Ductile Iron Pipe
Research Association

Strength and Durability for Life®

APPLICATIONS

Ductile Iron Pipe for Wastewater Applications

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The 1972 AMENDMENTS to Public Law 92-500 (the Clean Water Act) established the federal government's largest domestic funding program in an attempt to improve the quality of the nation's receiving waters through a construction grants program for wastewater treatment works. The act coincided with the formation of the U.S. Environmental Protection Agency (EPA) in early 1971. Despite dramatic improvements due to the tremendous commitment of resources and funds under the construction grants program, the original intent of the Clean Water Act has yet to be fully realized.

Generally speaking, the responsibility for new projects and capital improvements, as well as ongoing operation/maintenance costs for wastewater systems, now falls directly on local authorities with minimal assistance from state regulatory agencies.

Sewer utilities throughout the nation are taking an effective and farsighted approach to all improvement and replacement projects. They are carefully evaluating present– and future–sewer systems in terms of design, construction, and maintenance criteria, and they are building much more efficient collection systems, treating sewage under tighter restrictions, and specifying stronger, more durable materials.

In selecting a pipe material for sewer service, the design engineer must evaluate the pipe's expected performance and consider the many factors affecting it. These factors include physical strength, available joints and their resistance to infiltration/inflow, ease of handling and installation, impact-resistance, resistance to corrosion from hydrogen sulfide gas and industrial chemicals, life expectancy and maintenance costs, and system economics such as initial costs and availability.

Initial capital costs must be compared to annual operating/maintenance costs and system life to get a "true picture" of the annual debt service passed on to utility customers. Wastewater piping systems greatly influence the annual costs of utilities, a fact confirmed by the EPA grants program where billions of dollars were spent on the following problems:

1. Infiltration and inflow: conveying and treating massive flows of unnecessary surface and ground waters.
2. Replace/refurbish existing piping: Some gravity and force mains replaced or relined utilizing EPA funding had a useful service life of less than 20 years (in some cases, less than 10 years).
3. Gravity sewers versus pumping: installation of lift stations in lieu of deep-bury gravity mains where the net result is often higher total cost (over a 20- or 40-year period), more maintenance, and less dependability.

Ductile Iron Pipe, which has long been the material standard for sewer force mains, pump station piping, and wastewater treatment plant mechanical piping, has gained greater acceptance for use in gravity mains and interceptors.

General Design Considerations

Ductile Iron Pipe is an extremely durable material—its performance should exceed even that of its predecessor, gray Cast Iron pipe, which has continually served over 530 U.S. communities for more than a century. At least 21 U.S. communities currently have 150-year-old Cast Iron piping still in service.

Most Ductile Iron gravity sewer installations laid in accordance with good engineering practice should serve for a minimum of 50 years—with a goal of 100 years—without failure or infiltration/exfiltration in excess of 10 gallons per day per inch diameter per mile. Zero infiltration is achievable with Ductile Iron Pipe due to its pressure-tight joints. Realistic allowance, however, should be made for infiltration/inflow at manholes, service laterals, and roof/foundation drain connections, etc.

The strength of Ductile Iron Pipe permits a wide variety of design applications including shallow bury/heavy traffic loads, deep bury/high soil prism loads, and high operating/surge pressures.

Ductile Iron Pipe is designed and manufactured in accordance with published standards of the American National Standards Institute (ANSI), the American Water Works Association (AWWA), and the American Society of Testing and Materials (ASTM).

ANSI/AWWA C150/A21.50 and ANSI/AWWA C151/A21.51 are the design and manufacturing standards for Ductile Iron Pipe for water and other liquids under pressure and ASTM A746 is the standard for Ductile Iron gravity sewer pipe. The design procedure embodied in these standards, which is consistent for all diameters, is the most conservative for any piping material commonly used in sewer applications.

