A short review: Techniques for trenchless sewer rehabilitation

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Abstract

Proper functioning of the sewage system and the wastewater pipes is very important because the sewage system is carrying wastewater away from family houses, factories, buildings, as well as streets, into the wastewater treatment plants, and further into the recipient. Urbanization is becoming more and more evident, and there is a growing need for sewer maintenance and its renovation, using as little work on the terrain surface as possible. Wastewater pipes, same as any other material or part of a building, degrade over time, and after a certain time it is necessary to replace the pipes or refurbish them. As the sewage pipes are ageing, cracks are appearing because of unequal settling, the dynamic loads of automobile passage, or any other loads above the pipes, aggressive chemical compounds, tree root intrusion, or something else. According to the traditional methods of sewage pipe rehabilitation, sewer pipes were excavated and replaced by new pipes, while no-dig methods for the renewal of pipes use the old pipes, through which a new pipe is inserted, or lining is placed inside the existing pipe. This paper will briefly describe these methods: Pipe Bursting or In Line Expansion, Slipnining, Cured In Place Pipe, and Modified Cross Section Liner. Also, pictures will be used to show each of the above mentioned methods for trenchless sewer rehabilitation.

Key words: methods, rehabilitation, sewer, trenchless, wastewater pipes

1 Introduction

The sewer system is indispensable in every city and it is very important to keep it functioning properly. In order for the sewer system to function properly, it is necessary to perform regular maintenance and take care of the damage and possible leaks in the sewer pipes [1]. Good maintenance of the sewer system is a prerequisite for the rational management of this set of urban infrastructure, for good sanitary conditions in the urban environment and a good protection of the environment; therefore it should be given serious attention [2]. The maintenance, repair, and rehabilitation of the sewer system infrastructure is no trivial task. In fact, sewerage systems form one of the six most capital intensive infrastructure systems; the other five are: schools, roads, water, storm drainage, and solid waste disposal [3, 4].
Traditional methods of underground pipe rehabilitation or replacement have typically encompassed the use of open cut or lining methods of construction [5]. The traditional method of repairing broken or otherwise non serviceable underground pipes is by excavation

(usually requiring sheeting and shoring), pipe removal, pipe replacement, backfilling and then restoration of the site to its original condition [6]. The replacement of pipe using conventional cut and cover techniques can have adverse impacts on the daily life and activities of the people and businesses around the rehabilitation project. Typically, road closures, traffic delays and redirections, loss of access to businesses and homes, as well as undesirable noise and sight pollution are common with open cut type projects [5]. Additional costs are typically incurred by the need to restore the existing finished surfaces including sidewalks and pavements in addition to landscaping [7]. Due to the numerous modern trenchless technologies used for pipe replacement, pipe rehabilitation no longer necessarily requires a new construction project, i.e. a construction intervention at the location [8].
In an attempt to reduce the cost and disruptions associated with excavation and replacement, the sanitary sewer system rehabilitation industry has developed "no-dig" (trenchless) technologies for sanitary sewer collection system rehabilitation [9, 10]. Over the last thirty years, engineers have developed a whole range of technologies to rehabilitate sewer pipes, manholes, pumping stations and other elements of sewer systems without the need for excavation [11].
Trenchless construction is an emerging area of construction involving innovative methods, materials, and equipment used for the installation of new and the rehabilitation or replacement of existing underground infrastructure with minimal or no need for open cut excavation [7]. Also, trenchless technology has been described (but not universally accepted) as the collection of technologies and methods that can be used to repair, upgrade, replace or install underground infrastructure systems with minimum surface disruption [12, 13].

Trenchless sewer rehabilitation methods include:
- Pipe Bursting, or In-Line Expansion
- Sliplining
- Cured-In-Place Pipe, and
- Modified Cross Section Liner [14, 15].

Table 1: Comparision of trenchless techniques according to the pipe diameter, installation lengths and costs [14, 15]

Method	Pipe diameter [cm]	Installation lengths [m]	Cost range [$/m]
Pipe Bursting	10-60	230	130-260
Sliplining	10-400	300	260-550
Cured in Place Pipe	10-270	150-900	80-215
Modified Cross Section Liner	10-40	800	58-162

Trenchless technology brings with it the following favorable features when compared to the traditional method of excavation:
- no excavation is necessary between access locations (often existing manholes) which are generally spaced at considerable distances apart;
- a limited number of construction vehicles and activity is necessary and they are focused only at the access locations;

- a continuous 24-h working environment is possible with minimal disturbance to the adjacent community;
- there is significantly less visibility of construction operations which can lead to fewer insurance claims and less contractor liability;
- a completed system results, which in some cases is stronger than the original
- a final system results, which can have greater flow characteristics than the original [6].

