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American Concrete Pipe Association, Irving, Texas 75063-2595, USA

Competitive product analysis to discover fundamental differences between pipe materials that strengthen specifications for concrete pipe

Over the 170-year plus history of the American concrete pipe industry, precast concrete pipe products have not been the only choice for specifiers. Alternative materials have ranged from wood to clay to steel and thermoplastics and now there are composites. However, there has never been a time as there is now when there have been as many choices of alternative materials for pipeline systems and culverts. In addition, while choices are being made, new materials are being introduced to the marketplace. The traditional and new competitive materials are flexible pipe commodities that are mass produced and sold directly from the source, or through a national network of distributors. Concrete pipe, on the other hand, is an engineered product available only from the concrete pipe production facility.

■ Kim Spahn, P.E.,
American Concrete Pipe Association, USA ■

The concrete pipe industry primarily competes with corrugated metal pipe (CMP), high density polyethylene (HDPE) and polyvinyl chloride (PVC). The new flood of competitors includes ribbed PVC, triple wall polypropylene, steel reinforced polyethylene (SRPE), and fiberglass. Clay pipe is still used for sanitary sewers in some states, but wood pipes are now relegated to history. To complicate the competitive environment, market forces and trade agreements are permitting concrete pipe and flexible products from other countries to enter the U.S. market. The concrete pipe industry prepared for the onslaught of new competitive

pipeline and culvert materials through the 1980s, 90s and early 21st century. Concrete pipe producers introduced new concrete pipe designs and took the production and quality of concrete pipe to new heights through education/certification of industry personnel, research, new product development, and the rebuild of plants with the option of totally robotic facilities.

Rigid and flexible pipe are not the same

With all these choices of materials and products for pipelines and culverts, it is now imperative that designers and specifiers know how drainage pipe materials perform over the design life of a project. To manage their professional liability, they must under-



■ Kim Spahn, P.E., American Concrete Pipe Association/Castle Rock, CO. Kim is the Director of Engineering Services for the American Concrete Pipe Association. She is a registered professional engineer in the state of Texas, and now resides in Denver, CO.

After graduation from the University of Texas at Arlington in 2002 with a Bachelor of Science in Civil Engineering, Kim worked as a hydraulic and structural engineer for Nathan Maier Engineers and HKS, Inc. Kim@concrete-pipe.org

stand how materials interact in sewer systems that may be comprised of, among other things, multiple product materials including pipes, manholes, catch basins, stormwater detention and retention systems, and treatment devices. All pipelines and culverts must function as a conduit and a structure, and there are fundamental differences between units of rigid and flexible pipe (Figure 1). This tenet is the start-point for any pipeline and culvert designer and/or specifier.

Another consideration by many as a start-point, or certainly to be considered with the type of installation (rigid vs. flexible), is the cost of the pipeline. Here, specifiers undertake a Least Cost Analysis (LCA). The cost, however, must be analyzed over the life-time (design life) of a project and should include initial, maintenance, rehabilitation, direct and indirect replacement. In addition, there are tangible factors such as planning, specifications, hydrology, hydraulics, structures, installation, durability and economics. Intangible costs include travel delay; loss of business due to road blocks and detours; political implications; and the owner's liability. Calculations of an LCA account for

