Assessing the Longevity of CIPP Sewer Liners: A Comprehensive Study of Service Life and Failure Modes

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Keywords: Sewer rehabilitation; CIPP Liners; Service life assessment

Abstract: Addressing Europe's current challenges of aging sewer networks, the presented research focuses on the uncertainties in service life and aging behavior of the most used renovation technique, Cured in Place Pipe (CIPP) lining. Examining its aging behavior, common defects and deficiencies were analyzed through literature review and expert interviews. The findings influenced the proposition of a calibration setting for a deterioration model using survival curves. Identified defects stress the need for precise installation and curing processes. The study recommends a thorough review of the initially specified 50-year service life, acknowledging uncertainties during the installation process.

Introduction

Europe's urban sewer networks are aging, while municipalities in Europe are struggling to meet the annual rehabilitation demand costing approximately 40 billion Euros per year (Bosseler et al., 2024). Trenchless sewer rehabilitation, particularly sewer lining, has gained prominence for its time and cost efficiency compared to traditional open trench methods. This method, known as Cured in Place Pipe (CIPP), involves inserting a resin-soaked flexible tube into the damaged sewer, curing it in place to create a plastic pipe. Despite being widely adopted, limited knowledge exists about the service life and aging behavior of liners, with initial assumptions suggesting an average service life of 50 years. Given continuous developments in materials and installation methods over the past decades, a comprehensive investigation and reassessment of specified service life regulations become imperative to address uncertainties. The presented research aims to estimate the service life of CIPP sewer liners, analyze their failure modes and propose a calibration setting for survival curves as deterioration model based on these findings as an essential reference for the investment and rehabilitation planning for utilities.

Material and Methods

The study explores the liner service life through a literature review and international interviews with 21 experts. It aims to assess service life expectancy, identify defects, and proposes a new calibration setting for survival curves. Combining these findings with the results of a data analysis of up to 30 years of liners by Berliner Wasserbetriebe, the research proposes a new calibration setting for survival curves. These calibrated survival curves, based on a Gompertz distribution (Le Gat, 2008), prove effective for modelling aging in sewer pipes, facilitating the calculation of rehabilitation probabilities (Riechel, 2021).

Results and Discussion

The analysis of the literature review and interview results has shown that crucial defects and deficiencies (outlined in Table 1) originate mostly from improper installation, like curing deficiencies, wrinkling, problems with connections, underfitting and possible bulging/deformation. Notably, the curing process, particularly in glass fiber liners with UV light curing demand significant attention. The shift from synthetic fiber liners with heat-initiated curing to glass fiber liners with UV-initiated curing since the 2000s has altered control parameters, introducing complexities like light intensity, temperature, and lamp pull speed, thereby increasing uncertainties in predicting service life. Despite the initial expectation of a 50-year service life for liners with good installation quality, 71% of interviewees estimate a longer lifespan, within which 33% assuming 70 years or more. A thorough review of the initially stated 50-year service life is recommended, also considering comparisons of liners with new plastic sewer pipes. Using the analyzed failure modes and experiences from the interviews and Berliner Wasserbetriebe data analysis results, a calibration for liner survival curves can be suggested. Figure 1 illustrates a calibration approach for survival curves in liner systems based on initial assumptions. However, achieving more precise calibration requires accurate information on the service life and condition development of liners.

Conclusions

In conclusion, the growing use of CIPP sewer liners prompts crucial questions about their service life and subsequent renovation possibilities. Municipalities and sewer network operators face challenges in estimating the long-term durability and incorporating it into investment planning. Despite conservative estimates of 50 years, confidence in material durability suggest a likely lifespan beyond 50 years. Various influencing factors onto the service life of a liner-host-pipe-system were identified through the research and summarized in Figure 2.

Installation quality, especially curing deficiencies, are identified as the primary factor impacting service life. These issues, hidden in the liner-host pipe interface, are challenging to visually inspect. The lack of robust data highlights the necessity for enhanced non-destructive examination methods and standardized procedures in liner condition assessment. Further research is imperative for a comprehensive understanding and modelling of the liner aging behavior as well as a possible re-calibration of the proposed survival curves for informed planning and safe operation of CIPP liners in sewage systems.

