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Inside Manufacturing: CIPP Lights Way in Buried Pipe Repair

Spiral-wound, UV-curable fiberglass CIPP bests competitors and bears loads in "trenchless" wastewater pipe rehabilitation project.

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When the city of Amarillo, Texas, needed to repair more than 400 ft/122m of corroded 24-inch diameter iron wastewater pipes buried beneath a busy four-lane highway, it faced a dilemma. Corrosion was severe — the major culprit was hydrogen sulfide (H2S) — and evidence of soil intrusion had been found in the pipes, which carry sewage away from Amarillo's hospital district. Excavation and replacement of the two pipes — a 330-ft/100.6m section and a 79-ft/24m section, that were buried, respectively, at depths of 18 ft/5.5m and 14 ft/4.3m — would be prohibitively expensive and disrupt highway traffic for a prolonged period. However, there was some question about whether the "trenchless" alternative, a composite cured-in-place pipe (CIPP), could produce a solution sufficient to the task.

Click Image to Enlarge

Source: Reline America Reline America uses a patented spiral winding system to produce structural fiberglass composite sleeves for UV cured-in-place pipe installations.

MORE THAN A LINER

For the underground construction industry, CIPP liners have become a welcome pipe rehabilitation alternative. When the CIPP approach is used, the damaged pipe remains in place, but it is lined and sealed by a mating inner pipe sleeve that is inserted into the "host" pipe. The insertion procedure requires only small excavations or manhole access at each end of the pipe's damaged length, which, for the Amarillo project, would make repair possible with little disruption of traffic.

The most common form of CIPP, however, is a tubular sleeve of thermoset resin-saturated fabric (typically a nonwoven polyester felt) with an inner polyethylene liner. Typically manufactured inside (liner) out and then inverted during installation as water pushes the tube through the damaged pipeline, the sleeve is cured by sealing the tube at both ends and pumping hot water or steam into the tube to inflate it and cure the resin.

In the case of the Amarillo pipe repair, however, this construction was judged to be inadequate to the task. “The corrosion was so bad that in multiple areas of the pipe, only a dirt tunnel remained,” says Seth Martin, product engineer for CIPP manufacturer Reline America (Saltville, Va.). “In cases where there is a hole behind the damaged pipe, or a section of missing pipe, some liners will expand, or balloon, into that extra space.”

STRUCTURAL COMFORT ZONE

Reline America’s Blue-Tek CIPP sleeve, however, proved to be the exception. According to Martin, Reline’s was the only CIPP product that the City of Amarillo was comfortable using on this project due to its high structural properties. “Our liner won’t balloon,” says Martin. “It was literally installed as a standalone product, designed to receive the full structural load.”

Developed by Brandenburger GmbH (Landau, Pfatz, Germany) in the 1990s, Blue-Tek technology and its North American marketing rights were licensed to Reline in 2005. The sleeves are structural composites, reinforced with spiral-wound, continuous glass fibers. Martin says the sleeves incorporate a proprietary “unique fiber architecture that was developed through extensive testing.” Strength values for the liner exceed the minimums defined in ASTM 1216, the current standard for inverted, hot-water/steam-cured CIPP. “In fact,” he claims, “the normal strength is five times the minimum strengths specified.”

According to third-party tests conducted in the U.S. and Europe by independent laboratories, notably Polymer Solutions (Blacksburg, Va.) and the Institute for Underground Infrastructure a/k/a IKT Laboratories (Exterbruch, Germany), the liner can be designed with a short-term modulus of elasticity (E-modulus) of 1.1 million lb/in^2 to 2.1 million lb/in^2. The reduction factor (determined by a 10,000-hour creep test) can range from 1.3 to 1.6, which means 77 to 62 percent of the initial E-modulus strength is expected to be retained during 50 years of service.

Further, the resins in Blue-Tek liners are cured using ultraviolet (UV) light. Unlike conventional liners, which are formulated at the factory with heat-triggered catalysts, UV-curable liners need no refrigeration to prevent premature crosslinking and exotherm cure before installation. Blue-Tek liners have a six-month shelf life, during which they need only to be sealed in light-tight packaging to prevent exposure to sunlight. UV curing also eliminates problems associated with disposal of styrenated water after heat cure. According to Reline, a number of UV-curable formulations of vinyl ester and polyester (orthopolyester, isopolyester and NPG) from various suppliers have been approved for use with Reline’s resin formulation and process.