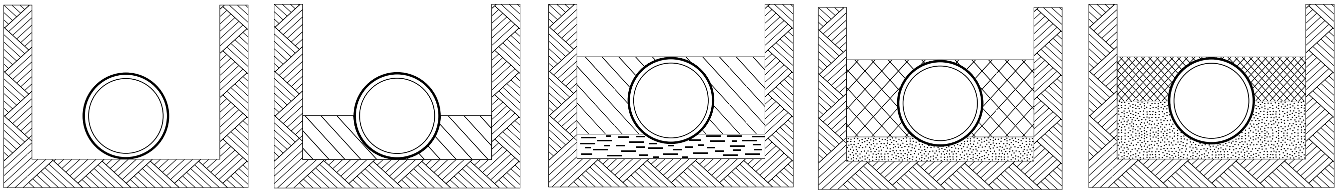
The basis of the design standard is the long-established fact that Ductile Iron Pipe, subjected to internal pressure and external loading conditions, behaves as a flexible conduit. This means that the pipe is designed separately to withstand external loads and internal pressure. The result is more conservative than designing for the combined loading condition.

Additionally, the external loading calculations for Ductile Iron Pipe utilize a very conservative full earth prism as opposed to a method assuming a narrow trench and arching of the soil as utilized in polyvinyl chloride (PVC) pipe design recommendations. The following criteria are used to calculate the required thickness of Ductile Iron Pipe in any given application:

1. Earth load is based on the prism load concept, a conservative assumption for loads experienced by a flexible pipe.
2. Truck loads are based upon a single AASHTO H-20 truck with 16,000 pounds wheel load and an impact factor of 1.5 at all depths.
3. External load design includes calculation of both ring bending stress and deflection. Ring bending stress is limited to 48,000 psi, providing a safety factor of 2.0 based on ultimate ring strength.
4. Deflection of the pipe ring is limited to a maximum of 3 percent for cement-lined pipe and 5 percent for flexible linings. Again, this limit provides a safety factor of 2.0 against applicable performance limits of the linings.
5. Five trench types have been defined to provide the designer a selection of laying conditions.
6. Internal pressure design is based on working pressure plus a surge allowance of 100 psi. A safety factor of 2.0 is applied to this calculation.

Table 1 provides illustrations of the five standard laying conditions, which, along with the design tables, allow engineers to choose the most economical combination of pipe thickness and trench conditions for any given application. Tables 2 and 3 provide guidelines for depth of bury based on laying conditions and assumed earth prism/traffic loadings. Table 2 covers cement-mortar lining, which is the standard lining provided by pipe manufacturers. Table 3 covers flexible linings, which can be factory-applied for hydrogen sulfide resistance and other special waste stream requirements. Ductile Iron Pipe is available in 3- to 64-inch diameters and is manufactured in 18- to 20-foot laying lengths.

TABLE 1
Standard Laying Conditions for Ductile Iron Pipe



Type 1	Type 2	Type 3	Type 4	Type 5
Flat-bottom trench.†	Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.	Pipe bedded in 4-inch minimum loose soil.‡ Backfill lightly consolidated to top of soil.	Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-inch minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99.)	Pipe bedded to its centerline in compacted granular material, 4-in. minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99.)

* For 14-inch and larger pipe, consideration should be given to the use of laying conditions other than Type 1.
† "Flat-bottom" is defined as undisturbed earth.
‡ "Loose soil" or "select material" is defined as native soil excavated from the trench, free of rocks, foreign material, and frozen earth.