2 Techniques for Trenchless Sewer Rehabilitation

2.1 Pipe Bursting

Pipe bursting (Figure 1) is a trenchless technology that replaces a sewer by breaking and displacing the existing pipe and installing a replacement pipe in the void created. The system uses a pneumatic, hydraulic, or static bursting unit to split and break up the existing pipe, compressing the materials into the surrounding soil as it progresses. The new replacement pipe is simultaneously pulled or pushed with the bursting head to fill the void created [16]. The main difference between each method is the manner in which force is generated and transferred to the original pipe during the bursting operation. Static methods burst the original pipe using static forces, or forces developed from the geometry of the bursting head as it is pulled or pushed through the existing pipe. The pneumatic pipe bursting method utilizes a bursting head that displaces the soil using a horizontal hammering force developed with air from a compressed air system. Hydraulic expansion method of pipe bursting is defined by the method in which the host pipe is burst. Rather than the pipe being burst from the transfer of an axial pulling or hammering force radial into the plane of the pipe diameter, the bursting head expands radially fragmenting the pipe from inside. Using hydraulic cylinders, the head expands to burst the pipe, then contracts to allow the winch to pull the cable and advance the head incrementally forward [5]. The Pipebursting™ method, patented by the British Gas Company in 1980, was successfully applied by the gas pipelines industry before its applicability was identified by other underground utility agencies [14].

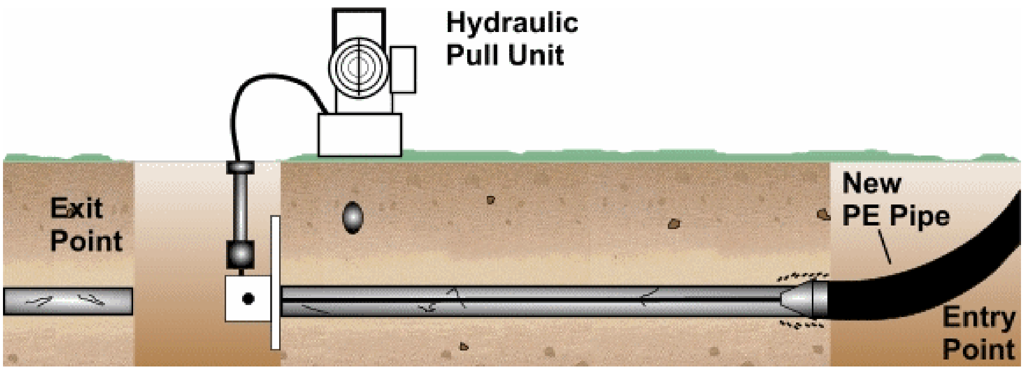

Figure 1: The pipe bursting process [17]

Upsizing of the new pipe to a diameter greater than the existing pipe is possible in some circumstances [18]. It is possible to upsize to about 30 percent greater than the diameter of the existing pipe, but this depends on soil conditions, the proximity of other existing structures, and the depth of cover [14].

In general, the pipe bursting project is subdivided into sections or lengths that the specific equipment being used can burst based on the geometry and layout of the total length of pipe being replaced. The length of pipe that can be replaced in a section is dependent on the type of pipe being burst, degree of upsize, soil conditions, geometry of the original installation, and the type of bursting equipment and method used [5]. After the pipe bursting is completed, laterals are re-connected, typically with robotic cutting devices [14].