	Rigid vs. Flexible Material			
	Precast Concrete Pipe	CMP & Spiral Rib	HDPE	PVC
Applicable Material Specifications	ASTM Reinforced Pipe C 14, C 305, Reinforced Pipe C 19, C 305, Arch Pipe C 306, Structural Pipe C 307, AASHTO M28, M176, M205, M207, M242, M243	ASTM Manufacture A 750 (open), A 762 (solid), B 743 (solid), Design A 756 (open), B 756 (solid), AASHTO M28, M216, M218, M245, M246, M274, Reinforced M207, M207, M208	Manufacture AASHTO M284, ASTM F 2308, Cast Classification ASTM F 2308, HDPE ASTM F 2136, SRPE ASTM F 2412	ASTM - Manufacture C 3034 (4" to 10"), F 876 (10" to 36"), F 883, Cast Classification D 1744, Strength D 2412, AASHTO - M284, M276, M264
Significant Material Requirements	Composed of cement, aggregate, and water in exact blend with rational and total cementitious, approved supplier's data, and admixtures	Sheet thickness (gauge) adequate for structure and durability needs. Coating thickness and integrity affect manufacture and handling.	High strength should be used. Cell class 40500-C. Material must have ability to withstand stress loading.	HDPE resin/blend. Minimum cell class 12500 or 12618
Hydraulics	Laboratory values for Manning's "n" of 0.015. Reinforced design value 0.012. Lower design value coefficient because of pipe bell which can result in smaller diameter compared to alternate materials in subsequent cast and situations.	Low Manning's "n" for open rib = 0.015. Coagulated = 0.022 to 0.028. Reinforced design value for open rib = 0.018. Coagulated 2.20' x 12" = 0.022 to 0.027. 3' x 11" = 0.027 to 0.028. 5' x 11" = 0.028 to 0.028.	Laboratory values for Manning's "n" of 0.010 - 0.015. Reinforced pipe has shown values of 0.010 to 0.021. Lower Manning is assumed in AASHTO design. Design "n" value = 0.012 - 0.016 (usually higher, varies with ID and corrugation) growth of liner from loading. Manning's formula calculations should reflect that the lower ID (minimum) is used and to use the lower Manning ID.	Laboratory values for Manning's "n" of 0.016. Recommended design value 0.016. Manning's formula calculations should reflect that the pipe will have less than nominal ID.
Required Pipe Strength or Pipe Stiffness	Calculate load on pipe by determining dead load, live load and loading factor. Then determine the required pipe strength.	Requires support of soil envelope. Pipe stiffness determined by gauge thickness, material type, and corrugation profile. Modified Iowa Formula address deflection and relationship of structural soil support and flow around.	AASHTO LRFD Bridge Specs., Section 12. Pipe stiffness decreases with increase in diameter (1/3 of 10' pipe = 42. FIB. of 48' pipe = 18).	AASHTO LRFD Bridge Specs., Section 12. Minimum pipe stiffness = 90.
Applicable Material Specifications	ASTM C 1479, AASHTO Highway Bridge Specifications (Section 21), AASHTO 12.	ASTM A 750 (open), A 756 (solid), AASHTO Highway Bridge Specifications (Section 26)	ASTM D 2221, AASHTO Highway Bridge Specifications (Section 30)	ASTM D 2221, AASHTO Highway Bridge Specifications (Section 30)
Soil Stiffness	E is not a factor in the design of rigid culverts.	Modified Iowa Formula determines theoretical deflection. Pipe parameters and soil stiffness increase.	Soil stiffness relative to pipe stiffness is critical. Min. E = 4000.	Soil stiffness relative to pipe stiffness is critical. Min. E = 4000.
Soilfit	Compared to required density up to 10% to 12% above top of pipe. Critical only up to springs from installation - native soil with little or no compaction.	Compared to required density in 10' to 12' lbs to 12' above top of pipe. Material should be granular with little or no plasticity. "Trash" Min. 2" each side of pipe. Compaction. Min. soil disturbance each side of pipe.	Compared to required density in 10' lbs to 12' above top of pipe. Removal of trash less must allow measurement of compacted material. Usually requires select material.	Compared to required density in 10' lbs to 12' above top of pipe. Removal of trash less must allow measurement of compacted material. Usually requires select material.
Installation Testing	Visual inspection for alignment and grade. Deflection not significant. Less sensitive to installation.	Installation sensitive. Check for alignment and grade. Deflection should be less than 1%.	Check for alignment and grade. Deflection should be less than 1% certified value (D). Require laser profile or measured bed. Pipe performance determined by soil envelope and installation. Deflection (curve) continues at reduced rates over long term.	Check for alignment and grade. Deflection should be less than 1% certified value (D). Require laser profile or measured bed. Pipe performance determined by soil envelope and installation. Deflection (curve) continues at reduced rates over long term.
Service Life - Life Cycle Cost Analysis	100 years or more common. Longer life and no expected replacement costs.	Max. 50 years with coatings under favorable conditions. Shorter life = higher replacement costs.	Not known - anticipated. Shorter life = higher replacement costs.	Not known - anticipated. HDPE rated pipe - max. 50 years. Shorter life = higher replacement costs.
Corrosion Resistance	Generally not applicable unless installation is in an extremely "hot" soils with acid or high potential of sulfides in replacement location, which can be countermeasured with changes in mix design, leach-in, etc.	Low pH soils and resistance of 2,000 - 10,000 ppm on soil contact. Damaged coating allows water to oxidize replacement location. Min. thickness galvanized and aluminum and other coatings especially susceptible to leach load erosion.	Low susceptibility to corrosion. Interaction of stress and environment is determinant of durability to some extent. In common materials such as strong oxidizing acids, alkali, other reagents such as detergents, volatile acids, sulfides and organics can cause surface corrosion. Some materials have excellent stress resistance.	Low susceptibility to corrosion. Interaction of stress and environment is determinant of durability to some extent. In common materials such as alkalis, ketones, amines and chlorinated hydrocarbons, and volatile acid environments to better test they also accelerated stress resistance.
Permeability	Not applicable. Non-combustible. Structural integrity not affected.	Not generally applicable. Coatings may be permeable.	Permeable and self-sealing. Once burning, does not lose structural soil source. Smith test forms when burning.	Permeable. Needs external fuel source. Smith test forms when burning.
Flexibility	Results depending forces level of all products. Specific gravity = 2.40.	Pipe is lighter than the nominal weight if designed. Specific gravity can affect live and dead load.	Specific gravity of material is 0.91 - 0.96 (less than water). Specific gravity will affect live and dead load.	Specific gravity of material is 1.4. Buoyancy force will affect live and dead load.
Manufacturing Considerations	Proven record of pipe from construction equipment. Causes proper installation of joint material.	Pipe is lighter than the nominal weight if designed. Specific gravity can affect live and dead load. Best practices may damage coating and accelerate deterioration.	Subjective to different manufacturers. Collection of statistics. Very flexible in reaction to other "flexible" pipe. High % of strength obtained from soil envelope.	Other than manufacturer of joints and structures, force % of strength obtained from soil envelope.

