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SANITARY SEWER CONSTRUCTION COST COMPARISON BETWEEN TRENCHLESS CIPP RENEWAL AND OPEN-CUT REPLACEMENT

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Renewal and replacement of aging underground infrastructure, which mainly includes pipelines is one of the vital issues for the North American municipalities every day. Conventional replacement of these aging pipelines utilizes open-cut trenching methods that could be expensive both in rural and urban areas. In trenchless cured-in-place pipe (CIPP) pipeline renewal method, a liquid thermoset resin-saturated material is put inside the deteriorated pipe by hydrostatic, air inversion, or pulling inside mechanically and inflating. Then, the curing of the liner material used could be done in-place using three different ways such as, hot water, steam- or UV-cured to result in a final cured product. Trenchless methods are considered much more cost-effective. However, to make a comprehensive comparison, engineers and project owners will benefit from additional data. The objective of this study is to review past studies dealing with CIPP renewal method and open-cut pipeline replacement, and to compare their construction costs for renewing the small, medium, and large diameter sanitary sewer pipelines with the help of statistical analysis. It was found that mean construction costs of CIPP renewal is 57%, 63%, and 18% less as compared to the open-cut pipeline replacement for small, medium, and large diameter sanitary sewer pipes, respectively. It can be concluded that using CIPP method, municipalities can save millions of dollars in the renewal of underground utility systems. A life cycle cost analysis to evaluate and compare the construction, environmental, and social costs between CIPP renewal method and open-cut pipeline replacement is recommended.

Keywords: Trenchless technology, Cured-in-place pipe, Underground infrastructure, Pipe diameter.

1 INTRODUCTION AND BACKGROUND

A large proportion of underground infrastructure was built in the mid-1950s during a rapid economic growth in the regions of the United Sates and Canada. Currently, these aging pipeline systems have exceeded their design lives and have lost their structural capacity. Renewal and/or replacement of this aging and deteriorating sewer pipelines is a major obstacle faced by municipalities (Hashemi *et al.* 2011, Kaushal 2019).

The sewer pipeline system is the basic urban infrastructure for public sanitation. In the U.S., there are 1.2 million miles of water supply mains, and there are nearly an equal number of sewer pipes, 26 miles of sewer pipes for every mile of interstate highway (Alsadi 2019). These conveyance systems are prone to structural failures, blockages, and overflows (Najafi and Gokhale 2005). USEPA (2012) estimates that more than $270 billion is needed to maintain the underground infrastructure over the next 20-25 years. Additionally, more than $51 billion is needed for fixing the conveyance system itself (Kaushal *et al.* 2019, Serajiantehrani 2020).

Because of deterioration of municipal underground infrastructure systems and a growing population that demands better quality of life, the efficient and cost-effective installation, renewal, and replacement of underground utilities is becoming an increasing important issue. The traditional open-cut construction method requires reinstatement of the ground surface, such as sidewalks, pavement, landscaping; and therefore, considered to be a wasteful operation (Hashemi 2008, Kaushal *et al.* 2019). Trenchless technologies include all methods of underground utility installation, replacement and renewal without or with minimum surface excavation. These methods can be used to replace, upgrade, repair, or renovate underground infrastructure systems with minimum surface disruptions, and therefore offer a viable alternative to the traditional open-cut methods (Najafi and Gokhale 2005, Kaushal *et al.* 2020).

In trenchless cured-in-place pipe (CIPP) pipeline renewal method, a liquid thermoset resin-saturated material is put inside the deteriorated pipe by hydrostatic, air inversion, or pulling inside mechanically and inflating. Then, the curing of the liner material used could be done in-place using three different ways such as, hot water, steam- or UV-cured to result in a final cured product. Though the trenchless methods are considered cost-effective, engineers need additional data to make a comprehensive comparison data (CUIRE 2018).

The total cost of a typical pipeline project depends upon various factors such as size, material, depth and length of installation, project site, subsurface conditions, and type of pipeline or utility application. With open-cut pipeline replacement, it is estimated that more than 70 percent of a project's construction costs will be spent for reinstatement of surface only, not installation of the pipeline itself (Najafi 2011). In addition, among the different trenchless pipeline renewal techniques, CIPP is considered as cost-effective, safe, efficient, and productive alternative (Das *et al.* 2016).

