A primer on sanitary sewer rehabilitation

Repair and renewal can reduce extraneous flow and address structural defects

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Portions most of sanitary sewers – collection systems that are intended to carry only sanitary wastewater – include more than just pipes. The pipes are part of an entire conveyance system that includes pump stations, force mains, manholes, storage facilities, and other components.

For the continued health and operation of these systems to operate most effectively, excess flows, such as those from infiltration and inflow (I/I) need to be minimized. Extraneous water entering any collection system can consume some or all the available capacity as originally designed. These additional flows have a significant effect in sanitary sewers, which are relatively small because they are sized to collect wastewater flow, not stormwater.

Sewer rehabilitation is a means to reducing the extraneous flow entering the system. Correcting defects lowers the potential for overflows and flooding. Defects also can be structural in nature and rehabilitating them can help prevent structural failure. Some rehabilitation practices apply to mainlines located in the public right-of-way or dedicated easement, while others are better suited to rehabilitation of private sewer laterals that connect homes/buildings to the sewer mains in the public right-of-way.

Flow sources

Extraneous water may enter the pipes from unintended sources, either from surface water, groundwater through defects, or direct illicit connection. These defects are pipe system deficiencies resulting from system aging, structural failure, lack of proper maintenance, and/or poor construction and design practices. They can include conditions such as broken pipe; leaking joints; manhole lids with holes and/or poor sealing; and root infested sewer laterals. The figure on p. 45 shows where leaks can occur. In sanitary sewers, this can lead to excessive I/I, which can be more noticeable after precipitation conditions.

When the available capacity is reduced, or consumed, water levels rise and surcharging can occur. Surcharging, when the water level exceeds the height of the pipe, can accelerate pipe deterioration by forcing water to leave the pipe through defects into surrounding soil, and bringing in surrounding soil when the surcharge is alleviated, causing voids to form outside the pipe. Surcharging can lead to sanitary sewer overflows (SSOs) either in the street or into buildings as well as surface flooding. I/I entering sanitary sewers is the highest level of concern.

Sewer laterals, which connect buildings on private properties to sewer mains, often are a significant source of I/I. A comprehensive I/I reduction program requires effectively addressing private property I/I (PPII) sources. Private property laterals can account for half of the I/I entry to sanitary sewers.

Growing extraneous flow is one symptom of the poor structural condition of aging sewers in many cases. Hence, sewer rehabilitation provides a solution to extend the useful life of the asset. Consequently, rehabilitation can result in reduction of extraneous flow, which in turn reduces sewer surcharges and unintended poor system performance.

System management

State-of-the-art water sector experience indicates that before investing in sanitary sewer capacity expansions to handle excessive I/I, it is prudent to improve sewer system structural conditions to realize practical levels of I/I reduction. Only then should a utility or sewer district consider supplementing with right-sized conveyance and/or storage and downstream treatment systems. Asset management approaches to sewer system rehabilitation are effective and adding criteria to reduce extraneous I/I will help prioritize public investments.

Moreover, reducing PPII is critical for overall success of I/I reduction efforts. Rehabilitating the sewer system should be undertaken first to determine the magnitude of I/I reduction possible. It may be that partial or comprehensive rehabilitation of the system restores adequate levels of the conveyance capacity.

Repair versus renewal

Sewer rehabilitation can be considered both repair and renewal to reduce extraneous flow and address structural defects. Rehabilitation is different from system replacement in that repairs selectively target I/I sources and structural defects rather than complete replacement of pipes and/or manholes. Not all sewer defects cause capacity restrictions or are considered I/I sources.

Repairs generally are made to enable the pipe to function to the end of its useful life. They can involve location-specific repairs that seal the sewer pipeline and may restore the structural integrity of the pipe at that location. However, this type of repair does not restore the structural integrity of the entire pipe. Some repairs also may seal an entire pipe segment but not restore structural integrity.

Sewer repair encompasses many methods, including internal and external point repairs, sealing joints or cracks, spray-lining or applying a coating, and partial replacement.

Renewal is more comprehensive than repair and extends the useful life of the pipe. Renewal includes techniques that renew the structural integrity of the entire sewer pipeline segment between manholes. Pipeline renewal techniques include various liners, coatings, and panel systems as well as replacing segments of pipe. Like all rehabilitation methods, eventually renewal technologies will generally decrease in effectiveness until replacement becomes the most cost-effective alternative.

Sewer rehabilitation projects can include a mixture of repairs and renewal – with a focus on both restoring structural integrity and practical reduction of I/I. Each system component is analyzed to determine where defective areas allow I/I to enter the system and the most cost-effective repair or renewal method is applied to eliminate that source of I/I while ensuring that the extraneous water does not migrate to enter the system through a different defect.

For sewer mains, a rehabilitation project may include a combination of selective sealing, point repairs, partial replacement, and lining. It is through a comprehensive analysis that the most cost-effective combination of repair, renewal, and replacement techniques are employed to meet objectives for structural condition improvements, I/I control, or both. Some methods can only be used on larger diameter pipe, while others are more universal.

