COST-VALUE ANALYSIS OF STORM SEWER PIPE
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A legacy of high-performance storm sewers depends upon responsible engineering.
By Al Hogan, P.E.

There is never a better time than the present to consider how you, your firm, municipality or agency selects and specifies storm sewer pipe. America's professional engineering organizations are striving to raise awareness of the extent of the poor condition of the nation's infrastructure, and this includes buried pipelines. According to the American Society of Civil Engineer's "Report Card of America's Infrastructure," the most recent score for wastewater is a D-, which is a decline from the previous score of D+ in 1998. Because of the declining state of our infrastructure and recent catastrophic failures like the I-35 Bridge in Minneapolis, professional organizations are stressing the need for sustainable designs that utilize long-lasting infrastructure products.

Professionals understand the vital importance of their expected duties to use their knowledge and abilities to always, and without fail, place the health, safety and welfare of the public at the forefront of all design and construction decisions. While the duty of care remains an imperative, economic constraints placed on projects and the need to be competitive in the marketplace often present themselves as compelling forces. These forces are causing many professionals and agency specifiers to consider ways to reduce design and project costs as low as possible. To keep project costs low, some specifiers and consultants are allowing more alternative products in the stormwater piping portion of their projects. Although this perceived cost-cutting measure may be appropriate in some situations, many decisions to be competitive solely on capital cost could oversimplify future needs of a storm sewer system and result in even greater challenges that affect the health and safety of the end users and the community.

Competition is good for business and consumers. American concrete pipe producers harbor a genuine desire to be competitive and ask only that specifiers take the time to fully research and understand the products that will be used by the public. Specifiers must consider all costs of a project throughout its design life, develop technically correct designs, and produce contract documents that contain correct and clear specifications and details.

All pipe products have specific applications, design, installation and inspection requirements, and all have different risks associated with them. Understanding the characteristics of various pipe materials and products will build industry and the public's confidence in pipe selection criteria and, in many circumstances, lead to better storm sewer specifications.

Early decisions about storm pipe materials can be based upon the severity of the environment of the sewer or level of importance of a pipe product and/or material to solve a problem. Critical applications that deserve careful attention are:

- portions of the pipeline that are subject to high traffic volumes;
- portions of the pipeline with large dead and/or live loads;
- areas where pipe failure could cause flooding to adjacent property or roads;
- critical portions of the storm sewer that regulate or assist with stormwater quality;
- any portion of a storm sewer that controls runoff volume to downstream properties; and
- any run of the pipeline that would be difficult to replace due to depth of bury or proximity to other critical structures or services.

The higher the level of importance of the application, the more important it is to consider long-term performance, including confirmed structural strength in the decision of the pipe material to be selected. Concrete pipelines in critical applications have a history of high performance.

Pipeline design must address hydraulics of the system and structural capacity to accommodate anticipated loads. The design process cannot be completed without a thorough knowledge of pipe materials and how the structure is designed. There is a fundamental difference in the structural design requirements for both a rigid and flexible pipelines.

- The structural component of pipe design is often overlooked, taken lightly or oversimplified with fill height tables. The use of published fill heights may be sufficient in non-critical applications or installations; however, almost every project contains a critical portion of storm drain. Fill height tables should be used only in the following scenarios:
    - The designer completely understands the design and trench condition assumptions made to develop the fill height table.
    - The fill height table is developed in such a way that the design engineer can select a conservative trench installation that he or she is confident can be met or exceeded on the job site.
    - The project has trench backfill materials and installation requirements that meet or exceed fill height table assumptions
    - The designer has the flexibility to be conservative in his or her selection of an allowable/maximum fill height.
- In all cases, the designer should complete a full structural design or be able to use an accepted design confirmation process or tool to make sure the pipe product will accommodate the anticipated construction and lifetime loads. Full design or structural confirmation of any pipe product requires the following:
    - The engineer must know construction site conditions and soil properties, or specifications and installation details that clearly specify in-situ soil and trench construction details of the structural design calculations.

- The engineer must be able to mathematically approximate the load that will need to be accommodated by the pipe.
- The engineer must understand the national specifications and the independent design method of the product to be used.
- The engineer must understand long-term material properties and how to conservatively use the material properties and soil interaction to properly complete any structural design for any of the available pipe products.

Simply utilizing published fill height tables from material suppliers, product associations or DOT documents does not relieve a professional of his or her duty to ensure that the design is correct and structurally sound.