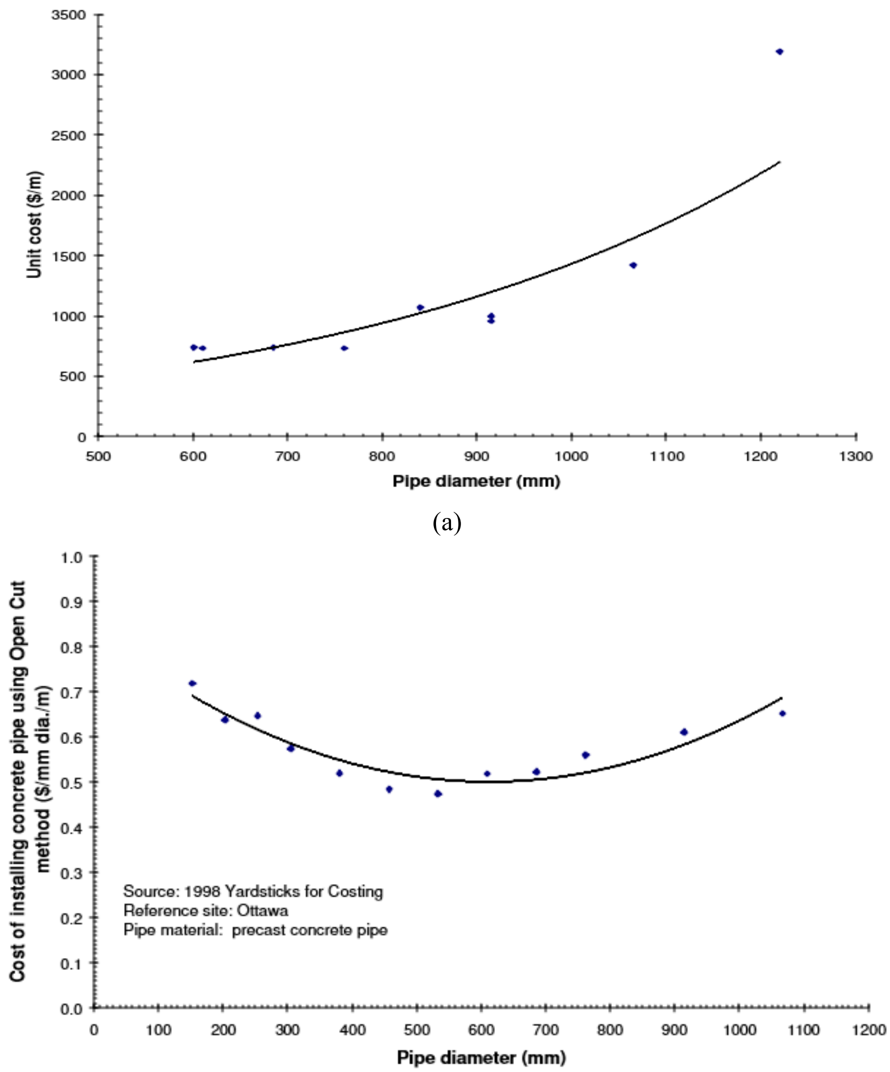
Trenchless CIPP renewal technique is an alternative to trenching and replacing sewer pipes, and this method has been used to install renewed pipelines to the tune of several-million feet, globally. Today, CIPP has been among the most widely used trenchless pipeline renewal methods for structural and non-structural water and wastewater applications (Kozman 2013).

This paper reviews past related studies on CIPP renewal method and open-cut pipeline replacement, and to compare their construction costs for renewing the small, medium, and large diameter sewer pipelines with the help of statistical analysis.

2 PAST STUDIES

Tighe *et al.* (2002) performed a study to compare the overall project costs of traditional open-cut pipeline renewal method with trenchless renewal methods. They considered different factors, such as future maintenance costs, performance, and user-delay costs in the study. The results indicated that traditional open cut methods reduce the life of pavement about 30 percent and increase the maintenance and rehabilitation costs of pavement from \$64/m^2 (690/ft^2) to \$110/m^2 (1,185/ft^2). However, trenchless technologies have fewer costs associated with pavement disruptions.

According to Zhao and Rajani (2002), increase in the cost of pipe renewal with size is because of the increased level of complexity in carrying out the pipeline renewal work. To illustrate the range of costs in a location, the cost diameter relationship from a study of CIPP projects in Phoenix is shown in Figure 1(a). In the same study, Zhao and Rajani (2002) reported a cost curve for open-cut pipeline replacement (Figure 1 (b)).



(a)

(b)

Figure 1. (a) CIPP renewal cost with pipe diameter (b) Cost curve for Open-cut pipeline replacement (Zhao and Rajani 2002).

Najafi and Kim (2004) presented an investigation of parameters involved in constructing sewers by the help of trenchless technology methods in urban centers in comparison with tradition open-cut pipeline replacement. Their study involved a breakdown of the engineering and construction costs and the social costs for both these methods. These researchers considered life-cycle cost of a project in phases such as, pre-construction, construction, and post-construction parameters. They also asserted that considering the life-cycle costs of a project, trenchless pipeline technology methods are more cost-effective than traditional open-cut pipeline method.

According to Piehl (2005), the cost for trenchless CIPP method ranges from $100 per linear foot for 458 mm (18 in.) diameter pipe to $800 or more per linear foot for the large-diameter pipe. Shahata (2006) in his study predicted the life-cycle cost for water mains by including the factors involving uncertainties such as, discounted rate, service life, and the new pipeline installation or renewal cost alternatives. It was found that the open-cut pipeline replacement method is more cost-effective for large diameter pipeline ranges than CIPP method.

