A Progressive Solution to Materials Used for Water Infrastructure

Tyler W. Pierce

University of Central Florida

Abstract

Historically, the materials utilized to construct the underground piping of the water infrastructure have been predominately cast iron, ductile iron and concrete pipe (Baird, 2011). However, with much of the developed world's water infrastructure in need of rehabilitation within the next thirty years, it is important to examine all available solutions and materials before investing considerable quantities of public resources in the momentous undertaking ("Dawn," 2001). A prime solution to the complications associated with the traditional materials is the use of plastic pipe in its place. The noncorrosive nature of plastic provides longevity, making it an ideal material for the harsh conditions ubiquitous among water and wastewater systems. Moreover, plastic pipes can be installed via trenchless techniques as opposed to traditional open-trench operations required for the installation of iron and concrete pipes. Utilizing trenchless methods provides an affordable alternative that alleviates many of the societal disruptions associated with open-trench installations (Turner, 2007). Consideration for a population that is increasingly conscious of environmental stewardship further substantiates the use of plastic due to its lower carbon footprint and reduced energy consumption (Baird, 2011). Plastic is the future of water infrastructure and provides the long-term economical solution necessary to solve the problems it faces today.

A Progressive Solution to Materials Used for Water Infrastructure

The subject of water infrastructure has a scope well beyond that of that of the engineering profession. It is a complex system that requires not only design and implementation, but also consideration of the economic feasibility for municipalities and of utmost importance the best interest of the public. Historically, water infrastructure has relied upon cast iron, ductile iron and concrete pipes for water and wastewater systems. Today, many of these original systems are in need of replacement due to the life expectancy of the current materials (Baird, 2011). The question is then, what material is best suited for the future design of water infrastructure? Conceivably, the existing infrastructure could be replaced with identical materials, however, there are major issues such as corrosion, leaks and breaks, and the high cost associated with the materials currently in use. It must also be noted that in the future, the water infrastructure will again require renovation, as it does now. The use of materials similar to these currently in place is sure to yield issues similar to those that are faced today. For these reasons, it is advantageous to seek alternative materials.

A multitude of factors must be considered concerning the choice of material with which to construct the future water infrastructure. The material chosen must have a long life expectancy in the face of harsh soil conditions and other environmental factors, such as ground settling and earthquakes, while remaining environmentally friendly. Of utmost importance, the material used must ensure the health of the public. As the Environmental Protection Agency (EPA) establishes more stringent requirements for drinking water, it is essential that distribution systems can handle these changes (Turner, 2007). While meeting all the aforementioned requirements, the material must be economical in order to be a practical solution for municipalities that face strict budgets.

An ideal material will address all the pitfalls of traditional material, while remaining affordable. Unlike ferrous materials and concrete, plastic is does not corrode or breakdown. Research and case studies reveal plastic pipe as a solution for new and rehabilitation water infrastructure projects. The types of plastics used in water infrastructure are wide ranging, including high density polyethylene (HDPE or PE), polyvinyl chloride (PVC) and acrylonitrile-butadiene-styrene (ABS) ("Living, 2011).

Discussion

Whether it is the oldest cast iron pipes laid in the 1800s or more recent networks produced in the 1920s and post-World War II era, all are in need of replacing within the next 30 years. The American Water Works Association (2001) determined that the average life expectancy for these pipes are 120, 100, and 75 years, respectively. The reason for this convergence is attributed to the changes in materials used to produce the pipes over time. It will cost between $660 billion and $1.1 trillion over the next two decades to replace the existing systems (Holland, 2010a). With such a considerable investment inevitable in the near future, it is crucial to choose the best possible material for rebuilding America's infrastructure.

Corrosion is one of the largest problems associated with the use of iron pipes in underground networks. It alone accounts for $50.7 billion every year in the United States according to 2002 congressional study (Holland, 2010b). Corrosion due to soil conditions, pipe material, and the characteristics of water flowing through, weakens the pipe and leads to breaks and leaks (Lary, 2010). A study by the American Society of Civil Engineers determined that an average of 700 mains break each day in North America, resulting in 2.6 trillion gallons of potable water lost. This accounts for 17% of all drinking water pumped each day. Some distribution systems even have losses of 50% of their water ("Living," 2011). Not only is this an extreme waste of an essential resource, but it is also very costly not only because of the cost accrued in treating the water in accordance with the strict standards set by the EPAs Safe Drinking Water Act, but also because it results in excess costs exceeding $4.1 billion dollars in electricity each year (Holland, 2010a).

