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TEST OF STRENGTH

Pipeline rehabilitation passes strain gauge testing after seven years of service

In March 2010, an unusually configured culvert passing under Florida State Route 16 was rehabilitated with a solution called CentriPipe, utilizing PL-8000 fine aggregate composite concrete developed by AP/M Permaform. Florida Department of Transportation (FDOT) has been monitoring the project

closely, with the structural integrity of the rehabilitation of particular interest. PL-8000, whether applied with CentriPipe SpinCaster or in special cases such as the SR 16 project, sprayed onto the internal walls of failing structures, is engineered to provide a structurally sound pipe or culvert, independent of the failing substrate.

The material is a high-strength, high-build, abrasion- and corrosion-resistant fine aggregate concrete based on advanced cements and additives. Graded quartz sands are used to enhance particle packing and further improve fluidity and hardened density. The resultant concrete has thin-section toughness, high modulus of elasticity and self-bonding properties. Fibers are added to aid in the casting process, for increased cohesion and to enhance the flexural strength of the liner. It is a strong material and suitable for sewer and pipe rehabilitation.

"Really, a material like PL-8000 has such amazing properties that engineers are just starting to catch up with its capabilities," said Ed Kampbell, president of Rehabilitation Resource Solutions. Kampbell has been an AP/M Permaform consultant for several years, writing design guides and technical bulletins to help designers understand new cementitious materials. "To really make the most of this new material, we also have to understand the details of culvert rehabilitation. I call them 'buried bridges,' and the SR 16 culvert was a very good application of this concept."

New cast pipes created with this material can be very thin; in this culvert rehabilitation, the total thickness was a 2-in. layer of

new concrete in a failing, 13-ft-diameter, corrugated metal pipe. This thickness was designed and certified by engineers for the rehabilitation, and is conservative given the strength characteristics of the concrete. Still, many designers contemplating trenchless sewer rehabilitation have asked for verification of the real-world structural performance of PL-8000 and the system as a whole. In 2016, after six years in place, the evaluation of the SR 16 culvert proved to be an opportunity to answer these lingering performance questions.

In late 2016, visual inspection and sophisticated strain gauge testing of the Florida SR 16 culvert provided evidence that PL-8000 is a structurally sound and long-lasting rehabilitation technology. After reviewing the report based on strain gauge testing, FDOT District 2 Maintenance Engineer Robert S. Kosoy, P.E., said, "The strain data show that the movements under heavy truck loading were minor and that this 13-ft-diameter corrugated metal pipe, which was lined in 2010, continues to perform well."

A Tricky Rehabilitation

"Just visually, this was a unique culvert, and a uniquely difficult rehabilitation project," said Scott Kelly, Southwest regional manager for AP/M Permaform. "It was a very large diameter—13 ft—bolted multi-plate pipe culvert with very little cover, about a foot at the crown of the roadway and tapering to, literally, just 10 in. from top of pavement to culvert at the edge of a paved two-lane highway. It looked like it was all pipe."

Tropical Storm Faye blew through this region in 2008 and heavy storm flows created a large void on one side of the culvert, which also was visibly rusting and failing. At the time, a regional maintenance manager named Spencer Townsend said, "You could have put a couple of minivans in this hole."

Given the relative thinness of cover and the void, it was clear that any rehabilitation technique used had to have extreme structural strength. This ruled out sliplining and cured-in-place pipe, which also would have been prohibitively expensive at this diameter. To make matters more challenging, FDOT and the affected Florida counties (Clay and Nassau) wanted to keep SR 16 open during rehabilitation, as it is an economically important truck route connection between Interstate 95 and U.S. Highway 301 in the center of the state.

In response to these circumstances, FDOT and Transfield Services (contracted regional maintenance managers) decided on CentriPipe, which would be something of a pilot project in Florida.

"It's a newer application for this type of product," Townsend said in 2010. "PL-8000 is very high strength, and it has an additive that makes it very sticky, so it's perfect for shooting on a pipe."

