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Pressure pipe 101

A (re)introduction to prestressed and bar-wrapped concrete cylinder pipe for pressurized applications.

By Rick Deremiah, PE

Road and bridge engineers have long relied on the tensile strength of steel to complement concrete's significant compressive strength and thereby increase an asset's overall durability. The same principle — reinforcing concrete with steel to increase structural flexibility — has been deployed in the water and sewer industries for almost the same amount of time in the form of concrete pressure pipe (CPP).

This gives concrete pressure pipe one of the longest performance histories and lowest failure rates of any pipe material. Concrete pressure pipe is highly customizable (see chart below), enabling engineers to tackle tight spaces, long stretches of hilly terrain, and precise sequencing requirements without special bedding and backfill procedures. Operators like the pipe as it requires little maintenance over 70-, 80-, and even 90-year-or-more time spans. The pipe is available as:

- Two types of prestressed concrete cylinder pipe (PCCP) — L-301 and E-301. Manufacturing begins with a steel cylinder with steel joint rings attached. Concrete is placed inside or around the steel cylinder and allowed to cure. The pipe is then circumferentially prestressed by helically wrapping high-tensile-strength steel wire around a concrete-lined steel cylinder (L-301) or a concrete core containing the steel cylinder (E-301). The wire wrap places the steel cylinder and concrete core in a state of circumferential compression, allowing the pipe to withstand hydrostatic pressure and external loads. The high compressive strength of concrete and the high tensile strength of steel combine to form a robust structure capable of withstanding a wide range of loading conditions.

The steel components are electrochemically protected from corrosion by a high-pH portland cement mortar coating.

- Bar-wrapped concrete cylinder pipe (BWP), B-303. The stiffest and strongest of the commonly specified semi-rigid water pipes, B-303 is made using a welded steel cylinder with sized, welded-steel joint rings attached.

Water Transmission

Who: Canyon Regional Water Authority, New Braunfels, Texas Engineer: River City Engineering, New Braunfels Contractor: Mountain Cascade Inc., Mansfield, Texas Material: B-303 bar-wrapped concrete cylinder pipe

The steel cylinder is lined with centrifugally applied mortar or concrete. Mild steel reinforcing bar is helically wound around the outside of the cylinder under controlled spacing and tied off to the steel joint rings. Lastly, a coating of dense portland cement mortar is applied to the pipe exterior for both physical and corrosion protection.

B-303 allows for easy modifications — adding an outlet, making service taps, and performing simple repairs — in the field.

Canyon Regional Water Authority managers specified 46,000 feet of 30-inch B-303 bar-wrapped concrete cylinder pipe to connect two pipelines because an existing concrete pressure pipeline has performed well over time. Customized fittings accommodated the service area's hilly, sometimes steep, terrain. Introduced in 1973 by one of Hanson Pressure Pipe's legacy companies, Snap Ring restrained joints eliminated the need for field-welding during installation.

CONCRETE PRESSURE PIPE BASICS

	B-303, Bar-wrapped concrete cylinder pipe	L-301, Prestressed concrete lined cylinder pipe	E-301, Prestressed concrete embedded cylinder pipe
Diameter (inches)	10-72	16-48	54-144
Length (feet)	20-35	16-32	12-24
AWWA Manufacturing Standard	C303	C301	C301
AWWA Design Method	M9	C304	C304
Design Basis	Semi-Rigid	Rigid	Rigid
Lining	Mortar/Concrete	Concrete	Concrete
Coating	Mortar	Mortar	Mortar
Joint	Rubber gasket with steel joint rings	Rubber gasket with steel joint rings	Rubber gasket with steel joint rings
Applications	Water transmission mains, distribution feeder mains, treatment plants, intake and discharge lines, plant piping	Water distribution and transmission lines, wastewater lines, treatment plant process lines, industrial process piping	Water distribution and transmission lines, wastewater lines, treatment plant process lines, industrial process piping, power plant cooling water systems

Hanson Pressure Pipe

How to assess risk

Utilized for water/wastewater applications in 90 of North America's 100 largest metropolitan areas, concrete pressure pipe has one of the lowest rates of failure when compared to other pipe products.

In fact, at last year's American Society of Civil Engineers Pipelines Conference, researchers shared their analysis of 10 years of performance data. Their technical paper reported that, based on the electromagnetic and acoustic inspections of 118,808 pipe sections (about 2.1 million feet), only 3.9% had electromagnetic signatures consistent with prestressing wire break damage. The rest, according to "Numbers Don't Lie: PCCP Performance and Deterioration Based on a Statistical Review of a Decade of Condition Assessment Data," were in "like new" condition.