Hashemi *et al.* (2011) evaluated the CIPP AWWA Class IV, pipe bursting, and open-cut methods based on diameter, cost, and service re-connection to find out the best renewal option for water main distribution. They used statistical techniques to analyze the data for 152 mm (6 in.), 203 mm (8 in.), and 304 mm (12 in.) diameter pipes and found the average costs of open-cut and CIPP pipeline renewal as $2,460/m ($750/ft) and $1,066/m ($325/ft), respectively.

3 METHODOLOGY

Four sources were used to collect the construction cost data for CIPP renewal and open-cut pipeline replacement: (1) introduction and conceptual cost comparison of trenchless technology methods (Najafi 2013), (2) Ohio Department of Transportation, (3) Michigan State University, and (4) construction and rehabilitation cost of buried pipes adopting trenchless technologies (Zhao and Rajani 2002). Thereafter, statistical analysis was used to compare the mean construction costs of CIPP renewal method with open-cut pipeline replacement.

4 RESULTS AND DISCUSSIONS

After the data collection and organization, regression analysis was performed to compare and analyze the construction costs between CIPP renewal method and open-cut pipeline replacement. Figure 2 shows the comparison of mean construction costs ($/ft) of CIPP renewal method with open-cut pipeline replacement for pipe diameters ranging from 6 in. to 90 in.

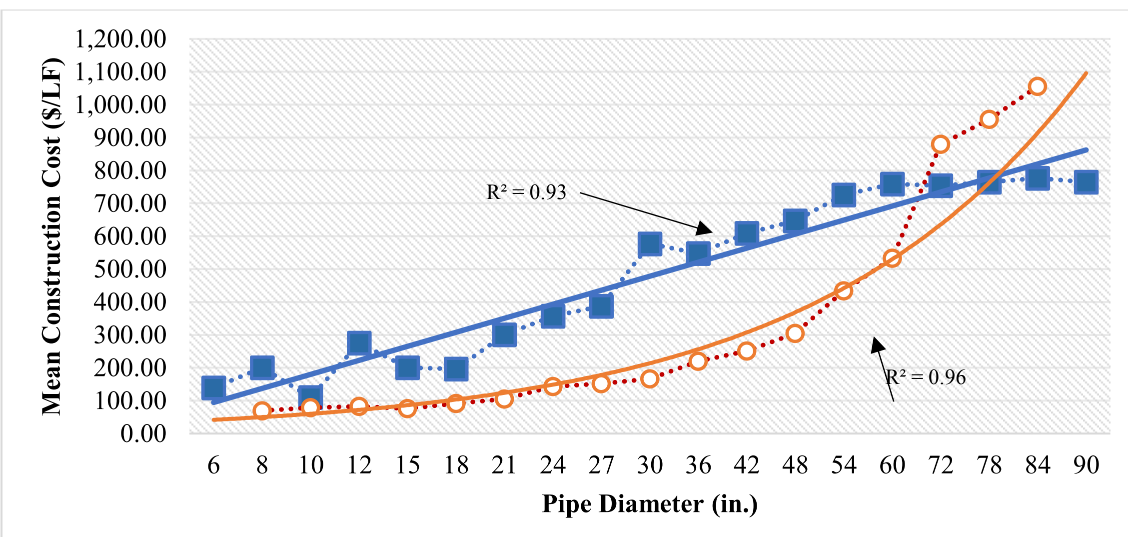


Figure 2. Mean construction cost comparison of CIPP renewal with Open-cut pipeline replacement for different pipe diameters.

It can be observed that there is an exponential relationship between the mean construction cost of CIPP and its diameter. However, a linear relationship is seen between the mean construction cost of open-cut pipeline installation and its associated diameters. In addition, the values of correlation coefficient (R^2) for CIPP renewal method and open-cut pipeline replacement are found to be 0.96 and 0.93, respectively.

Table 1 shows the mean construction costs ($/ft) for small (up to 12 in.), medium (12-30 in.), and large (above 30 in.) diameter CIPP renewal and open-cut pipeline replacement.

Table 1. Mean construction costs for different diameter CIPP renewal and Open-cut pipeline replacement.

Pipe Diameter	Mean Construction Cost of CIPP ($/ft)	Mean Construction Cost of Open-cut ($/ft)
Small (up to 12 in.)	77	181
Medium (12-30 in.)	122	336
Large (above 30 in.)	579	705

5 CONCLUSIONS

It can be concluded that mean construction costs of CIPP renewal is 57%, 63%, and 18% less as compared to the open-cut pipeline replacement for small, medium, and large diameter sanitary sewer pipes, respectively. In addition, the mean construction cost of CIPP renewal shows an exponential behavior with increase in the pipe diameter. However, for open-cut pipeline installation, a linear behavior is seen between the mean construction cost and pipe diameter increase.

Acknowledgments

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