

Twenty-Two Years of Advancing Research in Underground Infrastructure and Trenchless Technologies: CUIRE's Commitment

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22 years have already passed since the Center for Underground Infrastructure Research and Education (CUIRE) was established. In 2006, the first trenchless technology conference was held at the University of Texas at Arlington (UTA). CUIRE is dedicated to advancing research, development, and training in underground infrastructure technologies, particularly focusing on pipelines. Through collaboration with industry, government agencies, and professional associations, CUIRE ensures its programs are both relevant and impactful, addressing the pressing needs of modern infrastructure. CUIRE is involved in groundbreaking research, with over 16 PhD students actively contributing to its projects.



Recent research endeavors include use of trenchless technologies for comprehensive asset management of culverts and drainage structures, real-time monitoring systems for water assets, and development of innovative pipeline renewal methods. In addition, research efforts include development of polymeric spray applied pipe linings (SAPLs) in high-pressure pipe applications; product evaluations for underground stormwater storage, infiltration chambers, and modules under highway truck loading; and leading a nationwide study to assess innovative technologies for monitoring water assets. These projects not only push the boundaries of current knowledge, but also offer practical solutions to infrastructure challenges faced by communities nationwide.

1 APPLICATION OF SAPL IN PRESSURE PIPE APPLICATIONS

Spray applied pipe lining (SAPL) can address pipe deterioration and prevent failures when designed based on the host pipe condition. Due to its minimum access requirements, this technology is one of the most cost-effective and versatile trenchless pipeline renewal methods. Polymeric SAPL is applied inside a pipe for either corrosion prevention or to enhance the load-bearing capacity of the host pipe by creating a new interactive structure. CUIRE is conducting testing for the application of SAPL in pressure pipe-

lines, process pipelines and industrial applications. The researchers at CUIRE are continuously advancing into developing a testing program to better evaluate the use of SAPL material in pressure pipes based on the different AWWA Structural Classifications.

Material Properties Testing

Material properties testing is required to determine the material's mechanical response under various conditions. This can be useful in designing the liner material for different and challenging applications. The properties of polymeric materials are influenced by time, temperature, and loading rate; therefore, we tested these

properties at short—and long-term time intervals, as well as at different temperatures and loading rates. These tests show the material's response against tensile straining due to excessive or continuous loading, resistance to bending, impact resistance, ground movement, and temperature changes, and shear impact due to sudden loading for shallow-depth pipes. Figure 1 shows a short-term tensile testing, and Figure 2 presents the short-term flexural testing using a universal testing machine.

To effectively improve the consistency of testing results, a comprehensive approach, considering parameters such as spraying techniques, specimen location,

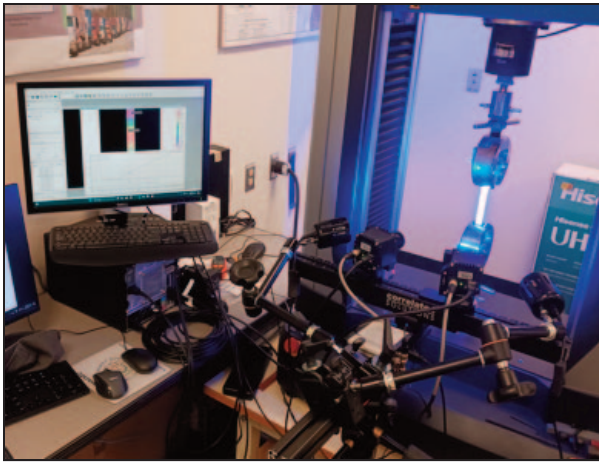


Figure 1: Short-term Tensile Testing Figure



Figure 2: Short-term Flexural Testing

These projects offer practical solutions to infrastructure challenges

and cutting and spraying conditions, was carefully considered while preparing samples. The material properties obtained from the testing results were used to design the full-scale laboratory testing for Class II, Class III, and Class IV as per AWWA Structural Lining Classification System.

Full Scale Laboratory Testing for the Application of SAPL in Pressure Pipes

A short-term hole-spanning testing was performed by researchers at CUIRE for a 30-inch diameter host pipe with hole-spanning sizes of 0.5, 1, 2, 4, and 6 inches. The pipe samples with 0.5, 1 and 2-inch hole spanning sizes were lined with pure polyurea elastomeric material, and the lining system passed 500 psi pressure without failure. The 4 and 6-inch hole-spanning testing is still in progress. The short-term hole spanning test will determine the structural capability of the liner material as per AWWA Class II, which classifies the capacity of the liner mate-

rial to bridge the corrosion holes in the host pipe under the desired working pressure. Figure 3 shows the pipe sample with a hole and polymeric liner exposed through this hole.