References

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Figures and Tables

Table 1: Results of highlighted defects/deficiencies influencing service life of CIPP liners from 21 interviews (multiple answers allowed)

Defects/deficiencies	Percentage of all interviewees highlighting this defect/deficiency
Curing deficiencies	48 %
Wrinkling	24 %
Flushing damages	24 %
Inner foil damages	24 %
Connection problems	24 %
Underfitting	19 %
Bulging/deformation	14 %

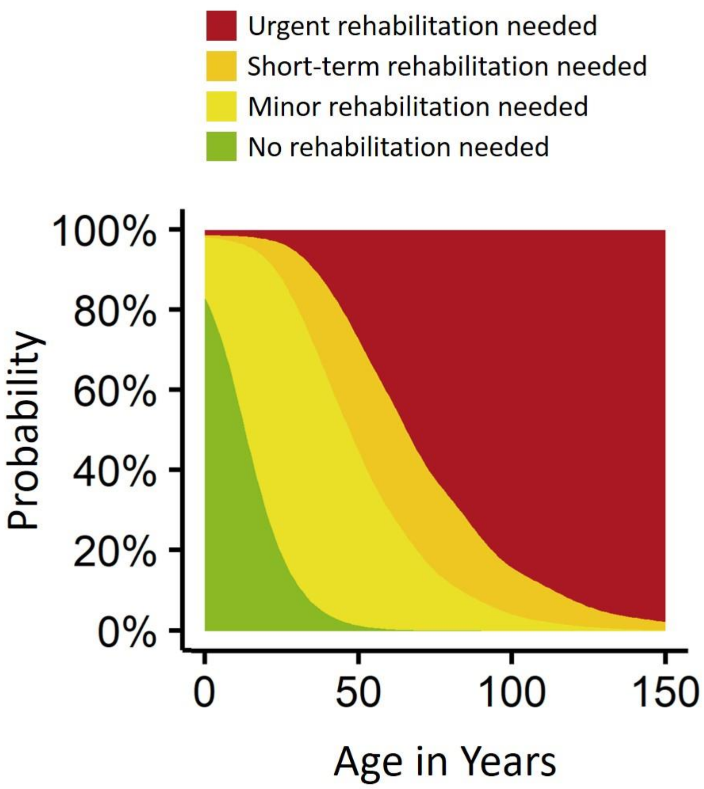

Figure 1: Revised calibration of liner survival curves proposed by Berliner Wasserbetriebe based on presented research results and internal data analysis

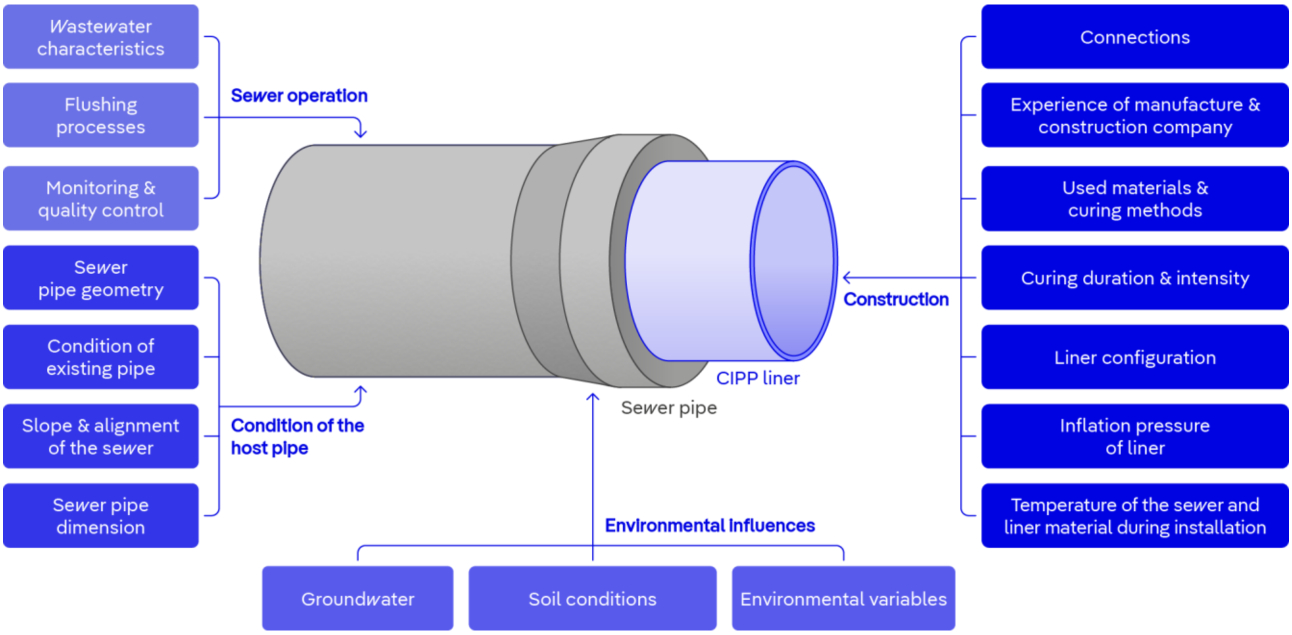

Figure 2: Influences on liner-host pipe system based on literature review and interview results