PIPE SLEEVES MADE TO ORDER

Reline America uses in-house-developed algorithms to design each CIPP sleeve. Selection of resin type, reinforcement fiber, fiber architecture and fiber volume vary according to customer needs and the liner design. For the

Amarillo project, Reline used neopentyl glycol (NPG) orthopolyester resin — with a pH of 1-9 to resist H_2S and other chemicals in the sewage flow media — formulated with a UV photo-initiator from DSM Composite Resins AG (Schaffhausen, Switzerland) and a fiberglass mat from P-D Glasseiden GmbH Oschatz (Oschatz, Germany), which is made with chemical-resistant Advantex glass fiber procured from Owens Corning Composite Solutions LLC in Toledo, Ohio (formerly Saint-Gobain Technical Fabrics).

The liner was fabricated at Reline's Saltville plant on automated continuous spiral winding equipment, which was built in-house and is computer controlled by in-house software that is preprogrammed for each sleeve, according to customer specifications. Roving and fabric sheets of fiberglass were drawn through a resin bath and then wet wound in a spiral pattern over a film liner on a specially adapted mandrel. The film becomes the inner layer of the CIPP sleeve. As the part is wound, it also is encased with another film that forms the sleeve's outer layer. These inner and outer "multilayer approved styrene barriers" remain in place during storage, transport, installation and the entire cure cycle. The films fully encapsulate the resin-impregnated liner, preventing water or other contaminants from contact with the resin before it is cured. Thus, there is never an opportunity for raw resin to touch the host pipe or to be exposed to any fluid that remains in the pipe. Because the material constituents of the pipe liner are selected for the required corrosion resistance, the inner film is no longer needed after cure and is removed. However, the outer film remains in place as an impermeable barrier between the liner and host pipe.

To ensure a consistent product, resin content (by weight) and viscosity are carefully controlled to ensure consistent wetout, and several internally developed quality-control measures are used to validate that the automated system applies the same quantity of resin to every square inch of liner. "IKT testing verified its nonporous and nonwicking character, two characteristics of a resin-rich surface," says Martin. The two sleeves produced for the Amarillo project have 50 percent fiber volume and an E-modulus of 1.15 million lb/in^2.

As each wound, uncured tube exited the spiral winding process, it was flattened, which is typical of CIPP piping, and then fed onto a conveyor that directed it into a wooden shipping box. (Martin notes that waxed cardboard boxes can be used to ship small liners.) The liner was carefully folded, accordion-style, as it entered the container, a strategy that enables technicians at the job site to extract it easily during installation.

As an additional precaution to prevent premature cure through exposure to sunlight, all containers are lined with an opaque gas-barrier film. "We use a multilayer film that includes a variety of thermoplastics and bonding agents," says Martin. However, Reline maintains that testing has found no detectable levels of volatile organic compound (VOC) emissions from the finished sleeve, largely because the impermeable outer and inner films are effective gas barriers that confine styrene within their boundaries. Additionally, the outer sleeve reduces risk during installation. "If the sleeve needs to be removed," Martin points out, "it can be — one strength our competitors don't have."

INSTALLED, CURED AND DOCUMENTED

The week before the scheduled installation, the City of Amarillo hired a local firm, Amarillo Utility Contractor (AUC), to set up a bypass pumping system, which diverted the wastewater around the damaged portions of the pipes. Preparatory work involved digging access pits for the bypass pumps, installing temporary bypass lines that rerouted the sewage through nearby storm drains that pass under the highway, followed by three days for cleaning the host pipes.

On Sept. 20, 2007, Reline began sleeve installation in the lengthier of the two damaged pipes. Reline's installation crew winched a polyethylene slip sheet through the damaged pipe, providing a smooth surface on the pipe's bottom half that would protect the CIPP sleeve from damage when it was drawn through the host pipe. (It remains in place after the pipe is cured.) With the slip sheet in place, Reline then used a double-capstan, constant tension winch to pull the continuous 330-ft/100.6m long, 0.30-inch/7.7-mm thick sleeve through the host pipe.

When the liner was in position, the ends were plugged, and a blower was used to begin inflating the sleeve at 3.6 psi/0.248 bar. In general, inflation pressure varies from 3 psi to 8 psi (0.207 bar to 0.552 bar), in the lower range for larger diameter pipes and the higher range for those with small diameters.

When the liner was partially inflated, Reline's UV light "train" — a unique wheeled vehicle fitted with nine electrically powered UV bulbs and a rear-mounted closed circuit television (CCTV) camera (see Step 8, p. 2) — was inserted through a special opening in the end plug of the starting manhole. "Reline's light train includes integrated video capabilities, so real-time curing video was captured in the Amarillo installation," Martin confirms.

