Trenchless Technology Center Newsletter

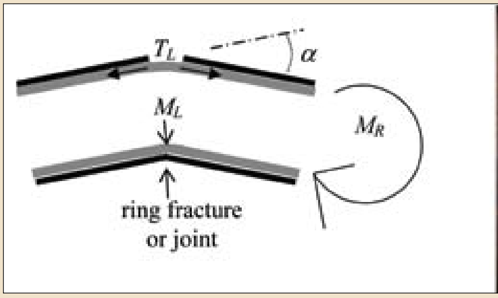
S E P T E M B E R 2 0 1 0

Experimental Evaluation of Selected Limit States for CIPP Liners

In seeking to extend the useful life of deteriorated potable water mains, you must consider the presence of voids and discontinuities in the pipe walls. The TTC is undertaking an experimental investigation of various limit states that could cause liner instability as a result of internal water pressure and uneven ground movements. One such discontinuity is ring fracture, frequently found in small-diameter cast iron pipes that suffer from loss of beam support. Movement of the pipe can continue at this point and a lining product must be able to accommodate such movement, which tends to take the form of angular deflection. When considering pipes that have been in place for many years, it is reasonable to assume that natural settlement of the bedding has long been completed and that transverse fracture of brittle cast iron pipes occurs due to differential ground movements induced by frost, moisture changes in 'reactive' clays or a nearby excavation. A schematic diagram of this limit is shown in Figure 1, where a local bending moment ML and tensile force TL in the liner wall occur across ring fractures or joints (Allouche et al, 2005). Rajani et al. (1996) examined this phenomenon using elastic springs to characterize the soil response, while Trickey (2005) demonstrated how typical thermal conditions can produce ring fractures as a result of differential ground movements.

Experimental Setup: Six-inch diameter, 4-ft long specimens of 70-year-old cast iron pipe were prepared in such a way as to simulate transverse ring break at their center and were then lined with a glass-fiber, reinforced CIPP liner. The specimens were capped and the assembly was subjected to three-point flexural loading using a custom-build testing apparatus and a 50,000-lb, servo-controlled actuator. The angular deflection was increased from 0 to 12.5 degrees (corresponding to a vertical displacement of 5 in.) in 0.25 degree increments. The behavior of the host pipe and the liner were monitored with increased deflection, and geometrical changes in the liner structure were noted. Strain and stress measurements in the axial and hoop directions within the liner structure at the location of the ring failure were monitored. In a separate test the liner was capped, filled with water and pressurized, while subjected to three-point flexural loading. The angular deflection was, again, increased from 0 to 12.5 degrees in 0.50 degree increments. At each increment the liner was subjected to a sustained internal pressure of 60 psi. At the final increment of 12.5 degrees (vertical displacement = 5 in.) the sustained pressured was increased to 90 psi.

Results: As the host pipe was discontinued at its center, it behaved like a hinge connection with a vertical force applied at the location of the 'ring fracture.' The liner was found to exhibit a linear-elastic behavior up to the point where the displacement exceeded the distance to the natural axis of the host pipe at the supports. As the vertical deflection approached 3.7 in., a sudden increase in the tensile stress across the ring fracture took place. At this point, it appeared that the liner de-bonded from the host pipe, carrying a much larger portion of the load at the location of the fracture. Subsequently, the stress at the invert of the pipe in the longitudinal direction increased to nearly 2,500 psi. Next, the linear began to exhibit plastic deformation in the hoop direction, resulting in the formation of a fold at the invert of the liner (see Figure 3). Figure 4 displays the stresses recorded at the invert of the liner (inner wall) as a function of the vertical displacement. As the fold began forming, the longitudinal stress in the liner decreased while a significant increase in stress was registered in the hoop direction with increase in vertical displacement. It is worth nothing that the presence of internal pressure is expected to prolong the formation of this failure mechanism, i.e., such fold was not noted in the specimen that was subjected to internal pressure while under similar degree of vertical deflection, as shown in Figure 5. The complete findings of the study will be reported at No-Dig 2011. For further information, please contact Dr. Erez Allouche at *allouche@latech.edu* or Shaurav Alam at *sza003@latech.edu*.



