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Use of Plastics as Piping Materials

Please note

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The use of plastic pipe dates back to the mid-1930's, when the Germans utilized it for sanitary drainage. Plastic pipe is now used in almost every industry of the industrialized countries.

This Digest describes the nature and general characteristics of plastic piping. Because the properties of various plastic piping materials differ significantly from one another, the designer and the user should become familiar with the advantages and limitations of each type of plastic.

General Nature of Plastics

Plastics are man-made materials based on organic polymers to which a variety of other ingredients are incorporated to facilitate processing and to improve properties such as fire and weather resistance. On the basis of how they react to heat, plastic materials are generally classified into two basic groups: thermoplastic[1] and thermosetting plastics[2]. Thermoplastics can be reversibly softened by heat and hardened by cooling; thus, they can be repeatedly reshaped by application of heat. On the other hand, thermosetting plastics (thermosets), once formed and thus having undergone curing, acquire a fixed, unchangeable shape.

A wide range of plastics can be formed, extruded or molded into plastic pipe and pipe fittings. Plastic pipe has many of the properties of metal pipe, but the extent of these properties differs from those in metal pipe. Consequently, many of the practices and principles relating to engineering design and installation of other piping materials are not applicable to plastic piping.

Properties

The selection of a suitable piping material depends on the medium being transported and on the specific service conditions. Some of the attributes of plastics may be favourable or unfavourable, depending on the particular service conditions and the type of plastic. The effect of some unfavourable attributes can be reduced or eliminated through proper design and installation of the pipes. Choosing the right material therefore requires a thorough knowledge of the physical features of various plastics.

A list of the properties important in plastic piping applications follows.

Resistance to corrosion and erosion

With respect to corrosion, plastic piping has outstanding resistance to water, nearly all acids, alkalis, salt solutions and other corrosive liquids, and gases[3-5]. As for erosion, its resistance depends on the fluid being transported, on the type of plastic and on the service conditions.

Resistance to chemical attack by a given plastic usually decreases with the increase in concentration of a specific chemical. Some types of polyethylene (PE), for example, can be used to convey 70 per cent sulfuric acid at 23°C (73°F), but they are not satisfactory for a 95 per cent concentration. Operating temperatures are also an important factor in the ability of a given plastic to resist chemical attack. For example, some PE pipe materials that are suitable for transporting nitrous oxide gas at 23°C should not be used with this gas at 50°C (122°F). The specific formulation of a given plastic may also determine the degree of resistance to a chemical or to its concentration.

Smoothness of internal walls

Plastic pipes have smooth inner walls that promote high flow rates and resistance to the formation of deposits, thus preventing clogging. In contrast, most metal piping corrodes with time, so that the accumulation of rust and scale increases the friction loss and reduces the carrying capacity.

Table I. Properties* of Plastic Piping Materials and Traditional Piping Materials.

Material	Density g/cm³	Coefficient of thermal expansion, 10^{-6}/°C	Thermal conductivity $W \cdot m^{-1} \cdot °C^{-1}$ ($Btu \cdot in \cdot h^{-1} \cdot ft^{-2} \cdot °F^{-1}$)	Tensile strength, MPa (psi) (ASTM D 638)	Modulus of elasticity, GPa($10^5 \cdot$psi) (ASTM D 638)
Plastics: Thermoplastics	0.09-1.80	50-180	0.14-0.5 (0.96-3.5)	23-50 (3,400-7,300)	1.0-3.1 (1.5-4.5)
Themosets	1.30-2.00	22-31	0.19-0.26 (1.3-1.8)	62 (9,000)	0.90-19 (1.3-13)
Metals: Aluminum	2.70	23	220 (1,540)	76 (11,000)	69 (100)
Brass	8.50	19	120 (830)	500 (74,000)	100 (150)
Copper	8.75	17	390 (2,700)	220 (32,000)	120 (170)
*Ferrous metals***	7.20-7.85	12-16	33-52 (230-360)	160-1400 (2,400-200,000)	90-270 (130-390)
Lead	11.35	30	35 (240)	17 (2,500)	14 (20)
Concrete	1.80-2.50	11	--	1.4-3.4 (200-500)	14-34 (20-50)

* Values given are approximate and should be considered only as a guide;
Details on the properties of individual plastic pipe materials will be presented in future Digests.
** This group of materials comprises cast iron and a variety of steels.

Thermal properties

Plastics have considerably lower thermal conductivity than most other piping materials (Table 1), thus resulting in low heat losses or gains. For drain-waste-vent (DWV) applications, the lower thermal conductivity is an advantage since fatty substances either do not deposit within the drain line, or do so at a reduced rate.

Plastic piping materials expand to a greater degree than traditional materials in response to higher temperatures. This must be taken into account when designing piping installations which will undergo large temperature fluctuations. For example, the coefficient of thermal expansion of poly(vinyl chloride) (PVC) Type I (50 to 63 x 10^{-6}/°C) is about four to five times greater than that of steel (12 x 10^{-6}/°C), and that of polyethylene (PE) Type I is approximately fifteen times greater than for steel.

To allow for this expansion, supports for plastic pipe are spaced closer together than those for metallic pipe. For the same reason, underground piping is usually "snaked" in the trenches.