Additionally, evaluating the buckling effects caused by groundwater hydrostatic pressure on polymeric SAPL liners due to water within the annular space between the liner and the host pipe is an important criterion for the Class III structural classification system. Geometric imperfections may exist due to the deteriorated state of the host pipe, inconsistencies in liner installation, or adhesive failure, all of which significantly affect bonding capacity. Non-bonded areas create gaps between the liner and host pipe, through which groundwater may seep, exerting external pressure on the lining system.

Researchers at CUIRE also conducted a short-term external buckling test involving a SAPL liner confined within an 8-inch

host pipe. The test evaluated the impact of varying liner thicknesses while maintaining a consistent annular gap. These tests aimed to determine the liner's short-term resistance to hydraulic pressure and its resistance to buckling effects caused by groundwater. The short-term hole spanning and external buckling tests, along with the vacuum pressure test, confirmed the liner's structural properties as per class II and III. Figure 4 shows the external buckling test assembly and the pipe sample with an annular space between the host pipe and pipe sample sealed at both ends.

To evaluate the use of polymeric SAPL per AWWA Class IV, researchers at CUIRE tested the liner material under internal hydrostatic pressure to evaluate its integrity with no support from the host pipe. The testing included 8-inch diameter pipe samples, which were tested at different temperature conditions from 41F to 150F degrees. Figure 5 shows hydrostatic pres-



Figure 3: Hole-Spanning Testing Pipe Sample



Figure 4: External Buckling Test Assembly (Left) and Inside View of the Pipe Sample Sealed at both Ends (Right)



Figure 5: Hydrostatic Pressure Testing Equipment

sure testing equipment, and Figure 6 illustrates a picture of a broken test sample.

The test results determined the burst pressure, mode of failure, and hoop stress on the SAPL due to internal pressure. The test results established a relationship between the pipe thickness and pressure at different temperatures, which is required to determine the material's performance under different environmental and loading conditions.

CUIRE is also actively involved in research projects related to the Finite Element Method (FEM). These projects are focused on advancing the understanding and capabilities of structural analysis and



Figure 6: Burst Pipe Sample

numerical modeling for underground infrastructure. Our primary focus is on simulating and developing tests and parametric studies that improve structural methodologies.

One significant project involves conducting 3D Finite Element Method (FEM) analysis on Polymeric Sprayed Applied Pipe Linings (SAPL) in pressure pipes applications. This research evaluates the effects of various parameters, such as pipe diameter, pipe thickness, and running these FEM at different pressure ratings and environmental conditions. By optimizing the thickness of the polymeric material through non-linear FEM analysis,

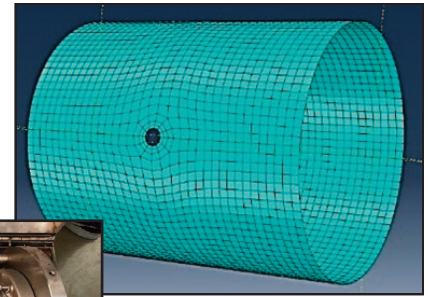


Figure 7: 3D FEM model, meshing of Hole Spanning Pipe Sample

we aim to create a design equation and standard guidelines for SAPL application. Detailed 3D models are developed using ABAQUS® software.

The FEM models have been validated through extensive experimental hole spanning testing, external buckling hydrostatic pressure testing, and pressure integrity testing on full-scale SAPL samples. Figure 7 represents the 3D FEM model with meshing of the hole spanning sample before applying the pressure to the model. The laboratory models tests replicate real-world conditions, ensuring the reliability of our FEM models.

2 FULL-SCALE LIVE LOAD TESTING OF EMBEDDED STORMWATER STORAGE, INFILTRATION CHAMBERS, AND MODULES

CUIRE's wide research capabilities have led them to partner with Xerxes, a leading innovator in composite underground storage solutions products. Together, they are working on creating test procedures and product evaluations for stormwater storage and infiltration chambers, and modules. The test procedures determine how well HydroChain stormwater chambers and modules can withstand vehicular, and soil loads under various real-world scenarios.

The chambers were embedded in a soil box and then backfilled with aggregates. Highway truck loading was simulated



Figure 8: HydroChain S-29B Chambers Assembled in the Soil Box

with a 330-kip actuator. During the test, different sets of data, such as load applied with the actuator, deflection at the crown of the chambers, strain data and pressure data were collected and analyzed to determine the structural integrity of the chambers.