2.2 Sliplining

Sliplining is the insertion of flexible liners directly into the sewer. Either continuous or jointed discrete lengths of pipe are pulled or pushed through the existing pipe [16, 19]. Sliplining creates a new pipe inside the old sewer without a complete excavation. The sliplined pipe is then reconnected to the existing sewer at both ends [16].
The annular space between the liner pipe and the hosting pipe is then filled with a cement or chemical-based grout [20]. If the annulus between the sections is not grouted, the liner is not considered a structural liner. Continuous grouting of the annular space provides a seal. Grouting only the end-of-pipe sections can cause failures and leaks [14]. The grout may cause the new and host pipe to act as a composite, increasing the pipe's ring stiffness and its resistance to external hydrostatic loads. Where grouting is necessary the proper selection and application of grout is often the most difficult part of a slip lining job [21].
The various polymeric pipe materials used to slip line sewers are high density polyethylene (HDPE), polypropylene (PP), fiberglass reinforced polyesters (PET-R), reinforced thermosetting resins (TR-R), and polyvinyl chloride (PVC). However, HDPE is by far the most commonly used material in this application. HDPE is well suited because it is flexible, has a high modulus, is tough and is corrosion resistant [6]. Methods of sliplining include continuous, segmental and spiral wound [14, 22]. All three methods require laterals to be re-connected by excavation or by a remote-cutter. In continuous sliplining (Figure 2), the new pipe, joined to form a continuous segment, is inserted into the host pipe at strategic locations. The installation access point, such as a manhole or insertion pit, must be able to handle the bending of the continuous pipe section [14].

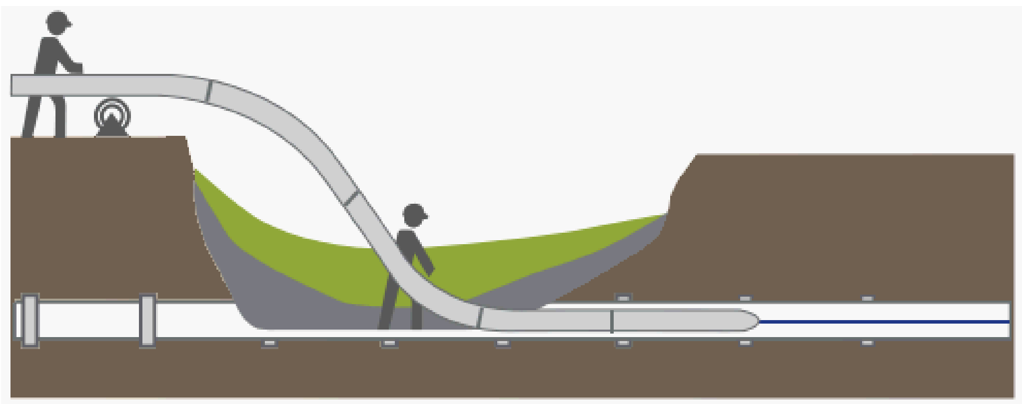

Figure 2: The continuos sliplining process [23]

The segmental method involves the use of short sections of pipe that incorporate a flus sleeve joint. These segments are assembled at insertion pits and are pushed into the host pipe. Spiral wound slip lining is a process based on forming pipe in situ by using PVC-ribbed profiles with interlocking adges [20].

2.3 Cured in Place Pipe

The cured in place pipe (CIPP) process (Figure 3) involves the installation of a flexible tube that has been impregnated with a thermosetting resin into an existing tube [20]. The resin is then cured to produce a rigid pipe within the host pipe. The combination of the fabric material, with or without fibres, and the resin can be designed to produce a new pipe that has full structural capabilities or semi-structural capabilities [16].
A full length CIPP tube is prepared at the ground surface (Figure 4). It consists of a resin impregnated geotextile inner layer with an outer sacrificial polyethylene sleeve for containment of the resin. When properly prepared, the tube is installed into the existing pipe through a manhole via a temporary inversion standpipe and elbow. The tube is clamped to the end of the inversion assembly and water is used to fill the standpipe [6]. The force created by the column of water in the standpipe pushes the tube into the host pipe turning itself inside out as it advances [6, 24]. This process results in no relative movement between the CIPP and the existing pipe wall [6].
The CIPP method can rehabilitate pipelines with defects such as cracks, offset joints, and structurally deficient segments. The two primary methods of installing CIPP are winch-in-place and invert-in place. Laterals are typically reinstated with robotic cutting devices [15], or, for large-diameter pipes, by manually cutting the liner [14].