Rigid pipe design requires an understanding of material properties of reinforced concrete. Reinforced concrete pipe (RCP) is a confirmed structural component when it arrives at the job site. Even though the full design strength of the installed system requires some level (approximately 10 percent to 30 percent) of support from the bedding and backfill, the majority of the system strength is in the pipe wall (approximately 70 percent to 90 percent) when it arrives on site.

Most engineers specify conservative trench installation materials and backfill procedures for RCP installations. This conservative approach normally requires a very low percentage of support from the bedding and backfill. This flexibility for the designer to utilize available soil materials to the spring line of RCP allows for some real-world field and installation imperfections while still providing for proper structural system strength. The concrete pipe industry provides a variety of design aids posted on of the American Concrete Pipe Association's Web site to help the designer.

HDPE pipe design requires knowledge of the material properties of plastics and the importance of the soil-pipe interaction to create the structural component of the installed system. Most practicing civil engineers have not received any formal training on the material properties or behavioral properties of plastics. An article in the October 2007 issue of *Modern Plastics Worldwide*, "Long-term testing critical for material selection" by Chris O'Connor, stressed the need for engineers and designers to fully understand plastic properties.

Most HDPE storm pipe producers provide one pipe stiffness and a limited selection of profile configurations for each of the different sizes of conduits they manufacture. Due to this lack of options for increased pipe wall strength, most installations require high-quality imported pipe embedment materials to be placed a minimum of 12 inches above the pipe combined with high strength in-situ trench walls to accommodate the design loads properly. If the field conditions or embedment materials vary from the design assumptions, then the anticipated structural strength can be compromised.

Corrugated steel conduits also depend heavily on the soil and steel conduit interaction to obtain the structural component and load carrying capability of the installed system. In most CMP installations, a majority of the structural strength of the installed system is provided by the soil interaction component of the installation. Various wall thicknesses and corrugation patterns are available to help the designer accommodate more load in the pipe wall if required in project design requirements.

All pipeline designs must also include a hydraulic analysis. Pipelines must be sized to meet post-construction runoff. It is important to know that published research data on hydraulic efficiency and accepted roughness coefficients combined with an understanding that lab values under ideal circumstances will be much lower than design values. The concrete pipe industry recognizes and promotes a 20 percent to 30 percent increase in the lab-tested value of 0.010 and suggested Manning's roughness coefficient (typically denoted as "n") with a value of 0.012 for storm sewers. Years of field experience and lab work indicates that Manning's "n" values for corrugated metal pipe ranging from 0.022 to 0.024 are reasonable. The use of smooth lined plastic pipe lab values of 0.009 to 0.015 for design applications has been questioned in third-party research papers, including "Installed Condition of HDPE in Kentucky and Ohio" and "Health of Installed HDPE in Texas" by the University of Texas at Arlington.

Installation of RCP, high-density polyethylene pipe (HDPE) and Corrugated Metal Pipe (CMP) must be performed according to the manufacturer's specification and comply with relevant standards (ASTM C 1479 and AASHTO Sect. 27 for RCP, ASTM D 2321 and AASHTO Section 30 of the AASHTO LRFD Bridge Construction Specification for HDPE, and ASTM A 798 and AASHTO Section 26 for CMP). Because flexible (HDPE and corrugated metal) pipe transfers loading to the surrounding support soil, the type of backfill used, the width of the installation trench and the resulting soil strength must be carefully determined, approved and inspected during installation by the specifying engineer. Deflection testing of HDPE and CMP pipelines, usually 30 days after installation, is now required by some state transportation agencies for underground drainage pipe. Mandatory mandrel testing, video inspection and laser deflectometer testing of the interiors of drainage culverts for ovality are becoming standard DOT requirements. In some of the DOT specifications, deflections exceeding 5 to 7.5 constitute structural failure of flexible pipe systems and require removal, reduction in payment to the installer, or some type of permanent remediation or ongoing monitoring. The current AASHTO specifications mentioned above contain very specific language about allowable deflections and remedial actions required for the various piping products. Current research by Professor Ali Abolmaali, University of Texas at Arlington, from field laser testing of HDPE pipelines indicates that certain plastic pipe installations may result in failed ovality tests if proper installation is not performed. Reinforced concrete pipe is less dependant on soil support; however, in critical installations some DOTs require video inspection for excessive cracking or possible joint separation to confirm proper installation procedures have been successfully completed.

To assure successful completion of proper pipe selection, the design professional must prepare a complete set of contract documents. A combination of specifications, plans and standard installation details to match design parameters and geotechnical information complements proper pipe material selection and clearly defines the installation requirements of a pipe product.