TABLE 2
Maximum Depth of Cover for Ductile Iron Pipe with Cement Lining

Pipe Size in.	Pressure Class	Nominal Thickness in.	Laying Condition – Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, ft.[A]				
3	350	0.25	78	88	99	B	B
4	350	0.25	53	61	69	85	B
6	350	0.25	26	31	37	47	65
8	350	0.25	16	20	25	34	50
10	350	0.26	11**	15	19	28	45
12	350	0.28	10**	15	19	28	44
14	250 300 350	0.28 0.30 0.31	C	11** 13 15	15 17 19	23 26 27	36 42 44
16	250 300 350	0.30 0.32 0.34	C	11** 13 15	15 17 20	24 26 28	34 39 44
18	250 300 350	0.31 0.34 0.36	C	10** 13 15	14 17 19	22 26 28	31 36 41
20	250 300 350	0.33 0.36 0.38	C	10 13 15	14 17 19	22 26 28	30 35 38
24	200 250 300 350	0.33 0.37 0.40 0.43	C	8** 11 13 15	12 15 17 19	17 20 24 28	25 29 32 37
30	150 200 250 300 350	0.34 0.38 0.42 0.45 0.49	C	— 8** 11 12 15	9 12 15 16 19	14 16 19 21 25	22 24 27 29 33
36	150 200 250 300 350	0.38 0.42 0.47 0.51 0.56	C	— 8** 10 12 15	9 12 14 16 19	14 15 18 20 24	20 22 25 27 32
42	150 200 250 300 350	0.41 0.47 0.52 0.57 0.63	C	— 8 10 12 15	9 12 14 16 19	13 15 17 20 23	21 23 25 28 32
48	150 200 250 300 350	0.46 0.52 0.58 0.64 0.70	C	— 8 10 12 15	9 11 13 15 18	13 15 17 19 22	20 22 24 27 30
54	150 200 250 300 350	0.51 0.58 0.65 0.72 0.79	C	— 8 10 13 15	9 11 13 15 18	13 14 16 19 22	20 22 24 27 30
60	150 200 250 300 350	0.54 0.61 0.68 0.76 0.83	C	5** 8 10 13 15	9 11 13 15 18	13 14 16 19 22	20 22 24 26 30
64	150 200 250 300 350	0.56 0.64 0.72 0.80 0.87	C	5** 8 10 12 15	9 11 13 15 17	13 14 16 19 21	20 21 24 26 29

** Minimum allowable depth of cover is 3 ft.
[A] These pipes are adequate for depths of cover from 2.5 ft. up to the maximum shown including an allowance for a single H-20 truck with 1.5 impact factor unless noted.
[B] Calculated maximum depth of cover exceeds 100 ft.
[C] For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.
1. Ring deflection limited to 3%, minimum safety factor of 2.
2. Earth load (P_e) based on soil weight of 120 pcf.

TABLE 3
Maximum Depth of Cover for Ductile Iron Pipe with Flexible Lining*

Pipe Size in.	Pressure Class	Nominal Thickness in.	Laying Condition – Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, ft.[A]				
3	350	0.25	78	88	99	B	B
4	350	0.25	53	61	69	85	B
6	350	0.25	26	31	37	47	65
8	350	0.25	16	20	25	34	50
10	350	0.26	11**	15	19	28	45
12	350	0.28	10**	15	19	28	44
14	250 300 350	0.28 0.30 0.31	C	11** 13 15	15 17 19	23 26 27	41 43 44
16	250 300 350	0.30 0.32 0.34	C	11** 13 15	15 17 20	24 26 28	41 43 45
18	250 300 350	0.31 0.34 0.36	C	10** 13 15	14 17 19	23 26 28	40 43 45
20	250 300 350	0.33 0.36 0.38	C	10 13 15	14 17 19	23 26 28	40 43 44
24	250 300 350	0.33 0.37 0.40 0.43	C	8** 11 13 15	12 15 17 19	20 23 26 28	37 41 43 45
30	150 200 250 300 350	0.34 0.38 0.42 0.45 0.49	C	— 8** 11 12 15	9 12 15 16 19	17 20 23 25 28	33 37 40 42 44
36	150 200 250 300 350	0.38 0.42 0.47 0.51 0.56	C	— 8** 10 12 15	9 12 14 17 19	17 20 23 25 28	33 37 40 42 45
42	150 200 250 300 350	0.41 0.47 0.52 0.57 0.63	C	— 8 10 12 15	9 12 14 17 19	16 20 23 25 28	32 37 40 42 45
48	150 200 250 300 350	0.46 0.52 0.58 0.64 0.70	C	— 8 10 12 15	9 12 14 17 19	17 20 23 25 28	33 37 40 42 45
54	150 200 250 300 350	0.51 0.58 0.65 0.72 0.79	C	— 8 10 13 15	9 12 14 17 19	17 20 23 25 28	33 37 40 43 45
60	150 200 250 300 350	0.54 0.61 0.68 0.76 0.83	C	5** 8 10 13 15	9 12 14 17 19	17 20 23 25 28	33 37 40 43 45
64	150 200 250 300 350	0.56 0.64 0.72 0.80 0.87	C	5** 8 10 13 15	9 12 15 17 19	17 20 23 26 28	33 36 40 43 45