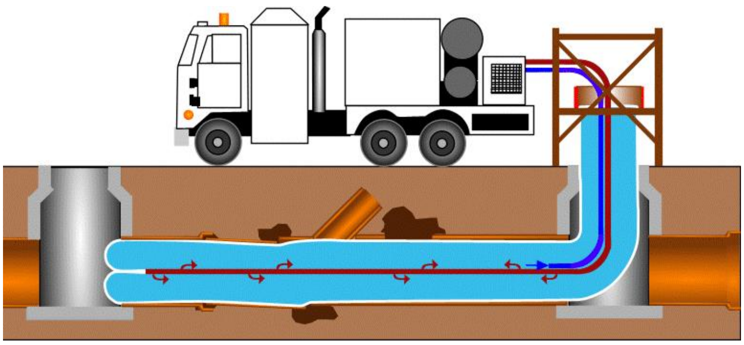

Figure 3: The cured in place pipe process [25]

Figure 4: CIPP large diameter liner [26]

At present, 80% of the world trenchless repair technology is CIPP lining repair technology, which was invented by the British in 1971 [27], so CIPP is proven technology with 40 years of successful installations [28]. The construction crew for renewing the laterals consist of 5 to 6 technicians [29], or 7 technicians [30], a mobile resin impregnation trailer and a steam generating truck [29]. This method is used for sewers, storm water drains, pressure pipelines carrying effluents [31].

2.4 Modified Cross Section Liner

The modified cross section lining methods include deformed and reformed methods [14, 15], swagelining™, and rolldown. These methods either modify the pipe's cross sectional profile or

reduce its crosssectional area so that the liner can be extruded through the existing pipe. The liner is subsequently expanded to conform to the existing pipe's size [14].
During deformed and reformed pipeline renewal, a new flexible pipe is deformed in shape and inserted into the host pipe (Figure 5 and 6). While the method of deforming the flexible pipe varies by manufacturer, with many processes referred to as fold and form methods, a typical approach is to fold the new liner into a "U" shape, reducing the pipe's diameter by about 30 percent. After the liner is pulled through the existing line, the liner is heated and pressurized to conform to the original pipe shape.
Unlike CIPP, modified cross section methods do not make use of resins to secure the liner in-place. Lacking resin-coated lining, these methods do not have the curing time requirement of CIPP. A tight fit is obtained when the folded pipe expands to the host pipe's inside diameter under applied heat and pressure. As with the CIPP method, dimples are formed at lateral junctions and similar methods of reconnecting the laterals can be employed. Materials typically used for modified cross section linings include polyvinyl chloride (PVC) and high density polyethylene (HDPE) [14].

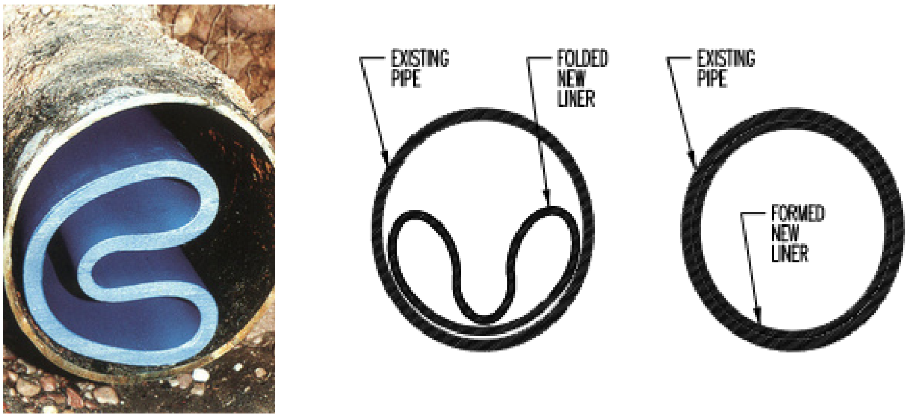

Figure 5 and 6: Real deformed pipe-liner [32] and deformed and reformed liners [14]

3 Conclusions

When considering the infrastructure of a city, the sewer system is one of its most expensive elements. Sewer system maintenance is essential for ensuring the transportation of wastewater to the treatment facility. Many cities have obsolete sewer systems, which cause health, environmental, and economic problems. For that reason, the issue regarding the rehabilitation of sewer systems and relevant related sewer system rehabilitation technologies is becoming very important. There is a wide range of currently available technologies for sewer system rehabilitation, starting with the traditional technology – excavation, toward modern technologies that do not require excavation, i.e. trenchless technologies.
There are significant advantages to trenchless technologies. Also, the methods that do not require excavation have great potential with regard to reducing traffic congestion in areas with a high frequency of traffic, near historical buildings, valuable trees, etc. Furthermore, if the pipes are located under the surface, trenchless methods can provide a significant reduction to excavation costs. The application of trenchless technologies for sewer system rehabilitation

can result in significant economic and social savings, as well as contribute to the protection of the environment and reduce the amount of time required for pipe rehabilitation.

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