In addition to corrosion weakening the integrity of iron pipes, it also causes mineral deposits to build up on their inner walls. This reaction, called tuberculation, narrows the diameter of the pipe, which reduces its hydraulic capacity. In order to compensate for the increased resistance, the power required by the pumps must be increased, which subsequently increases cost. It also decreases the quality and aesthetics of the water due to the leaching of iron into the water resulting in water with a characteristic red tint. When corrosion and tuberculation occur in iron pipes it is common that the number of bacterial colonies increases. This occurs because iron acts as nutrients for bacterial growth. A study by Kerr (2010) showed that the bacterial count on cast iron pipe was 97% higher than it was on either PE or PVC in both short and long term testing. It was also concluded that the diversity of bacteria was greatest on cast iron.

Plastic pipes have the capability to be the solution to these problems. Plastic, due to its noncorrosive properties, is considered by both American and European sources to have a life expectancy of more than 110 years (Baird, 2011). Plastic pipes can also be significantly less expensive than traditional materials from both a materials and installation perspective. Additionally, because PE and PVC pipes are durable and leak resistant, maintenance costs would be dramatically reduced (Turner, 2007). A study by the National Research Council of Canada found that cast iron and ductile iron pipes experienced 32.6 and 7.9 main breaks per 100 km, while in PVC it only averaged 0.5 breaks every 100 km (Sobot). Because of this type of evidence, which shows that PVC has such low incidence of breaks, the municipality of Calgary, Canada opened its procurement policies to include PVC as a material allowed to be used in water infrastructure. As a result of this change in policy, the city of Calgary ended up installing approximately 2,000 km of PVC pipe, which is half of its total length of pipe network. The result of this conversion enables Calgary to save an estimated $5 million dollars a year on water main breaks. Due to the switch to plastic piping, Calgary now has the lowest incidence of water main breaks in Canada, 0.2 per 100 km (Holland, 2010b).

For plastic pipes to be a feasible solution instead of iron and concrete, it must be economically competitive. For a product offering competitive advantages over its counterparts, such as durability, longevity and environmental benefits, plastic is surprisingly affordable. In a case study for Dalton Utilities in Georgia, a project to complete the second phase of their water distribution system rehabilitation was bid to qualified companies. The winning bid was $19.8 million dollars, $5 million dollars less than the next bid. This budget was possible because the contracting company decided to use HDPE instead of iron or concrete. Easier installations due to trenchless techniques made it possible to complete the project in ten months, as opposed to the four year requirement for iron or concrete (HDPE, 2010).

The lightweight nature of plastic makes it more affordable to ship from the manufacturer to the site. For example, an 8 inch plastic water main pipe weighs approximately 8 pounds per foot, whereas an 8 inch iron pipe weighs 33 pounds. This difference is significant, but even more pronounced in pipes used for storm water drainage. A standard 48 inch corrugated PE pipe that is 20 feet long weighs 600 pounds. The same sized reinforced concrete pipe weighs over 37 times the PE pipe, or 22,500 pounds. Using plastic pipes allows for fewer deliveries of pipe because a greater quantity can be shipped without surpassing a trucks weight limits. This saves time and fuel costs. Another factor effecting the cost of a project is its installation. To install steel and concrete pipes, a trench must be dug in order to lower the pipes into place with heavy equipment and each joint must then be connected. Plastic pipes can also be used in a similar manner, but require less heavy equipment and smaller crews to install the lighter weight pipe (A Greener, 2009).

