Curing quaking pipes

Research teams at two United States universities have investigated the potential for cured-in-place lining to protect pipelines during earthquakes.

CIVIL ENGINEERS AT Cornell University and State University of New York at Buffalo (SUNY Buffalo) have recently conducted research that shows retrofitting pipelines with cured-in-place pipe linings (CIPP) could prevent earthquake damage to seismically vulnerable 50-100 year-old cast iron pipelines.

Conducting a range of experiments across multiple research laboratories in the US, the findings of the study could allow public and private utilities to take advantage of improvements in seismic resistance and to renovate the ageing pipelines that still make up an important part of the country's critical civil infrastructure.

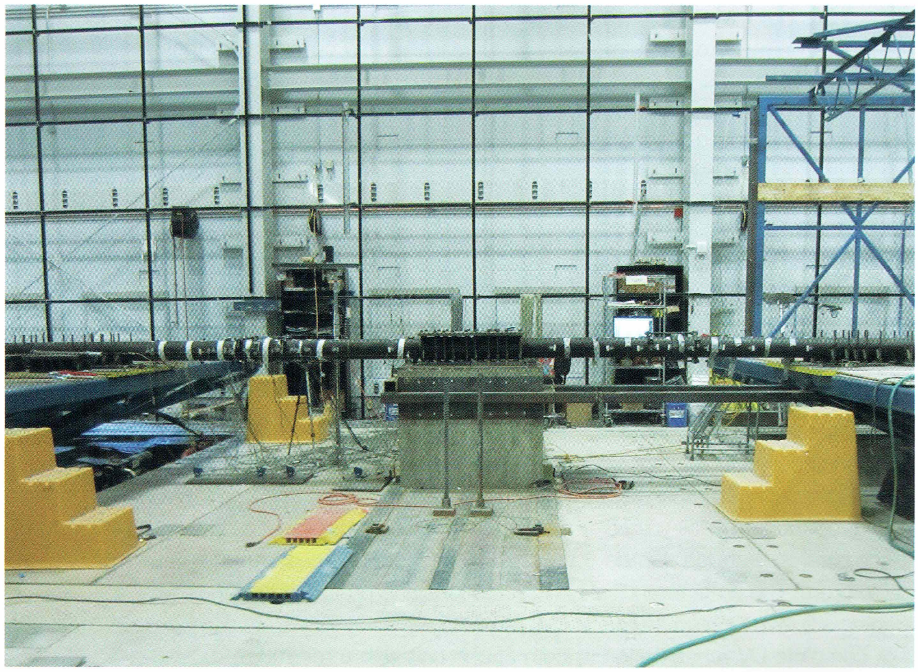
Led by Cornell Thomas R Briggs Professor in Engineering Thomas O'Rourke, the study into the structural effectiveness of CIPP during seismic events was conducted by a team of Cornell earthquake engineers alongside a team from SUNY Buffalo. Research took place at facilities located at both Cornell and SUNY Buffalo, with West Coast partners including the Los Angeles Department of Water and Power and the California State University at Los Angeles.

"The most important obstacle to the seismic upgrade of existing pipelines is the disruption of business and traffic caused by excavation of the pipelines," said Professor O'Rourke.

"Using No-Dig technologies and fibre-reinforced plastic (FRP) liners allows for retrofitting pipelines in place without the substantial business and traffic interruptions and safety concerns related to conventional excavation with repair or replacement."

SUNY Buffalo Professor André Filiatrault, who was also a part of the research team, said in-situ linings are not currently used for earthquake protection due to limited research and data.

"The lack of experimental validation and analytical procedures for evaluating the seismic response of pipelines retrofitted with FRP technology has been a serious barrier to the adoption of in-situ linings for improved earthquake performance," said Professor Filiatrault.



Pipeline specimens were anchored to shake tables to simulate the passage of a seismic wave through two adjacent push-on joints. Experiments took place at a University at Buffalo laboratory.

"The primary objective of our tests was to characterise the dynamic behaviour and failure mechanics of cracks and weak joints in ductile iron pipelines with FRP linings. A secondary objective was to verify and quantify how the FRP liner could affect the seismic performance of pipe joints."

Shaking the foundations

The research group partnered with pipeline rehabilitation companies Insituform Technologies and Progressive Pipeline Management on the project, with the companies installing the CIPP lining within the experimental pipe specimens. The ductile iron pipe test specimens were donated by the Los Angeles Department of Water and Power.

Full-scale dynamic testing of the underground lifeline systems was conducted in the Structural Engineering and Earthquake Simulation Laboratory at SUNY Buffalo, New York. The laboratory is the home of two high-performance 'six-degrees-of-freedom shake tables'. Pipeline specimens were anchored to both shake tables to simulate the passage of a seismic wave through two adjacent push-on joints.

To measure and record the data from the dynamic experiments, the pipeline specimens and shake tables were equipped with an array of over 100 sensors. Most of the instrumentation was concentrated in the vicinity of the two push-on joints of the pipeline specimens.

Meanwhile, CIPP-retrofitted pipelines were tested in order to measure their response to abrupt ground displacement and fault movement. These tests were performed at the Cornell Large-Scale Lifeline Test Facility at Cornell's Ithaca campus. According to a Cornell University spokesperson, the facility replicated the effects of full-scale fault rupture on underground pipelines, electric and telecommunication cables and other conduits for resources and services.

CIPP holds strong

Results from physical testing and analytical modelling showed that the CIPP-retrofitted pipelines were able to accommodate very high levels of transient ground motion and moderate levels of permanent ground deformation. This led the team to conclude that CIPP can provide substantial seismic strengthening in addition to efficient rehabilitation of ageing underground infrastructure.

"We were pleased to confirm that earthquake response and rehabilitation of critical lifelines can be enhanced substantially by in-situ pipe lining technologies," said Professor Filiatrault.

The research was presented at Quake Summit 2014, the annual meeting for the National Science Foundation's George E. Brown Jr. Network for Earthquake Engineering Simulation – a network of laboratories based at Purdue University. Held in Anchorage, Alaska, the 2014 summit was part of the tenth US National Conference on Earthquake Engineering.

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The Quake Summit 2014 conference paper was titled *Performance of Water Pipelines Retrofitted with Cured in Place Pipe Liner Technology Under Transient Earthquake Motions*. The paper described the behaviour of the CIPP liner-strengthened ductile iron pipelines under static loading and focused on the response of the liner under transient ground deformations (TGD).

Based on the joint response under quasi-static loading, the paper proposed a new constitutive numerical model for the longitudinal behaviour of CIPP liner-reinforced joints and cracked sections of pipe that considers strength degradation and energy dissipation. Both the test results and numerical analyses indicated that CIPP liner provides substantial longitudinal strength to the joints of ductile iron pipelines and significantly improved the pipes' seismic behaviour under high intensity TGD.

As well as Cornell Professor Thomas O'Rourke and SUNY Buffalo Professor André Filiatrault, the research team comprised Cornell Associate Professor Harry Stewart; Cornell Graduate Researchers Dimitra Bouziou, Brad Wham and Christina Argyrou; Cornell lab managers Tim Bond and Joe Chipalowski; SUNY Buffalo Professor Amjad Aref; and a SUNY Buffalo graduate research assistant.