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Wastewater Technology Fact Sheet

Pipe Construction and Materials

DESCRIPTION

There are several different pipe materials available for wastewater collection systems, each with a unique characteristic used in different conditions. The four different pipe materials described in this fact sheet are ductile iron, concrete, plastic, and vitrified clay.

Pipe material selection considerations include trench conditions (geologic conditions), corrosion, temperature, safety requirements, and cost. Key pipe characteristics are corrosion resistance (interior and exterior), the scouring factor, leak tightness, and the hydraulic characteristics.

Pipe manufacturers follow requirements set by the American Society of Testing Materials (ASTM) or American Water Works Association (AWWA) for specific pipe materials. Specification standards cover the manufacture of pipes and specify parameters such as internal diameter, loadings (classes), and wall thickness (schedule). The methods of pipe construction vary greatly with the pipe materials.

Some new pipe materials and construction methods use the basic materials of concrete pipes with modifications (i.e., coatings). Other pipe manufacturing methods use newly developed resins which offer improvements in strength, flexibility, and resistance to certain chemicals. Construction methods may also allow for field modifications to adapt to unique conditions (i.e., river crossings, rocky trenches, etc.) or may allow for special, custom ordered diameters and lengths.

Ductile Iron Pipe

Ductile iron pipe (DIP) is an outgrowth of the cast iron pipe industry. Improvements in the metallurgy of cast iron in the 1940's increased the strength of cast iron pipe and added ductility, an ability to slightly deform without cracking. This was a major advantage and ductile iron pipe quickly became the standard pipe material for high pressure service for various uses (water, gas, etc.).

Concrete Pipe

Two types of concrete pipe commonly used today are prestressed concrete cylinder pipe (PCCP) and reinforced concrete pipe (RCP). PCCP is used for force mains, while RCP is used primarily for gravity lines. PCCP may be of either embedded-cylinder (EC) or lined-cylinder construction (LC). The construction process for both the LC and EC begins by casting a concrete core in a steel cylinder. This single process produces the LC pipe. Once the cylinder cures, it is wrapped with a prestressed steel wire and coated with a cement slurry and a dense mortar or concrete coating to produce the EC pipe. The manufacturing process for reinforced concrete cylinder pipe (RCCP) is similar to embedded-cylinder, however, a reinforcing cage and the steel cylinder are positioned within a reusable vertical form and the concrete is cast instead of using the prestressed wire. RCCP can be cured by using either water or steam.

Plastic Pipe

Plastic pipe is made from either thermoplastic or thermoset plastics. Characteristics and construction vary, but new materials offer high strength and good rigidity. Fluorocarbon plastics are the most resistant to attack from acids, alkalies, and organic compounds, but other plastics also have high chemical resistance. Plastic pipe design must include stiffness, loading , and hydrostatic design stress requirements for pressure piping.

Thermoplastics are plastic materials which change shape when they are heated. Common plastics used in pipe manufacturing include Polyvinyl Chloride (PVC), Polyethylene (PE or HDPE for High-Density PE), Acrylonitrile-butadiene-styrene (ABS), and Polybutylene (PB). HDPE is commonly used with pipe bursting. PVC is strong, lightweight, and somewhat flexible. PVC pipe is the most widely used plastic pipe material. Other plastic pipes or composites with plastics and other materials may be more rigid.

Thermoset plastics are rigid after they have been manufactured and are not able to be reformed. Thermoset plastic pipes are composed of epoxy, polyester, and phenolic resins, and are usually reinforced with fiberglass. Resins may contain fillers to extend the resin and to provide specific characteristics to the final material. The glass fibers may be wound around the pipes spirally, in woven configurations, or they may be incorporated into the resin material as short strands. The pipes may be centrifugally cast. Stiffness may also be added in construction as external ribs or windings. Reinforced Plastic Mortar (RPM) and Reinforced Thermosetting Resin (RTR) (or Fiberglass Reinforced Plastic Pipe (FRP)) are the two basic classes of these pipes. Another name is Fiberglass Reinforced Polymer Mortar (FRPM). Thermoset pipes are often manufactured according to the specific buyer requirements and may include liners of different composition for specific chemical uses.

For plastic pipes, resins composed of polymerized molecules are mixed with lubricants, stabilizers, fillers, and pigments, to produce mixtures with different characteristics. Plastic pipes are generally produced by extrusion. Plastic pipe may be used for sliplining or for rehabilitating existing pipes by inserting or pulling them through a smaller diameter pipe. HDPE pipes may also be used for bursting and upgrading. The smaller diameter pipe may be anchored into place with mortar or grout.

Vitrified Clay Pipe

Vitrified clay pipes are composed of crushed and blended clay that are formed into pipes, then dried and fired in a succession of temperatures. The final firing gives the pipes a glassy finish. Vitrified clay pipes have been used for hundreds of years and are strong, resistant to chemical corrosion, internal abrasion, and external chemical attack. They are also heat resistant. These pipes have an increased risk of failure when mortar is used in joints because mortar is more susceptible to chemical attack than the clay. Other types of joints are more chemically stable. It has been shown that the thermal expansion of vitrified clay pipes less than many other types (such as DIP and PVC).

APPLICABILITY

The applicability of different pipe materials varies with each site and the system requirements. The pipe material must be compatible with the soil and groundwater chemistry. The pipe material also must be compatible with the soil structure and topography of the site, which affects the pipe location and depth, the supports necessary for the pipe fill material, and the required strength of the pipe material. The following list shows background information to be used in determining what type of pipe best fits a particular situation:

- Maximum pressure conditions (force mains).
- Overburden, dynamic, and static loading.
- Lengths of pipe available.
- Soil conditions, soil chemistry, water table, stability.
- Joining materials required.
- Installation equipment required.
- Chemical and physical properties of the wastewater.
- Joint tightness/thrust control.
- Size range requirements.

