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Studying the life-cycle performance of gravity sewer rehabilitation liners in North America

Raymond Sterling[a,*], Shaurav Alam[b], Erez Allouche[c], Wendy Condit[d], John Matthews[e], Declan Downey[f]

[a]*Trenchless Technology Ctr., Louisiana Tech University (retired), Minneapolis, MN, USA*
[b]*Trenchless Technology Ctr., Louisiana Tech University, Ruston, LA, USA*
[c]*Stantec, Edmonton, Canada*
[d]*Battelle, Columbus, OH USA*
[e]*Pure Technologies, Baton Rouge, LA, USA*
[f]*Trenchless Opportunities Ltd., Peterborough, UK*

Abstract

Pipe rehabilitation and trenchless replacement technologies have seen a steadily increasing use and represent an increasing proportion of the annual expenditure on operations and maintenance of the water and wastewater infrastructure around the world. Despite the large public investment in use of these technologies, there has been little quantitative evaluation of how these technologies are performing. A retrospective study conducted by the U.S. Environmental Protection Agency collected 25 samples between 2009 and 2013 of in-service gravity sewer liners from 11 cities in North America. Testing of the various liners included thickness, annular gap, ovality, specific gravity, porosity, flexural strength, flexural modulus, tensile strength, tensile modulus, surface hardness, glass transition temperature, Raman spectroscopy, environmental stress crack resistance and pipe stiffness as appropriate to the liner type and condition. Cured-in-place pipe (CIPP) liners comprised 18 of the 25 samples. Other liners included were PVC fold-and-form, HDPE deform-reform and sliplining. The samples had seen from 5 years to 34 years in service. A number of areas where the QA/QC of liner installation should improve were noted in the studies but, overall, the liners were in excellent condition and the physical test results indicated that these liners are expected to last their 50-year design life and probably well beyond.

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* Corresponding author. Tel.: +1-612-802-3394.
E-mail address: sterling@Latech.edu

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1. Introduction

This paper is derived from a research project conducted from 2008 to 2015 under the U.S. Environmental Protection Agency's (EPA's) Sustainable Water Infrastructure Initiative. Specifically, the research work was conducted under Task Order (TO) No. 58 under Contract No. EP-C-05057for the EPA National Risk Management Research Laboratory (NRMRL) and was entitled "Rehabilitation of Wastewater Collection and Water Distribution Systems." This research included preparation of a series of reports on the state of technology (SOT) for rehabilitation of gravity wastewater systems (mains, laterals, and manholes), sewer force mains, and water mains [1,2,3] which serve as excellent and comprehensive discussions of the technologies in use at the time of their preparation. References to these SOT reports and related documents (a review of quality assurance and quality control (QA/QC) measures for trenchless rehabilitation technologies [4] and a review of current decision-making models and methodologies [5] available to support rehabilitation versus replacement decisions) are provided at the end of the report and can be downloaded from the US EPA website (http://nepis.epa.gov).

The early project activities reinforced a key need in applying asset management principles to water and wastewater systems – the need to track how the rehabilitation system is performing in terms of structural deterioration and functionality, and hence to assess the expected life cycle of the rehabilitated structure. Since several major rehabilitation technologies had been used in the U.S. for over 15 years and CIPP for much longer, a detailed and quantitative evaluation of older rehabilitated systems had the potential to provide an important dataset to confirm or revise estimates of expected life. The result was the major retrospective evaluation program that forms the focus of this paper. There are two reports that fully describe this retrospective evaluation work [6,7] and there are several journal papers that provide archival reference to the key results from the project [8,9,10]. In general, the reader looking to gather the most detailed information and results from the project should access the full reports from the EPA website.

2. Retrospective Study Overview

The retrospective study of the condition of gravity sewer rehabilitation technologies which is the subject of this paper was divided into two main components: a pilot study and an extended study. The pilot study focused on CIPP liners and was conducted to explore the best approach for such a retrospective evaluation and to test evaluation protocols. The follow-on work took up two of the recommendations from the prior work: to develop a database structure to house such performance information on rehabilitation technologies and to collect a wider sample of physical test data and performance data from field-recovered samples. There were 18 CIPP liner samples collected over both studies that mostly ranged in age from 17 to 34 years, while two younger liners (5 and 9 years) were also included. Samples of other types of rehabilitation liners (two polyvinyl chloride [PVC] fold-and-form liners, three high density polyethylene [HDPE] deform-reform liners, and two polyethylene slipliners) were also collected and tested during the second phase of the project.

Testing of the various liners over both projects included thickness, annular gap, ovality, specific gravity, porosity, flexural strength, flexural modulus, tensile strength, tensile modulus, surface hardness, glass transition temperature, Raman spectroscopy, environmental stress crack resistance and pipe stiffness as appropriate to the liner type and condition.

The testing and measurement protocols were carried out in accordance with EPA NRMRL's Quality Assurance Project Plan (QAPP) Requirements for Applied Research Projects and the project-specific QAPPs. The details of these protocols are described in the EPA reports. ASTM testing standards were followed according to the parameter being measured. Where ASTM standards were not available (e.g. visual inspection, annular gap, liner thickness, ovality and environmental service conditions), the procedures used, numbers of measurements, specimen photos, etc. were documented in the QAPP. The following principal ASTM test standards were used in the laboratory testing of the current retrospective samples: specific gravity (ASTM D792), tensile properties (ASTM D638),