Conditions affecting rehabilitation

With many options available to rehabilitate sewers, the conditions affecting sewers should be considered before deciding on a rehabilitation method. Factors to consider when selecting a rehabilitation method include, but are not limited to,

- pipe characteristics (age, diameter, shape, material, length, joint type and frequency, slope, depth, and number of service laterals connected),
- soil and groundwater conditions that effect the structural conditions and active infiltration and/or high groundwater,
- sewer location (public right-of-way or an easement or private property),
- service area characteristics (number of connections and/or tributary area; and previous evaluation data from televised inspection, smoke testing, dye water testing; maintenance history on needed frequency of cleaning or root cutting; and flow monitoring data that indicates dry weather conditions and/or wet weather response), and
- installation conditions, access restrictions, and other factors to be considered during construction.

Sanitary sewer infiltration and inflow sources

Methodologies for sewer pipe rehabilitation

Sewer pipe failure most often results from lack of maintenance. Three stages of decay warrant definition and are a direct result of I/I.

- Stage 1 – Initial defect allows the deterioration process to begin. Pipe remains supported by the surrounding soil.
- Stage 2 – Structural defects continue deterioration to a point where soil around the pipe egresses into the pipe through infiltration at defects. This causes a loss of supporting soils and leads to voids developing outside the pipe, accelerating deterioration.
- Stage 3 – Loss of support from surrounding soil allows deformation or joint defects to degrade, leading to structural failure.

Based on a thorough condition assessment, both structural and nonstructural trenchless rehabilitation methodologies are proven to remediate and restore useful life of sewer pipe. The advantages of trenchless are numerous including time-to-benefit, minimal disruption to the community, and lower project costs. As opposed to defaulting to open-cut replacement methods, trenchless alternatives provide several options.

Trenchless methodologies: non-structural rehabilitation

Injection grouting. Utilizing the *Test, Seal, and Validate process with Remote Packer Method*, injection grouting is a remediation method for controlling infiltration and should be performed prior to pipe degradation requiring structural repair. With the aid of closed circuit televising (CCTV), the remote packer aligns squarely with the joint, expands bladders on both sides, and performs an air test. If it does not leak air, it will not leak water. If it fails the air test, a low-viscosity acrylic

Sanitary sewer rehabilitation summary matrix

Technique	Type	Estimated service life*	Advantages	Disadvantages	Potential application pipe diameter	Recommended for		
						Mainline	Lateral	Manhole
Cementitious coatings								
Shotcrete or Gunite	Structural/ non-structural	20+ years	All shapes and connections accommodated.	Address active infiltration, requires confined space entry	>1200 mm (48 in.)	Yes	No	Yes
Spun cast concrete	Structural/ non-structural	Same as concrete pipe	Robotically applied. Antibacterial additive can be added when microbiologically induced corrosion is present.	Address active infiltrations	750 to 3000 mm (30 to 120 in.)	Yes	No	No
Spray polymer coatings	Structural/ non-structural	50 years	Encapsulates sewer, can be designed for structural load, can improve flow coefficient	Sags and dips in pipe remain, service interrupted, must stop active infiltration	>150 mm (6 in.) provided host pipe wall can be cleaned and dried properly	Yes	No	Yes
Cured-in-place pipe (CIPP)	Structural	50 years	Prevents further degradation and collapse, improves flow coefficient	Sags and dips in pipe remain, service interrupted, infiltration may follow annular space	75 to 3000 mm (3 to 120 in.)	Yes	Yes	Yes
Thermo-formed pipe (fold and form)	Structural	20+ years	Prevents further degradation and collapse, improves flow coefficient	Sags and dips in pipe remain, service interrupted, infiltration may follow annular space	100 to 750 mm (4 to 30 in.)	Yes	Yes	Yes
Injection/ pressure grouting	Non-structural	20 to 25 years	Seals leaking joints, stabilize supporting soils	Offset joints or longitudinal cracks may not seal	>100 mm (4 in.)	Yes	Yes	Yes
Sliplining	Structural	50 years	Quick insertion, some bends are accommodated	Circular and noncircular, loss of cross-sectional area	100 to 3600 mm (4 to 144 in.)	Yes	Yes	No
Spiral-wound pipe	Structural	50 years	Prevents further degradation and collapse, improves flow coefficient	Sags and dips in pipe remain, service interrupted, infiltration may follow annular space	150 to 3600 mm (6 to 144 in.) larger sizes on case-by-case basis	Yes	No	No

*Source: National Database Structure for Life Cycle Performance Assessment of Water and Wastewater Rehabilitation Technologies (Retrospective Evaluation) – EPA/600/R-14/251 grout is pressure-injected through the defect into the surrounding soil to provide stabilization. A second air-test validates the seal.

Gel-times can be customized from 5 seconds to over 12 hours based on the degree of permeation required into the soil. The gel-soil matrix forms an impermeable barrier to eliminate groundwater intrusion and, according to the U.S. Department of Energy, has a 362-year half-life in the soil. It is noted there are multiple types and variations of grouts available for use, depending on the application and desired results.

