815 |  |
| 48 | 38 | 60 | 5.50 | 12.9 | 1,000 |  |
| 54 | 43 | 68 | 6 | 16.6 | 1,235 |  |
| 60 | 48 | 76 | 6.50 | 20.5 | 1,475 |  |
| 66 | 53 | 83 | 7 | 24.8 | 1,745 |  |
| 72 | 58 | 91 | 7.50 | 29.5 | 2,040 |  |
| 78 | 63 | 98 | 8 | 34.6 | 2,350 |  |
| 84 | 68 | 106 | 8.50 | 40.1 | 2,680 |  |
| 90 | 72 | 113 | 9 | 46.1 | 3,050 |  |
| 96 | 77 | 121 | 9.50 | 52.4 | 3,420 |  |
| 102 | 82 | 128 | 9.75 | 59.2 | 3,725 |  |
| 108 | 87 | 136 | 10 | 66.4 | 4,050 |  |
| 114 | 92 | 143 | 10.50 | 74.0 | 4,470 |  |
| 120 | 97 | 151 | 11 | 82.0 | 4,930 |  |
| 132 | 106 | 166 | 12 | 99.2 | 5,900 |  |
| 144 | 116 | 180 | 13 | 118.6 | 7,000 |  |

Dimensions \& Approximate Weights of Concrete Box Sections

| ASTM C 1577 - Precast Reinforced Concrete Box Sections <br> (HL-93 Live Load) |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Thickness, Inches |  |  | Waterway Area, square feet | Approximate Weight, lbs. per foot |
| Span, feet | Rise, feet | Top Slab | Bottom Slab | Wall |  |  |
| 3 | 2 | 4 | 4 | 4 | 5.1 | 720 |
| 3 | 3 | 4 | 4 | 4 | 8.1 | 825 |
| 4 | 2 | 5 | 5 | 5 | 7.1 | 1,015 |
| 4 | 3 | 5 | 5 | 5 | 11.1 | 1,145 |
| 4 | 4 | 5 | 5 | 5 | 15.1 | 1,275 |
| 5 | 3 | 6 | 6 | 6 | 14.1 | 1,530 |
| 5 | 4 | 6 | 6 | 6 | 19.1 | 1,680 |
| 5 | 5 | 6 | 6 | 6 | 24.1 | 1,835 |
| 6 | 3 | 7 | 7 | 7 | 17.1 | 1,970 |
| 6 | 4 | 7 | 7 | 7 | 23.1 | 2,150 |
| 6 | 5 | 7 | 7 | 7 | 29.1 | 2,330 |
| 6 | 6 | 7 | 7 | 7 | 35.1 | 2,510 |
| 7 | 4 | 8 | 8 | 8 | 27.1 | 2,680 |
| 7 | 5 | 8 | 8 | 8 | 34.1 | 2,885 |
| 7 | 6 | 8 | 8 | 8 | 41.1 | 3,090 |
| 7 | 7 | 8 | 8 | 8 | 48.1 | 3,295 |
| 8 | 4 | 8 | 8 | 8 | 31.1 | 2,885 |
| 8 | 5 | 8 | 8 | 8 | 39.1 | 3,090 |
| 8 | 6 | 8 | 8 | 8 | 47.1 | 3,295 |
| 8 | 7 | 8 | 8 | 8 | 55.1 | 3,500 |
| 8 | 8 | 8 | 8 | 8 | 63.1 | 3,710 |
| 9 | 5 | 9 | 9 | 9 | 43.0 | 3,900 |
| 9 | 6 | 9 | 9 | 9 | 52.0 | 4,135 |
| 9 | 7 | 9 | 9 | 9 | 61.0 | 4,365 |
| 9 | 8 | 9 | 9 | 9 | 70.0 | 4,595 |
| 9 | 9 | 9 | 9 | 9 | 79.0 | 4,830 |
| 10 | 5 | 10 | 10 | 10 | 48.0 | 4,600 |
| 10 | 6 | 10 | 10 | 10 | 58.0 | 4,860 |
| 10 | 7 | 10 | 10 | 10 | 68.0 | 5,115 |
| 10 | 8 | 10 | 10 | 10 | 78.0 | 5,375 |
| 10 | 9 | 10 | 10 | 10 | 88.0 | 5,630 |
| 10 | 10 | 10 | 10 | 10 | 98.0 | 5,890 |
| 11 | 4 | 11 | 11 | 11 | 42.0 | 5,075 |
| 11 | 6 | 11 | 11 | 11 | 64.0 | 5,645 |
| 11 | 8 | 11 | 11 | 11 | 86.0 | 6,210 |
| 11 | 10 | 11 | 11 | 11 | 108.0 | 6,775 |
| 11 | 11 | 11 | 11 | 11 | 119.0 | 7,060 |
| 12 | 4 | 12 | 12 | 12 | 46.0 | 5,870 |
| 12 | 6 | 12 | 12 | 12 | 70.0 | 6,490 |
| 12 | 8 | 12 | 12 | 12 | 94.0 | 7,105 |
| 12 | 10 | 12 | 12 | 12 | 118.0 | 7,725 |
| 12 | 12 | 12 | 12 | 12 | 142.0 | 8,345 |