A good starting point to develop proper pipe specifications is a review and in-depth understanding of current and accepted national standards. ASTM and AASHTO standards are based upon research, field experience, test projects, and debate and input from all stakeholders.

Proper installation details for any pipe product should be clear, constructible, technically correct and without contradiction to written project specifications that are also technically correct. To develop installation details, the designer must completely understand what the field conditions will be when the product is being installed, or make proper judgments based upon experience that will be conservative enough in approach and design as to safely overcome any field condition or installation shortcomings. Concrete pipe can compensate for some inadequacies in bedding and backfill, and even trench wall conditions.

Recent publications by Professor Pat Galloway, P.E., provide sobering information on the engineer's liability in specifying materials for pipe installations. In general, the engineer's liability is greater when selecting HDPE conduit, because ASTM D2321 indicates that the engineer is responsible for ensuring proper backfill and pipe installation. Unless the installing contractor has an established reputation for following recommended installation procedures for plastic pipe, the engineer, if not present during construction, may face liability. Because reinforced concrete pipe is installed as a structural element, contractor installation and soil conditions are not as critical as they are for HDPE conduit installations.

Safety and security are paramount to a professional engineer. Engineers must ensure, through specifications and other design guidelines, that projects are designed and constructed in a way that protects the safety and security of contractors and the public. Design engineers consider the following when specifying pipeline products and materials for safety and security:

- flammability of the plastic pipes that could lead to failures and road closures (RCP does not burn)
- oxidation of flexible pipeline products that could lead to failures and road closures
- damage to pipelines by construction equipment and installation methods
- premature and unexpected catastrophic structural failures of pipelines
- use of products with lowest risk of failure in critical high-volume roadways and/or evacuation routes
- vandalism of flexible pipelines that affects performance and/or could cause roadway closures

When evaluating the bidding practices to be used on a project, the engineer must consider economics. An economic analysis is much more than comparing historical unit bid costs. Specifiers often select drainage systems b ased solely on initial or capital costs. Lower initial costs, however, do not always result in the most economical storm sewer. A life-cycle cost analysis of the pipeline for each of the materials being considered can be included in the bid to compare overall lifetime cost of a project in today's dollars.

Many local and state governments are increasingly including some type of analysis in their material selection processes. The importance of considering the future of a facility during the design phase has been made clear by the multitude of problems many authorities are facing as our infrastructure deteriorates.

The additional maintenance costs, replacement cost and cost for detours, traffic delays, and social and economic costs for one replacement of an inferior product will far exceed any first-cost savings over a product that does not require replacement during the intended service life.

What is the cost if there is a structural failure of an installed pipeline? If a pipeline fails, there may be upstream flooding, property damage and possibly personal injury. It is obvious that unanticipated failures can have significant economic impacts, but these situations can also have various serious social impacts as well. Lowered expectations and less respect for the civil engineering profession are included in the social costs that should be of great concern to all engineers and designers.

Reinforced concrete pipe is the only pipe product that utilizes local raw materials. It is manufactured and transported by people that most likely live and pay taxes in the community served by the concrete pipe facility. Incomes generated by a concrete pipe facility tend to support other community services and businesses that benefit from the overall legacy of high-performance local storm sewers. The economic health of a community is an important and correct consideration that engineers and designers must weigh when specifying storm sewer materials and products.

Professional engineers must completely build a knowledge base to make sound design decisions and prepare complete specifications and standard installation details for all piping products. Firsthand field experience and observations can be reinforced only with a complete understanding of the body of knowledge published about all pipe materials available for storm sewers. Experience and knowledge can be strengthened by observing contractors installing various products and materials and how those products react to field conditions and installation techniques. Engineers should evaluate the durability and service conditions of various storm sewers after they have been in use for 10, 20 or even 50 or more years. Only by visiting pipe production facilities can designers and specifiers see how products are manufactured and how vigorously the producer verifies the quality of the finished product.

If you are part of the design and specifying community, we encourage you to research and fully understand the differences between pipe products. Apply your training, knowledge and best judgment to protect the public, your firm, the civil engineering profession and personal reputation when selecting storm sewer products and materials.

The legacy of the civil engineering profession for high-performance storm sewers should be an "A" on our nation's pipeline infrastructure report card. Future generations deserve the best effort by today's civil engineers so that they are not burdened with the cost of our country's current appetite for fast, easy and cheap goods and services. It is the duty of our consulting engineers and the engineers serving our municipalities and state governments to provide the strongest, longest-lasting and most cost-effective infrastructure in the world.

Al Hogan, P.E., is Eastern Region engineer with the American Concrete Pipe Association.