Plastic pipes can be used in open-trench installation, but they also offer the option of trenchless installations. Instead of digging trenches, various methods of construction are able to minimize surface and social disruption by allowing contractors to excavate underground without difficult river and waterway crossings or reconstructing paved surfaces (Holland, 2010a). This is not only more economical in many situations, but also minimizes social disruptions including soil displacement, surface restoration, and traffic congestion (Turner, 2007). Trenchless operations cannot be used for steel or concrete, but due to the flexibility and joint attachments of plastic, trenchless techniques can be implemented using this material. Whether using PE or PVC pipes, each is able to be connected to essentially form a monolithic pipe. PE pipes use a process called heat-fusion, while PVC uses butt fusing ("Living," 2011). Furthermore, interlocking joints have also been developed and are of use in trenchless applications (The Green, 2009). A popular trenchless technology is called horizontal directional drilling (HDD) (Turner, 2007). For this method, a horizontal tunnel is drilled underground. After the tunnel has been created, the pipe is then pulled through the tunnel (Horizontal). Without the nearly seamless and secure fittings offered by plastic pipes, this would not be possible. An important characteristic of plastic pipes is their flexibility. Flexibility allows the pipes to be pulled from the surface through the tunnel without being damaged. An added benefit is that the pipes are also able to conform to displacements of the earth during earthquakes and ground shifts (Holland, 2010a). In addition to

HDD, another method for using plastic pipe is sliplining. Sliplining, while not a long term solution, is capable of a life expectancy upwards of forty years. The sliplining technique involves inserting a slightly smaller plastic pipe inside the larger original pipe. A reaction using hot water causes the plastic pipe to expand to fit the original pipe. Pipe bursting, another trenchless installation technique, also has its benefits. This method uses a device to shatter the original pipe into the surrounding soil while pulling the new pipe behind it. The previous pipe therefore is not removed, which makes the process more economical and allows the system to expand its pipe size ("Living," 2011).

In today's age, environmental concerns are more important than they have been in the past. Water is vital to life and its conservation is important to many people. This fact, combined with staggering losses of 2.6 trillion gallons of water per day in United States, make a highly efficient water distribution system a necessity (Holland, 2010a). Depending on the joining technique implemented, leakage rates can be essentially zero with the use of plastic pipes. These plastic pipes can be joined using a traditional bell-and-spigot system, but unlike concrete and iron pipes, they can also be fused together. Fusing techniques include heat-fusion for PE pipes and butt fusing for PVC, both of which form a reliable water tight seal to guard against leaks (A Greener, 2009). In addition, new products have been introduced to plastic pipes, which utilize interlocking mechanisms located at the end of each pipe creating a permanent and leak free fit (The Green, 2009).

Beyond the benefit of water conservation, plastic pipes also produced a smaller carbon footprint and consume less energy during the manufacturing process. Recio and colleagues (2005) determined that PVC consumed the least energy and resulted in the smallest carbon footprint among all pipe materials tested, while ductile iron pipe consumed the most energy and resulted in the largest carbon footprint. The energy required for production of ductile iron pipe produced via recycled materials was 26% higher than PVC, and 56% higher if non-recycled material was used (Baird, 2011). The manufacture of plastic pipes requires 56,600 trillion fewer BTUs than iron and concrete ("Living," 2011).

Traditionally, municipal procurement policies in North America have favored ductile iron and cement pipes over plastics. This is because many bids will prohibit materials such as plastic, even though they are used by other municipalities and meet all required international, national and state certifications. Perhaps due to comfort with the materials currently in use, municipalities have previously remained unwilling to explore alternatives. Recently, however, the policies reflect a shift toward a progressive consideration of new materials. Projections anticipate that the use of plastic piping is expanding in terms of global water infrastructure design, particularly among systems in the United States due to upgrades and repairs of water and sewer pipelines (World, 2012).

Water infrastructure in North America underwent major expansion following the end of World War II. Because many iron and concrete pipes are deteriorating due to corrosion, the infrastructure requires extensive renovation at present or in the near future. For this reason plastic is an excellent option to consider of the available materials from which to reconstruct the system. Smarter spending for the future will be key for government entities. Pipes are projected to be the single largest expense in the rehabilitation of Americas water infrastructure. With such an investment in underground pipe networks, it is therefore pivotal to invest in the best suited product for the job. Plastic pipes offer countless advantages over traditional materials in both new-build and rehabilitation installations. The solution for a greener water infrastructure and demonstration of environmental stewardship rests with the use of plastics as the principle material in future construction. Plastic pipes offer the best possible solution to corrosion, increasing the longevity and durability of water infrastructure, while minimizing the use of limited public resources (Baird, 2011).

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