* Examples of flexible linings include polyethylene, polyurethane, epoxy, asphaltic, etc.
** Minimum allowable depth of cover is 3 ft.
[A] These pipes are adequate for depths of cover from 2.5 ft. up to the maximum shown including an allowance for a single H-20 truck with 1.5 impact factor unless noted.
[B] Calculated maximum depth of cover exceeds 100 ft.
[C] For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.
1. Ring deflection limited to 5%, minimum safety factor of 2.
2. Earth load (P_e) based on soil weight of 120 pcf.

Construction and Maintenance

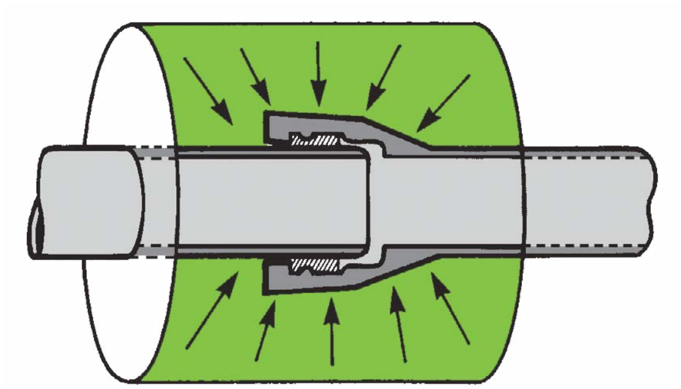
Durability, ease of installation, available standard fittings, and contractor familiarity make Ductile Iron Pipe cost-competitive and the material of choice for current wastewater applications. Superior material strength allows Ductile Iron Pipe to be installed with less stringent bedding and backfill specifications. Other flexible piping material, such as PVC, requires very rigorous bedding/backfill conditions to prevent over-deflection ("egging") and long-term creep, which can cause excessive infiltration or exfiltration.

Ductile Iron gravity and force mains are pressure-tight with design working pressures up to 350 psi with a 100 psi surge allowance. In addition, because of the unique compression gasket, or "push-on" joint, used in Ductile Iron Pipe for watertightness, infiltration/exfiltration and the increased pumping, treatment, and maintenance costs that result are virtually eliminated.

Ductile's push-on joint system has been proven effective in actual tests with up to 1,000 psi internal pressure, 430 psi external pressure, and 14 psi negative air pressure with no leakage or infiltration (see Figure 1).

FIGURE 1

Ductile Iron Push-On Joint Tests



Tested: 1,000 psi Internal Pressure
430 psi External Pressure
14 psi Negative Air Pressure
Results: No Leakage, No Infiltration

Ductile's push-on joints are among the fastest and easiest to assemble joints available today. Also, because Ductile Iron is manufactured in 18- to 20-foot lengths, it reduces the number of joints to be made and speeds installation time in deep trenches. These bottle-tight joints also prevent root growths and intrusion into the pipe joints.

Ductile and Cast Iron tees, wyes, saddles, and other outlets, which provide joint integrity equal to that of the pipe, make excellent service connections. In some cases, tees or outlets also can be used to access the pipe, eliminating the need for expensive manholes.

The dependability of Ductile Iron Pipe with push-on joints is evidenced by the fact that, while most state health departments require other piping materials to be encased in concrete where sewer and water pipes are parallel or cross within a certain distance, Ductile Iron Pipe can generally be used alone, **without** concrete encasement, in these applications.

Despite Ductile's strength, it is easy to cut in the field with an abrasive wheel saw, milling wheel saw, or other appropriate device.

Its long service life and durability make Ductile Iron Pipe the favored piping material of operations and maintenance personnel. Ductile Iron is highly resistant to shearing and breakage caused by differential settlement, frost heaving, and seismic events. It is easy to tap and repair, even in adverse trench conditions. Gravity and force mains can be cleaned using rods, cutter heads, and, in some cases, even pressure steam to remove solids and grease buildups. Other piping materials, notably PVC, can be damaged or fractured by these necessary cleaning operations.