- Field and shop fabrication considerations.
- Compatibility with existing systems.
- Manholes, pits, sumps, and other required structures to be included.
- Valves (number, size, and cost).
- Corrosion/cathodic protection requirements.
- Maintenance requirements.

ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages for specific pipe materials are listed in Table 1. The primary advantages and disadvantages to consider for pipes used in sewer applications include those that are related to construction requirements, pressure requirements (force mains), depth of cover, and cost.

TABLE 1 ADVANTAGES & DISADVANTAGES OF DIFFERENT MATERIALS

Advantages	Disadvantages
Ductile Iron	
• Good corrosion resistance when coated	• Heavy
• High strength	
Concrete	
• Good corrosion resistance	• Requires careful installation to avoid cracking
• Widespread availability	• Heavy
• High strength	• Susceptible to attack by H_2S and acids when pipes are not coated
• Good load supporting capacity	
Vitrified Clay	
• Very resistant to acids and most chemicals	• Joints are susceptible to chemical attack
• Strong	• Brittle (may crack); requires careful installation
	• Short length and numerous joints make it prone to infiltration and more costly to install
Thermoplastics (PVC, PE, HDPE, ABS)	
• Very lightweight	• Susceptible to chemical attack, particularly by solvents
• Easy to install	• Strength affected by sunlight unless UV protected
• Economical	• Requires special bedding
• Good corrosion resistance	
• Smooth surface reduces friction losses	
• Long pipe sections reduce infiltration potential	
• Flexible	
Thermosets(FRP)	
• High strength	• High material cost
• Lightweight	• Brittle (may crack); requires careful installation
• Corrosion resistant	• High installation cost

Source: Lamit, 1984, Moser, 1990, Peggs, 1985.

DESIGN CRITERIA

Design requirements may vary greatly. Pipe design is approached differently for both materials and construction methods. The mechanics of the soil that will surround the pipes is a fundamental design aspect for the support characteristics, especially for flexible pipes. The soil type, density, and the moisture content are important characteristics.

COSTS

Costs for piping comparisons should include both the costs of the materials as well as the construction costs. The pipe cost is usually given in dollars per unit length, traditionally in $/linear foot, plus the costs of the fittings, connections, and joints. Construction costs will depend on the type of digging necessary, special field equipment requirements, and an allowance for in-field adjustments to the system. Access to pipe systems will also be a relevant cost factor, as manhole spacing is dependant on pipe size.

Sanitary sewer construction costs depend on several variables, including depth, type of soil, presence of rock, type of bedding material, location (rural vs. urban areas) clearing costs, and other factors.

Typical pipe materials for small diameter sanitary sewers (8" through 24" diameter) include PVC, vitrified clay, and ductile iron. Typical average costs for sanitary sewers (excluding service connections and manholes) are provided in Table 2.

The cost per linear foot in the table is based on an average trench depth of eight feet and excludes service connections and manholes. The following is not included in the cost per linear foot:

1. Asphalt and gravel driveway repair.
2. Open cut of roads.
3. Boring and jacking.
4. Concrete encasement of pipe at stream crossings or other locations.
5. Erosion control.
6. Relocation of other utilities.

Soil material is assumed to be silt, clay, or other soil mixtures with no requirement for shoring, rock removal, or dewatering.

REFERENCES

Other Related Fact Sheets

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

1. Cast Iron Pipe Research Association, 1978. *Handbook*. 5th Edition.
2. Ductile Iron Pipe Research Association (DIPRA), no date. "Ductile Iron Pipe." Internet site at http://www.dipra.org/ductile.html, accessed March 2000.

TABLE 2 AVERAGE COST/LINEAR FOOT BY PIPE DIAMETER

Pipe Material	2"	4"	6"	8"	12"	15"	18"	24"
VCP	-	-	$25	$30	$38	$50	$65	$110
DIP	-	-	-	$38	$50	N/A	$75	$110
RCP	-	-	-	-	$11	$17	$23	$31
PVC	$15	$19	$23	$25	$30	$38	$50	$75
PE	-	$7	$12	$14	$9*	-	$16*	-
FRP	$21	$30	$42	$60	-	-	-	-
ABS	$11	-	-	-	-	-	-	-

* Corrugated
Source: RS Means Heavy Construction Guide (1998).

3. Lamit, L.G., 1984. *Pipe Fitting and Piping Handbook.* Prentice-Hall, Inc.

4. Moser, A.P., 1990. *Buried Pipe Design*. McGraw-Hill, Inc..

5. Peggs, L.A., 1985. *Underground Piping Handbook.* Robert E. Krieger Publishing Company.

6. U.S. EPA, October 1991. *Alternative Wastewater Collection Systems*. EPA/625/1-91/024.

7. WEF, 1986. *Alternative Sewer Systems*. MOP #FD12.

ADDITIONAL INFORMATION

American Concrete Pipe Association
Josh Beakley, Director of Technical Services
222 West Las Colinas Boulevard, Suite 641
Irving, Texas 75039-5423

Ductile Iron Pipe Research Association
L. Gregg Horn, P.E.
245 Riverchase Parkway East, Suite O
Birmingham, Alabama 35244

National Clay Pipe Institute
Edward Sikora
P.O. Box 759
Lake Geneva, Wisconsin 53147

University of Houston,
Mohan Neelam
Dept. of Civil and Environmental Engineering
Houston, Texas 77204-4791

David Venhuizen, P.E.
5803 Gateshead Drive
Austin, TX 78745

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

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