Because plastic pipe has a relatively low softening temperature compared with traditional piping materials, pipe runs must be kept well away from locations of high ambient temperatures and from other piping, ductwork or conductors which may create excessively hot conditions. Depending on the type of plastic and the stresses involved, the upper operating temperature limit varies from 50°C (122°F) to over 150°C (302°F).

Electrical properties

Plastics are generally not conductors of electricity. Thus, they are not subject to galvanic or electrolytic corrosion, a major cause of failure in metal pipe used underground. This lack of conductivity also precludes using them to ground electrical circuits.

Density

Plastic pipe is considerably lighter than metal, concrete and asbestos-cement pipe; it ranges in density from 0.90 to 2.0 g/cm^3, depending on the basic resin and formulation. This results in substantially lower installation costs, since plastic pipe can often be installed by hand instead of requiring the machinery needed to position pipe of similar size made of heavier materials. In addition to easier installation, the lower weight results in lower shipping and handling costs.

Mechanical properties

Plastics do not have the physical strength of metals (Table 1) but they are more flexible. They have more than adequate tensile and burst strength to withstand the operating pressures encountered in most service conditions within the temperature capability of the type of plastic being used. The mechanical strength varies inversely with temperature but impact resistance behaves in the opposite manner. Plastic pipe is generally tough; as a result, external shocks that could cause failure in more rigid or brittle materials may be absorbed by the material with little or no damage.

Flammability

Plastics are based on polymers and contain other organic ingredients that are usually combustible. The compounded plastics, however, show a wide range of behaviour in fire, with the burning rate depending on the type of resin, the formulation and the wall thickness. Because the plastic material used in pipes decomposes in building fires, the resulting products, which can easily spread the fire, should be taken into account when designing and installing plastics.

Pressure rating and coding

With the exception of sewer and drainage pipe, all plastic pipe is pressure rated. There are three different methods of determining pressure ratings:

- schedule number, obtained from the expression 1000 x P/S, where P is the service pressure and S is the allowable stress, both being expressed in the same units
- standard dimension ratio (SDR), calculated by dividing the outside diameter of the pipe by its wall thickness;
- pressure-level rating, which gives the pressure rating of the pipe at a given temperature. Plastic pipes are available commercially at many pressure ratings, and the most popular of these are: 50, 100 and 125 psi (340, 690 and 860 kPa); 160, 200. 250 and 315 psi (1.1, 1.4, 1.7 and 2.2 MPa).

The code used for thermoplastic pipe consists of four digits and an alphabetic prefix showing the kind of resin it contains. The first and second digits show the type and grade of resin, respectively; the third and fourth indicate hydrostatic pressure divided by 100. For example, PVC 1120 indicates a pipe made of poly(vinyl chloride), Type I, Grade I, with a 2,000 psi (13.8 MPa) hydrostatic test pressure.

Durability

Microbiological and rodent resistance

Laboratory tests and field experience with buried thermoplastic pipes and cables have indicated that the plastics used for pipe are virtually immune to attack by bacteria, fungi and other microorganisms or insects. Although tests with pipe samples have shown no evidence of attack by termites, plastic pipe has on occasion been damaged by rodents gnawing at the pipe surface if it gets in their way.

Weathering resistance

Plastics are, in general, susceptible to deterioration when exposed to the weather. More specifically, most plastics are subject to photo-chemical degradation induced by the ultraviolet light of solar radiation. This results in embrittlement of the plastic which reduces its strength and lowers its resistance to environmental cracking. Resistance to deterioration is, however, considerably improved by using weather-resistant formulations that include ultraviolet stabilizers.

Uses

The properties that determine the use of plastics as piping materials are: softening temperature, structural strength, dimensional stability, resistance to household and industrial chemicals, manufacturing cost and ease and cost of installation.

The most important applications of plastic piping are described below.

Plastic pipe in drain-waste-vent (DWV) applications

Where local building codes permit its use, plastic pipe is dominant for home and commercial DWV applications in most industrialized countries. A growing number of industries and institutions are successfully using plastic pipe to solve their acid waste problems.

Irrigation and water distribution

Resistance to soil environments and ease of installation as a result of their light weight and low cost make plastics the leading material in irrigation and water distribution systems.

Plastic pipe in oil and gas industries

Plastic pipe is currently used in handling all types of crude oils and natural gas. Because wax build-up in metal lines carrying crude oil and gases causes choking of these lines, the oil and gas industries now prefer to use plastic piping.

Miscellaneous applications

As mentioned before, plastics have an inherent resistance to a broad range of chemicals as compared with traditional piping materials. The mining industry thus uses plastics to avoid corrosion problems that exist as a result of dilute sulfuric acid. Likewise, plastic pipe is widely used in the chemical- and food-processing industry. Plastics generally do not contaminate end products, and there are resins that are approved by the Food and Drug Administration (U.S.), and National Sanitation Foundation (U.S.). (In Canada, the plastic piping materials used by the food industry must comply with the provisions of the Food and Drug Act and Regulations.)

Plastic piping is also used extensively in the treatment process of sewage and is particularly useful in water treatment plants for handling high-purity and de-ionized water, as it will not contaminate the water.

Specifications and Standards

Numerous specifications and standards available for plastic pipe and fittings include standards for raw materials, finished pipe and fittings, methods of test and recommended practices for design, installation and joining[3, 4-8].

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