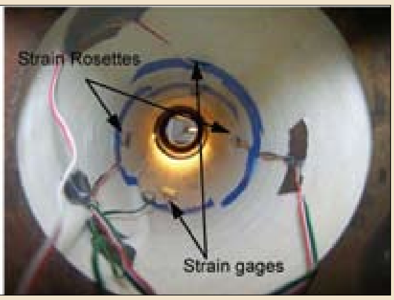


Fig. 1. Moment and wall stretching at ring fracture.
Fig. 2. Locations of strain gages and rosettes.

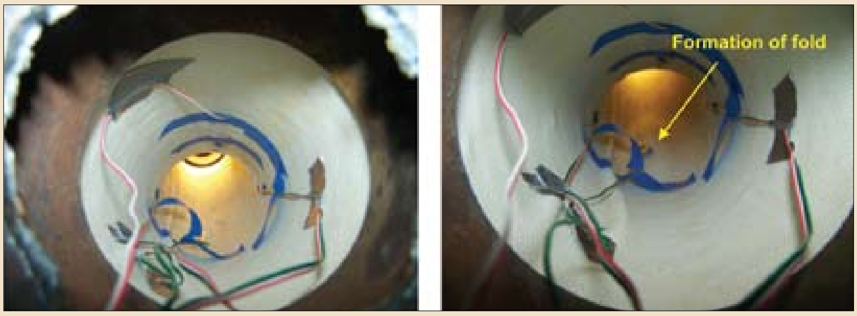


Figure 3. The liner immediately before (left) and shortly after (right) the formation of the fold at the invert.

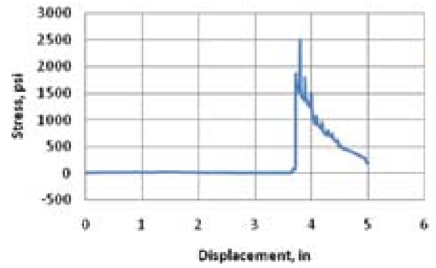


Fig. 4. Stress vs. deflection at the invert of the liner.   Fig. 5. Liner under 90 psi at vertical displacement of 5 in.

References

Allouche, E.N. Moore, I.D. and K. Bainbridge (2005). Laboratory Examination of Cured in Place Pressure Pipe Liner for Potable Water Distribution System. No-Dig, April 24-27, Kissimmee, Fla. Rajani, B. Zhan, C. and Kuraoka, S. (1996) Pipe-soil interaction analysis for jointed water mains, Canadian Geotechnical Journal, 33, 393-404. Trickey, S. A. _2005. “Three-dimensional finite element modeling of buried pipes including frost action.” MSc thesis, Dept. of Civil Engineering, Queen’s Univ. at Kingston, Canada.

2010 Fall Municipal Forum Program

Nine forums will be held in fall 2010 as follows: in Westminster, Colo. (Oct. 12); Portland, Ore. (Oct. 14), Boston, (Oct. 27), Dallas (Nov 4), Fountain Valley, Calif. (Nov. 15), Miami (Nov. 16), Fairfax, Va. (Dec. 1), Palo Alto, Calif. (Dec. 6), and Edmonton, Alberta, Canada (Dec. 8), In most of these locations, the forums have been running for at least several years and are well established. The exceptions are Palo Alto, near San Francisco, where the forum will be held for the first time, and Miami, where only one previous forum was held in 2007.

The forums are designed as one-day programs with low participation cost. Participants can earn CE units for attending municipal forums, while PDH certificates can be issued at no additional cost to the participants at some forums (Colorado and Texas). Starting this forum season, online registration will be offered. This feature will be added to the municipal forums program Web page, which can be accessed from *www.ttc.latech.edu*, in September.

The forums are typically attended well, with about 40 to 60 participants on average. New municipal and non-municipal participants joining the forums are always welcome. Municipal participants are encouraged to make requests for topics to be covered in the forums. Enquiries about making presentations at forum meetings can be made by calling or e-mailing the TTC. Contact Jadranka Simicevic at (318) 257-2744 or *jadranka@latech.edu*.

TTC IAB Meeting in Ruston

The TTC will hold its annual Industrial Advisor Board meeting in Ruston, La., Oct. 20-22. Presentations on TTC research projects will be shown to the Board and feedback about the research and other aspects of TTC performance will be obtained from the Board. Enquiries about participation in TTC activities as an Industry Advisory Board member or Sponsor are welcomed. Contact Dr. Rob McKim at (318) 257-4072 or *mckim@latech.edu*.

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