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Above: Due to Ductile Iron Pipe's exceptional strength and durability, it can be used in a wide variety of wastewater applications.

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Above: Ductile Iron Pipe is utilized for innovative solutions of sewerage piping problems. Illustrated is an "at grade" gravity sewer.

Available Linings

Ductile Iron Pipe and Cast and Ductile Iron fittings are normally furnished with a cement-mortar lining conforming to ANSI/AWWA C104/A21.4. Originally developed to prevent tuberculation in water mains, cement-mortar lining is also highly suitable for non-septic gravity sewers and sanitary sewer force mains. Long-term testing of lined pipe, both in the field and in the laboratory, has proven the effectiveness of cement-mortar lining.

Special linings are often recommended for Ductile Iron Pipe handling industrial chemical wastes such as acids, alkali waste, and pickling brine, or in instances where hydrogen sulfides are a problem, such as in septic sewers. Contact DIPRA member companies regarding the most suitable lining for these special services.

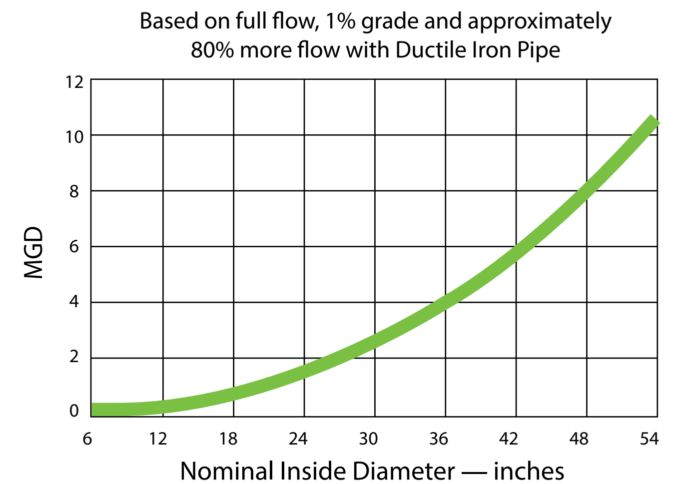
Gravity Sewers

Hydrogen sulfide gas (H_2S) can sometimes pose a problem in gravity sewers if the pipe has an air space allowing O_2 to combine with H2S creating sulfuric acid (H_2SO_4). Since H_2S is extremely hazardous to personnel, the designer should provide adequate slope and maintain a velocity of two fps in the piping system, which should help prevent the waste stream from becoming anaerobic and generating H_2S.

Gravity sewers are designed utilizing the Manning formula for uniform flow. The Manning roughness coefficient, n, is generally accepted as 0.011 for cement-mortar lining, and 0.01 for polyethylene, polyurethane, and epoxy linings. Ductile Iron Pipe typically has a larger inside diameter than other piping materials, which allows for greater design flows and carrying capacities. In larger diameter sewers, for example, Ductile's larger inside diameter could accommodate several million gallons per day additional flow (see Figure 2).

FIGURE 2

Additional Flow with Ductile Iron Pipe



As previously discussed, Ductile Iron Pipe's long service life and bottle-tight joints make it especially suitable for gravity flow applications.

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Well-suited for difficult installations due to its inherent strength, Ductile Iron is an excellent piping material for use in gravity sewer applications. Its superior ring strength, combined with its bottle-tight joints, makes it ideally suited for deep trenches and installations in areas of high water table.

Force Mains

Ductile Iron Pipe is especially suited for pressure sewer applications because its standard pressure classes provide for high operating pressures with a minimum 100 psi surge allowance. Surges, or hydraulic transients, are a very serious problem for pressure sewers as pump stations are vulnerable to power outages and surge control devices for raw wastewater are not always dependable. The surge forces, which can rupture some piping materials, are caused by momentum in the liquid due to change in velocity.