www.concrete-pipe.org/brochures/Rigid-vs.-flexible-material.pdf

future costs, considering present value, replacement costs, inflation, residual value, maintenance, rehabilitation and user delay. For each material, system or structure, the LCA method determines the present value or the total initial and future costs deducted back to today's value to give a pipeline designer or specifier a true picture of the product that is the most economical over the life span of a project.

Least Cost Analysis can be described by the following equation:
LCA = Initial Cost + Present Value of Future Costs (Replacement + Rehabilitation + Maintenance - Residual Value + User Delay)

With rigid pipe, up to 85% of the structure is delivered to the job site leaving the remaining 15% of the strength to come from the soil support once the product is installed. A flexible pipe system on the other hand, relies on up to 85% of its structural strength to come from the soil structure that is built in the field around the pipe. Although a rigid pipe might have a greater capital cost, the final costs of a proper installation are similar. Often, a concrete pipeline has a lower installed cost. And, it is proven that concrete pipelines last much longer with little maintenance. Figure 2 is a cost analysis of the pipe envelope comparing a rigid and flexible pipe installation showing similar installation costs.

The project design life is normally set by the owner or an authority responsible for the project and varies according to the system classification, end use, and location. Where a roadway or facility cannot be disrupted to replace the pipe, a project design life of 100 years or greater is warranted. Material service life factors include fabrication, durability, and installation. The 3-edge-bearing test in concrete pipe plants ensures that the concrete pipe will perform as expected. Flexible products and rigid products do not share the same durability properties. The U.S. Army Corps of Engineers (USACE) agrees that the product service life for concrete pipe is between 70 and 100 years. The service life of steel, aluminum, and plastic (flexible) is 50 years in most environments when properly installed. The concrete pipe industry considers the USACE estimate as conservative and is confident that properly installed concrete pipelines and culverts will function as designed for much longer than 100 years.