When sleeve inflation reached the predetermined pressure, a smaller winch (called the "third man") pulled the light train through the uncured sleeve for an inspection tour (UV lamps are not powered), permitting the Reline crew to view, remotely via live-feed video, the condition of the inflated sleeve prior to initiating cure. (Video inspections also are taped.) When the sleeve was seen to be correctly positioned, with no objects having washed accidentally into the pipe, the UV lights were turned on and the light train was pulled back through the liner at speeds that varied from 2 to 3 ft/min (0.61 to 0.91 m/min). Three infrared sensors and one thermocouple recorded the exothermic temperatures on the interior surface of the liner every 30 seconds for the duration of the curing process. The temperature readings were used to gauge cure progress. Blue-Tek installers are trained to evaluate the exothermic temperatures to determine the cure rate. The correct speed then is determined by a chart that shows the acceptable range of curing speed for each of the company's liners, based on its diameter and wall thickness, and the light train's speed is altered accordingly. While the UV bulbs produce some heat, it is the energy they produce in the ultraviolet portion of the light spectrum that triggers the curing process. For the 330-ft/100.6m pipe, cure took about two hours.

Interior air pressure and train travel speed also were recorded along with the liner footage at which each measurement was taken. To document the cure process, all data are recorded on a tamper-proof computer. "The equipment has installed protections that prevent tampering with data," Martin explains. "When a municipality asks if the cure was done correctly, the data is provided, confirming that the installation took place correctly. If an installer is allowed to alter data, then quality control is compromised." Further, the CCTV camera recorded a full video of the liner as it was cured.

When the cure was complete, the end plugs were removed and the light train was manually removed through the manhole. As is Reline's custom, an additional video inspection was performed after lateral connections were reopened and the pipe was again put into service. The company often follows up with another video inspection at the end of the first service year. Samples of the cured sleeves, cut from postcure trimmings, were tested in Reline America's laboratory. (If necessary, Martin notes, Reline's internal testing can be verified by an independent, third-party laboratory.)

The installation of the first Blue-Tek sleeve was completed in a single day, and on the following day, the 79-ft/24m long, 0.28-inch/7-mm thick sleeve was installed in the 14-ft/4.3m deep pipe using the same procedure, except that UV cure speed was maintained at 2 ft/min (0.61 m/min), curing the pipe in just under one hour. AUC then grouted the voids between the two pipes and the highway above it (where soil had washed out into the pipe), a process that was complete by the end of September.

COMING UP UNDERGROUND

Blue-Tek liners have been used in gravity-flow sanitary sewer pipes and stormwater pipes for 15 years and, more recently, pressure pipes up to 360 psi/25 bar to rehabilitate sewer force mains (where sewage must be pumped up from lower to higher elevations). "With this advancement for pressure pipe, Reline expects to launch a product for potable water pipes in the near future," Martin says. "We are currently testing several resin products already approved for potable water for use with our system."

Reline's current liner diameters range from 6 inches to 48 inches (152.4 mm to 1,219.2 mm) and the company expects to have liners available for pipes with diameters as large as 60 inches (1,524 mm) in the near future. Continuous lengths up to 1,000 ft/305m can be installed by standard Blue-Tek procedures and, if necessary, up to 2,000 ft/610m lengths can be custom ordered.

Martin adds that Blue-Tek has been used to repair pipes that are near collapse and pipes with active infiltration. Reline regularly consults with municipalities to help them solve difficult pipe rehabilitation problems. Martin cites a recent project with the City of Cincinnati (Ohio), where a 12-inch/305-mm pipe with 26 percent ovality was modeled to match a laser profile of the actual pipe, and then the model was lined with a Blue-Tek sleeve. (*Ovality* refers to a pipe that is partially collapsed. In this case, the pipe's vertical dimension, in cross-section, was 26 percent smaller than its horizontal measurement.) This modeling simulation provided clear data for the City of Cincinnati to determine whether a Blue-Tek repair could handle the structural load that was collapsing the pipe. "In this case, we demonstrated that a 9.8 mm liner could take the load, even in the nonround shape of the existing pipe," Martin says.

Estimated by Reline as a $2 billion to $5 billion (USD) annual industry, CIPP captured only 1.5 percent of the estimated $31 billion spent for construction and rehabilitation of underground piping infrastructure in 2007. Given that kind of growth potential, Reline expects its structural trenchless repair technology to expand the market for CIPP as it becomes better known and grows in repair footage in the North American underground construction industry.