At the time, the rehabilitation was judged to be a success. The 2-in. layer of PL-8000 was applied onto the bolted metal substrate, partly to ensure a minimum cover of 1 in. over the culvert's protruding bolts. Traffic never stopped, the rehabilitation supported the roadway, and the new concrete culvert had little effect on flow volume due to its thinness and its smoothness compared to the rough corrugated substrate.

Because it was a new technology being used in an extreme situation, FDOT and others were interested in the solution's long-term performance. In 2016, they were able to put that performance to the test.

Evaluation & Testing

"We did an initial walkthrough in January 2016, and it was actually just below freezing, which is unusual here in Florida," Kelly said. "And just visually, the rehabilitated culvert still looked brand new—the condition of the liner was incredible. No fractures, no voids, no visible wear—it was very satisfying."

As an AP/M Permaform representative, Kelly has a professional interest in this particular rehabilitation. "I'm often talking to engineers who buy into the 'thicker is better' school of thought," he said. "This is understandable, but frustrating—with our process, a new concrete lining that looks thin, compared to competing solutions, really is better because it's stronger, performs better structurally and doesn't have a significant impact on culvert flow volumes. The SR 16 culvert project was a really good example of this."

The like-new appearance of the repaired culvert was good evidence in itself—the

absence of fractures from heavy live loads proved that the lining was holding up to traffic loads. Additional independent testing was performed by Resensys LLC, a company that devises sensors and testing protocols to detect strains and stresses in existing infrastructure like bridges and roadways.

"It just made sense," Kelly said. "This particular culvert really is unusual in the amount of force transferred to the new lining, and getting good data on its performance would be very helpful to any agency or engineer working on similar projects."

On Nov. 21, 2016, a Resensys team installed four SenSpot sensors evenly spaced along the 96-ft-long culvert crown (top inner surface), plus a data logger to record data from the sensors.

According to Resensys, "The strain gauges used in wireless SenSpot sensors are foil strain gauge, SGD-30/120-LY40 provided by Omega Eng., where a half-bridge method (two perpendicular gauges) for strain measurement is used. The readings from the gauges are amplified by a zero drift amplifier with a gain=125, and then using a 14-bit analog to digital converter, the strain readings are reported by SenSpot sensor with a resolution of 2 microstrains." Put simply, the SenSpots are sensitive strain gauge sensors, able to measure very subtle deformations in infrastructure when under stress.

On Nov. 22, 2016, the culvert was deliberately subjected to extreme load testing.

"Basically, I arranged for a loaded 18-wheeler, with verified weight of 83,620 lb, to drive over the culvert in both directions, stopping each way with cab axles and then trailer axles directly over the crown of the culvert," he said. Axle alignment was verified visually, with an alignment tool and by monitoring the strain gauges during truck movement. Redundant methods were used to ensure truck weight was placed to have maximum impact.

The sensors showed that the loading effects were negligible.

According to the Resensys report, "During truck tests of Nov. 22, 2016, very little strain change was observed, and as a result, it is logical to assume that the structure can carry load up to (and possibly even larger than) the weight of the truck used when the tests were conducted."

Live load testing also was conducted, with the sensors left in place and data continuously recorded Nov. 22 to Dec. 9.

According to the Resensys report, no strain change was caused by traffic (live load). There was no transient strain change found during the reporting period, implying the structure's safe load carrying capacity under existing traffic conditions. The observation was consistent with the truck test loads conducted on Nov. 22.

"This data validates the use of PL-8000 here and also validates the design methodology used," Kampbell said. "Most engineers would have predicted a lot of give or bending, but that wasn't observed. As applied, the material went into compression, showing that even shallow cover provided a significant amount of support. These are very useful results for engineers working on culvert rehabilitations."

Kelly also believes this is an important finding for sewer network operators and infrastructure agencies. "It really proves the validity of project designs and the performance of PL-8000 and CentriPipe in real-world conditions, even after a service life of nearly seven years. I'm happy to have results like this to share with the conservative, data-driven engineers I talk with every week."

ABOUT THE AUTHOR

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