Trenchless methodologies: structural remediation

Pipe linings are tight fitting and installed continuously from one access point to the next. Linings provide structural renewal of the pipe barrel, improve the performance of the existing sewer, and are appropriate for various pipe sizes and shapes.

Cured-in-place pipe (CIPP). Used primarily for structural rehabilitation of sewer lines, CIPP consists of a tubular composite product composed of a reinforced mesh or felt material saturated with a thermosetting resin that cures through ambient temperatures, hot water, steam, or ultraviolet (UV) light. Resins typically are selected based on CIPP performance requirements (gravity or pressure) and the nature of the wastewater (domestic or industrial).

Sliplining. This method rehabilitates deteriorating sewer pipes by inserting a smaller pipe inside the host pipe. High-density polyethylene (HDPE) is a widely used pipe material for sliplining; however, other materials such as polyvinyl chloride (PVC), fiber-reinforced polymer (FRP) pipe, polymer concrete pipe, and other pipe materials have been used successfully. The slipliner pipe is inserted into the existing pipe at an excavated access pit location. For small diameter pipe, a continuous pipe – often butt-fused HDPE – is typically pulled through the existing pipe by a cable from the termination location. Large diameter pipes more often are pushed, jacked, or winched into place, piece by piece. Depending on the design conditions and pipe size, the annular space is grouted.

Spiral-wound pipe. This renewal technique is based on creating a pipe *in situ* by using HDPE or PVC-ribbed profiles with interlocking edges. The ribs, which may be reinforced with steel, enhance the hoop strength of the pipe. After the strips are installed, the annular space is grouted in entry size pipe. Small diameter pipe (12-in. or less) typically is not grouted except at the terminations and any side connections. Spiral-wound pipe can be fitted to circular or odd-shaped pipes such as horseshoe or egg-shaped sewers.

Fold-and-form pipe. This sewer rehabilitation method inserts a folded, thermoplastic pipe into the existing pipe. The folded pipe is expanded or re-rounded back to a circular shape through pressure, heat, or mechanical means. Fold-and-form pipes consist of PVC or HDPE thermoplastic material folded into a cross-sectional shape that is significantly smaller than that of the pipe to be rehabilitated.

Structural and nonstructural spray or spun cast systems

In-situ spray or spun cast coatings or structural solutions may be used to extend the life of an existing sewer by increasing its strength or protecting the existing surface from corrosion or abrasion. Coatings also may be used to improve hydraulic performance.

Corrosion protection (nonstructural). Coatings for corrosion control limit or prevent damage to the pipe walls, often above the flow line in entry-size sewer pipes. Various coatings are available for rehabilitation applications to pipes of all diameters. Spray-on epoxy, polyurethane, polyurea, and other chemical formulation coatings can be selected to match the application, pipe diameter or size, and level of protection needed. Because coatings for corrosion control require a bond to the host pipe, the host pipe wall must be properly cleaned and dried before application.

Reinforced shotcrete (structural). Shotcrete is the application of concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto the surface of the host pipe. Wire mesh rods can be used for underlying reinforcement. Shotcrete includes both wet- and dry-mix processes, but the term *shotcrete* typically refers to the wet process; the dry-mix process typically is referred to as *gunite*.

Centrifugally cast concrete (structural). Centrifugally cast concrete pipe is used to rehabilitate culverts, storm sewers, and sanitary sewers 750 to 3000 mm (30 to 120 in.) in diameter. Once the host pipe is cleaned and prepared, the concrete is robotically spun-cast onto the surface of the host pipe. Additive mixtures to the spun-cast concrete can provide resistance to corrosion and future bacterial growth on the interior surface of the pipe.

Cast-in-place concrete (structural). Rehabilitation with reinforced or nonreinforced concrete is an effective method for many conduit shapes. The structural condition of the pipe determines if steel reinforcing is required. Slip- or fixed-form construction practices are used for concrete placement typically in pipes with diameters larger than 1200 mm (48 in.). These pipe sizes allow for adequate access for materials to be handled properly.

Choosing the right method

It is common for multiple technologies and more than one methodology to be deployed on a mainline sewer rehabilitation project. Most lining projects require very little or no infiltration during the application as well as flow diversion and pipe cleaning. Coating projects may require flow diversion and specific surface preparation, depending on whether a bond to the host pipe or structure is required. Coating techniques require removal of active infiltration during application.

Three underlying assumption accompany all sewer rehabilitation techniques. Without meeting all three of these objectives, the sewer rehabilitation may not be successful.

- The technique is the appropriate choice for the pipe condition.
- The solution is adequately designed and specified.
- The repair or replacement material is installed correctly.

The table on p. 46 provides as an introduction to potential rehabilitation methods, type of rehabilitation, advantages and disadvantages, and applicable pipe size. As noted on this matrix, not all sewer rehabilitation techniques are common to both mainline sewer and the lateral sewers connecting private homes and buildings. This summary matrix should be considered a starting point for evaluating rehabilitation alternatives and it is not intended to be comprehensive.

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