System and Plant Expansion

Who: City of Bloomington, Ind., Utilities Department Contractor, water transmission main: Howell Contractors Inc.; Fort Wright, Ky. Contractor, treatment plant upgrade: F.A. Wilhelm Construction Co.; Indianapolis Material: L-301 prestressed concrete cylinder pipe (PCCP)

The Southeast Water System Improvement project expanded treatment capacity from 24 mgd to 30 mgd by adding 2 million gallons of storage; a 12 mgd booster station with expansion slots; and 44,000 linear feet of 24- and 36-inch L-301 prestressed concrete lined cylinder pipe (PCCP). The new water main from the plant parallels a 36-inch pipeline along a ridgeline for about half its length before diverging. Bloomington, Ind., Utilities Department managers chose prestressed concrete because it was cost competitive with the other material they were considering, ductile iron, and historical precedence: The existing 36-inch concrete pressure pipeline has provided uninterrupted service since

Still, some city engineers have concerns about the material stemming from a few high-profile failures of Interpace Corp. product, installed primarily in the East, as well as other failures occurring in the West and other parts of the country. These were caused by the effects of aggressive corrosive soils during the 1970s.

Investigations of the Interpace pipe revealed that a significant majority was made with faulty Class IV prestressing wire and Grade E cold-rolled steel cylinders. The industry learned a significant amount from the forensic investigations of these failures and, as a result, the American Water Works Association (AWWA) standard governing the pipe's manufacture was significantly improved. A new design standard takes advantage of computerized finite element analysis techniques and up-to-date mechanical characteristics of the constituent materials. Another positive result has been the introduction of condition assessment for PCCP, making it the only pipe material that can be accurately assessed.

Though Interpace is no longer in business, utilities with the defective pipe are successfully managing those lines by assessing and analyzing the pipe and repairing or replacing sections as needed.

Before signing on for an assessment, it's important to do a little research and ask a few questions with the help of any concrete pressure pipe manufacturer.

1967.

- Pipe history. Who manufactured the pipe? What type of pipe was used? What type of soils is it buried in and how corrosive? How was the system designed and how is it being operated? This will determine if the pipe was produced by Interpace, how well the pipeline was engineered, etc.
- Performance history. If there haven't been problems with the line since installation, there may be no reason to conduct a full-blown assessment. Regular visual inspections and maintenance may be sufficient.
- Cause of failure. Forensic investigation can help determine what caused the initial penetration that led to failure. In many cases, investigators have found one-off culprits such as directional drilling impacts on the pipe or having been installed directly onto rocks in the bedding. If failure has been caused by such isolated, man-made incidents, a full system assessment may not be necessary. However, if the failure resulted from corrosion (rare) or from defective wire (Interpace), it's a good idea to conduct a broader investigation of the system.

10 ways to ensure longevity

For new lines, longevity relies on proper handling and installation. Though the pipes are durable, damage during installation can lead to problems down the road. To ensure pipes reach their maximum life span, project managers should:

- Hire contractors who are familiar with the material and who will adhere to manufacturer installation recommendations.
- Employ properly trained inspectors to ensure the pipe is installed in the field according to applicable standards, project specifications, and with the manufacturers' recommendations.
- Provide proper training on pipe characteristics and installation, particularly for contractors who've never worked with concrete pressure pipe or larger sizes.
- Provide clear instructions/expectations for pipe handling, offloading, storage, slinging, and placing in the trench; bedding details including type and compaction; how joints go together; and how errors are to be reported.
- Understand the soil. Make sure it's free of rocks and debris, and analyze existing soil to determine suitability for backfill.
- Mix the joint grout properly. Grout is poured into fabric bands around the joints, providing corrosion protection to exposed portions of the steel joint rings. Follow manufacturer recommendations for the proportions of portland cement to sand; don't skimp to save costs.
- Inspect pipes upon delivery to ensure there was no damage in transit. Inspect again after installation, ensuring there was no damage from handling equipment and that there are no protruding rocks, organic material, or debris in the trench.
- Conduct daily on-site inspections during construction to ensure construction managers and/or contractors are following bedding, joint grout mixing, damage reporting, and other installation best practice procedures.
- Mark line locations at least every 100 feet to ensure they aren't impacted after burial by other contractors.
- Once the pipeline is in operation, monitor nearby construction activity to ensure directional drilling or excavation work doesn't impact or damage the pipes' protective coatings.

Sewage Tunnel

Who: Milwaukee Metropolitan Sewerage District
Contractors: J.F. Shea Construction Inc., Kenny Construction Co., Northbrook, Ill. Material: L-301 and E-301 prestressed concrete cylinder pipe (PCCP)

The Milwaukee Metropolitan Sewerage District implemented the Harbor Siphons project so wastewater diverted to a deep tunnel system could be directly transferred to the Jones Island Wastewater Treatment Plant. Crews drove shafts 300 feet deep into the harbor connecting to Lake Michigan, tunneled under the riverbed and an island and then back up into the plant. In addition to L-301 and E-301 prestressed concrete pressure pipe (PCCP) in seven sizes ranging from 42 inches to 96 inches, the shafts and tunnels required custom-designed fittings, mechanically restrained dual rubber O-rings that allow joints to be air-tested immediately after installation, and specially designed lifting lugs.

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