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Ductile Iron Pipe is often used for inverted siphons in difficult installations such as the stream crossing shown here because of its great strength, joint integrity, and its versatile and readily available joints and fittings.

Pressure sewers are designed much the same as water transmission lines. The Hazen-Williams formula is the most popular flow formula. The Hazen-Williams friction coefficient, C, is generally accepted as 140 for cement-mortar linings and 150 for polyethylene, polyurethane, and epoxy linings. Special linings are not usually specified if the pipe is always flowing full and the waste stream is domestic sewage. However, the designer has the option of the factory-applied linings to resist H2S as discussed under Gravity Sewers. In either case, the hydraulic efficiency of Ductile Iron Pipe, coupled with its larger than nominal inside diameter, results in reduced pumping costs over the life of the pipeline.

Piping for pressure sewers can be provided not only in push-on and mechanical joints, but also with restrained joints having deflection capabilities after installation. All Ductile Iron force main piping can be interfaced with pumps, lift stations, and plant piping with standard fittings and factory-supplied spools.

Special Wastewater Applications

1. Wastewater Treatment Facilities and Pump Stations

Ductile Iron Pipe with Ductile and Cast Iron fittings is the standard for most plant piping and mechanical room applications. All valves, pumps, couplings, and other appurtenances necessary for complete systems are compatible with pipe and fittings currently manufactured by DIPRA member companies.

2.Sewage Outfall Lines

Because of its durability and excellent flow characteristics, many treatment facilities utilize Ductile Iron Pipe for effluent discharge. This use includes not only land-based outfalls but also outfalls into oceans.

3.Other Piping Applications

Other special wastewater applications for which Ductile Iron Pipe is especially suited include:

a. Inverted siphons and river crossings
b. Bridge crossings
c. Elevated or pier-supported piping
d. Sludge transfer lines
e. Steep slope conditions (gravity or force main)
f. Piping in lake beds

Ductile Iron Pipe systems can utilize special joints such as restrained joints and ball and socket river crossing pipe, as well as standard push-on, mechanical, and flanged joints, all of which can be installed in the field with no special fabrication.

©David Justus

Ductile Iron is well-suited for use in pipe-on-supports applications due to its tremendous beam strength.

Service History and Dependability

Ductile Iron Pipe is a very economical solution for modern sewers. Ductile's long laying lengths and bottle-tight joints minimize potential infiltration and aid in construction. For most sizes, its larger inside diameters deliver up to several million gallons per day more flow than nominal pipe diameters. Its standard cement-mortar lining ensures an excellent friction coefficient and resistance to scour and cement deterioration from most domestic sewage. And its high material strength resists heavy impact, handles extreme external loadings, and in many cases, there is no need for special bedding or backfill.

Ductile Iron Pipe is often used for inverted siphons in difficult installations such as the stream crossing shown here because of its great strength, joint integrity, and its versatile and readily available joints and fittings.

Ductile Iron Pipe can be used in a wide variety of applications, including challenging conditions like deep trenches, shallow cover, seismic activity, subsequent adjacent excavations, beam loading, and ring crushing. Following its introduction in the early 1950s, Ductile Iron Pipe rapidly became the industry standard for water and wastewater pressure pipe. Engineers have long depended upon it to handle the most difficult applications. But today, in light of governmental restrictions on infiltration/exfiltration, demanding environmental guidelines, and potential liability from broken sewer mains, many of these same engineers are specifying Ductile Iron only.

Since Ductile Iron Pipe can stand up to the most demanding applications, it makes sense to insist upon the same quality pipe for the entire system, thus ensuring longevity and integrity throughout.

For more information contact DIPRA or any of its member companies.

Ductile Iron Pipe Research Association

An association of quality producers dedicated to the highest pipe standards through a program of continuing research and service to water and wastewater professionals.

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Social Media

Get in the flow with Ductile Iron Pipe by connecting with us on Facebook, Twitter, and LinkedIn.

Visit our website, **www.dipra.org/videos,** and click on the YouTube icon for informational videos on Ductile Iron Pipe's ease of use, economic benefits, strength and durability, advantages over PVC, and more.

Member Companies

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Ductile Iron Pipe is SMART certified

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