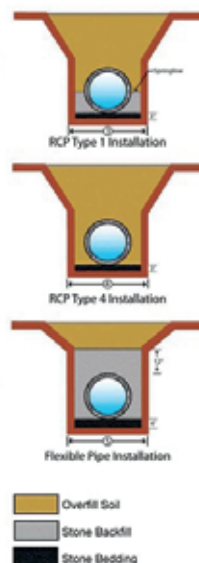
Measuring the performance and value of competitive products before specifying pipeline and culvert material is critical to building resilient sewer systems and culverts. John Ruskin (1819-1900), renowned English critic, social commentator, and economist of the Victorian Age got it right when considering products and services competing for the same consumer:

“It is unwise to pay too much, but it is worse to pay too little. When you pay too much, you lose a little money. When you pay too little, you sometimes lose everything, because the thing you bought was incapable of doing the thing it was bought to do. The common law of business balance prohibits paying a little and getting a lot-it can't be done. If you deal with the lowest bidder, it is well to add something for the risk you run. And, if you do that, you will have enough to pay for something better.”

Figure 2 C.A.P.E. (Cost Analysis of Pipe Envelope) Comparison Between Installed RCP and Flexible Pipe

Installation Type	Pipe Diameter	Stone Volume FT ³ /LF	Stone Cost \$/LF	Installation Type	Pipe Diameter	Stone Volume FT ³ /LF	Stone Cost \$/LF
RCP Type 4	12"	0.58	\$0.55	RCP Type 4	42"	1.35	\$1.27
RCP Type 1	12"	1.25	\$1.17	RCP Type 1	42"	3.83	\$3.59
Flexible Pipe	12"	4.44	\$4.17	Flexible Pipe	42"	12.18	\$11.42
RCP Type 4	18"	0.73	\$0.68	RCP Type 4	48"	1.54	\$1.45
RCP Type 1	18"	1.69	\$1.58	RCP Type 1	48"	4.79	\$4.47
Flexible Pipe	18"	5.81	\$5.44	Flexible Pipe	48"	14.67	\$13.75
RCP Type 4	24"	0.88	\$0.82	RCP Type 4	54"	1.73	\$1.62
RCP Type 1	24"	3.13	\$1.99	RCP Type 1	54"	5.79	\$6.43
Flexible Pipe	24"	7.17	\$6.72	Flexible Pipe	54"	17.35	\$16.26
RCP Type 4	30"	1.02	\$0.96	RCP Type 4	60"	1.92	\$1.80
RCP Type 1	30"	2.56	\$2.40	RCP Type 1	60"	6.92	\$6.48
Flexible Pipe	30"	6.53	\$7.99	Flexible Pipe	60"	25.22	\$18.95
RCP Type 4	36"	1.17	\$1.09	RCP Type 4	66"	2.15	\$1.97
RCP Type 1	36"	3.00	\$2.81	RCP Type 1	66"	8.14	\$7.63
Flexible Pipe	36"	9.89	\$9.27	Flexible Pipe	66"	23.29	\$21.84

- Notes:**
- ① Stone cost is based on \$15 per ton in place.
 - ② Stone unit weight is 125 pounds per cubic foot in place.
 - ③ Per AASHTO, the trench width for Type I, II and III installations are as follows:
 D_o + 12" for RCP 36" diameter or less
 D_o + 1/2D on either side of the pipe for RCP greater than 36" diameter
 - ④ Per AASHTO, Type IV installations have no minimum trench width.
 The above criteria in Note ③ will be used for these pipe envelope calculations.
 - ⑤ Per AASHTO the following trench widths are required for plastic pipe with less than 10' of cover:
 D_o + 18" for plastic pipe 30" Diameter or less.
 D_o + 1/2D on either side of the pipe for plastic pipe greater than 30" diameter.



FURTHER INFORMATION



American Concrete Pipe Association
 8445 Freeport Parkway, Suite 350
 Irving, Texas 75063-2595, USA
 T +1.972.5067216
 F +1.972.5067682
info@concrete-pipe.org
www.concrete-pipe.org