Additionally, CUIRE researchers performed modeling simulations to predict the structural behavior of the embedded HydroChain chambers under various load conditions, as shown in Figure 9. Studying

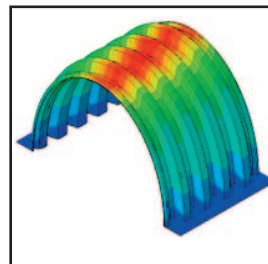


Figure 9: 3D FEM model, meshing and stress analysis of HYDROCHAIN Chamber

the impact of different design parameters gives CUIRE data that allows for increased structural performance and durability.

Through such research, CUIRE is helping lead the way in improved efficiency and cost-effectiveness of underground infrastructure systems. Sharing our findings through various publications and conferences contributes to industry knowledge, and helps utilities make informed decisions about infrastructure technology and maintenance.

3

INNOVATIVE TECHNOLOGIES TO IMPROVE MONITORING OF WATER ASSETS

The Water Research Foundation (WRF) project 5191, entitled "Innovative Technologies to Improve Monitoring of Water Assets," is a comprehensive investigation into the use of condition monitoring technologies by water utilities. The project assesses both existing and cutting-edge technologies to enhance the condition monitoring and management of water infrastructure. The research examines the published body of knowledge, surveys utility practices and explores case studies from various water utilities. These sources of knowledge then provide the necessary information to identify gaps and conclusions about condition monitoring approaches.

One of the primary objectives is to provide clear, actionable guidelines for water utilities for selecting the most suitable condition monitoring methods for pressure pipelines. This involves a thor-



Figure 10: Sample Case Study for a Pump Station (Source: CDM Smith)

ough evaluation of technical requirements, and effectiveness of different technologies. The project has engaged multiple stakeholders, including notable utilities throughout North America, ensuring a broad spectrum of input and validation. Figure 10 shows a sample case study for a pump station.

Project aims to drive significant advancements in the condition monitoring of water assets

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Kawalpreet Kaur,

Ph.D., is a post-doctoral research associate with a research interest in trenchless technology, pipeline rehabilitation, and asset management. Her current research focuses on designing, testing, and evaluating spray-applied pipe linings (SAPL) and underground stormwater storage infrastructure materials. She conducts various experimental tests to assess their suitability for field applications.



Diego R. Calderon

is a licensed professional engineer. His 18 years of experience include roles as university professor, researcher, municipal engineer, project manager, project engineer and field engineer. He is a certified NASCO trainer, a municipal engineer and a Ph.D. candidate at UTA. His dissertation revolves around innovative technologies for condition monitoring of water assets.



Sanaz Ghalambor,

Ph.D., with a Civil and Polymer Engineering background, is working as an Advisory Engineer- Spray-in-place Lining Solutions at Framatome. She has spent two decades in pipeline integrity, corrosion prevention, and rehabilitation. She's had several presentations at different conferences, including UCT, NASTT, and IWA, and has supported many water and wastewater rehabilitation projects.



Ehsan Rajaie

is a Ph.D. candidate at UTA and an infrastructure engineering assistant at TRWD. He has 14 years of civil engineering experience, including lecturing, research, design, and construction management. His recent research focuses on pipeline rehabilitation using trenchless technology and developing structural methodology using FEM, presented at conferences like NASTT and UESI.



Dr. Najafi

is a Professor and Director of the Center for Underground Infrastructure Research and Education (CUIRE). He is a Board Certified Pipeline Engineer–Water. He has more than 25 years of experience encompassing engineering, education, research, consulting, and management activities. He is the author of four trenchless technology books published by McGraw-Hill (the latest one published in 2022, see Figure 11).



Figure 11: Textbooks Published by Dr. Najafi



Table 1 presents a list of water utilities and organizations supporting this project. Through workshops, surveys, gap analysis, and collaborative efforts, the project aims to drive significant advancements in the condition monitoring of water assets, ultimately contributing to more efficient and reliable practices across the nation.

Table 1- list of water utilities and organizations supporting this project.

Water Utilities and Organizations	City, State
TRWD (Tarrant Regional Water District)	Fort Worth, Texas
WSSC Water	Laurel, Maryland
Underground Infrastructure	Houston, Texas
WaterOne	Lenexa, Kansas
American Water	Camden, New Jersey
Dallas County Public Works	Dallas, Texas
DC Water	Washington, DC
Los Angeles County Sanitation Districts	Los Angeles County, California
Greater Cincinnati Water Works	Cincinnati, Ohio
Orange County Utilities	Orlando, Florida
San Diego County Water Authority	San Diego, CA
Great Lakes Water Authority	Detroit, Michigan
Dallas Water Utilities	Dallas, Texas
Dallas County	Dallas, Texas
CDM Smith	Fairfax, Virginia

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