CHAPTER 6

REHABILITATION

FIGURES

TABLES

INTRODUCTION

Sewer system rehabilitation is a necessary part of any wastewater collection system operation and maintenance program. When sewer system defects have been identified during routine inspections, they need to be repaired before an emergency situation occurs.

Sewer systems deteriorate over time as a result of chemical attack, ground movement, excessive load transfers, root intrusion, and poor construction of the original system. When selecting a rehabilitation technique the following factors should be considered:

1. The cause of the deterioration.
2. Cost.
3. Potential infiltration and inflow reduction.
4. Traffic disruption and effect on other public utilities.
5. Maintaining sewage flows.
6. Safety.
7. Structural characteristics of the sewer system.
8. Compatibility with other planned public works projects.
9. Long-term effectiveness of the technique used.

If an emergency situation does occur and the repair work must be done by an outside contractor, measures should be taken to retain a contractor who will agree to mobilize and make the necessary repair immediately. The names, addresses, and phone numbers of contractors agreeing to provide emergency repairs should be recorded in convenient locations.

Before any type of rehabilitation program begins, it is important to notify the public utility companies with lines near the proposed rehabilitation of the type of work which will be completed and the work schedule. Utility lines should be clearly marked before any digging begins.

The personnel actually assigned to do the rehabilitation work must be trained properly regarding safety requirements before starting the rehabilitation work. The training program should include direction on safely entering confined spaces such as manholes and sewers and the safety requirements for using and handling rehabilitation equipment and materials. If necessary, traffic control measures must also be planned before starting the rehabilitation work. Details on safety are included in Chapter 9.

MANHOLE REHABILITATION

General

Manholes are usually rehabilitated to correct structural deficiencies or to eliminate the entrance of surface water or groundwater. Manhole rehabilitation may be required to minimize or prevent corrosion of the internal surface caused by sulfuric acid which can form when hydrogen sulfide is released from the wastewater. Rehabilitation procedures are often applied to manhole covers and frames to prevent the entry of surface waters. This extraneous flow enters through holes in the cover, through spaces between the frame and cover, and under the frame if it is poorly sealed. A program should be developed to insure that manhole rim elevations are properly adjusted following paving work.

Most rehabilitation work involving manhole sidewalls and bases is intended to reduce infiltration of water into the collection system. If a manhole is severely deteriorated, it is often less costly to replace the manhole. However, when a manhole is structurally sound, repair methods are normally effective for correcting the problem. The cause of deterioration must be determined and a comparison of costs of replacement versus rehabilitation must be done before a decision as to which corrective measure to use can be made.

Manhole Cover Rehabilitation

Manhole covers with open pick holes can contribute significantly to an inflow problem especially if the manhole is located in a low lying area subject to frequent ponding of stormwater. Several solutions are available for reducing inflow into the sewer system from manhole covers including the following:

1. Install bolts through the holes. Use stainless steel bolts sealed with caulking compound or neoprene washers installed on the bottom of the cover.

2. Use commercially available inserts installed under the cover which prevent water, sand, and grit from entering the manhole while gas is allowed to escape through vents.

3. Replace cover. A cover with concealed pick holes and a well-machined cover and frame joint is often the best solution. Sometimes it may be better to replace both the frame and cover at the same time to insure that the new cover fits the frame properly.

4. Self-sealing manhole covers with flexible gaskets bearing on the frames are available. The disadvantage of using these self-sealing covers is the difficulty of inserting the gasket into the groove. Also, the gaskets normally do not last very long. In areas where manhole covers are subject to removal by vandals, commercially available bolt down covers can be used.

Manhole Frame Rehabilitation

Deteriorated manhole frame and grade adjustment rings can be a significant source of inflow of surface waters. Manhole frame seals are often damaged by construction work, heavy traffic loads, freeze-thaw cycles, exposure to damaging chemicals and snow plowing. The method of repair depends on whether or not the frame must be raised or lowered.

Frame Seal. If a manhole frame does not need to be replaced and is properly graded, but is poorly sealed to the manhole, one of the following in-place rehabilitation techniques can be used:

1. Frames may be sealed in place by chiseling cracks and openings at the interface between the manhole frame and cone (or grading rings) and applying hydraulic cement coated with a waterproofing epoxy. Oakum rope is sometimes used to fill large openings before applying the hydraulic cement. This type of seal normally cannot withstand freeze-thaw forces.

2. Flexible rubber sleeves can be compressed against the side of the frame and adjusting rings with stainless steel expansion rings are available. These are referred to as manhole chimney seals and they can be placed internally, externally, or both internally and externally.

3. Elastomeric sealants are effective in sealing manhole parts subject to movement from freeze-thaw forces. The sealant is placed at potential lines of movement both inside and outside of the manhole.

Frame Adjustments. If a manhole frame must be adjusted several materials are available to provide the necessary adjustment and a watertight seal. These include:

1. Frame extension rings. These are commonly used during road resurfacing projects to raise the manhole rim elevation. They are designed to eliminate excavation of the existing frame and the need to install concrete grading rings. Frame extension rings are available to increase the rim elevation of a manhole by several inches. They also are designed to fit in the existing frame and to allow the existing manhole cover to be used. The extension rings are secured to the existing frame using set screws, epoxy compounds, or expansion bolts and are used with watertight caulks or sealing gaskets between the existing frame and the extension ring.

   Frame extension rings can also be purchased that allow for adjustments in grade, and slope of the manhole cover after installation.

2. Precast concrete adjusting rings with flexible rubber-like gasket material. The gasket material is placed in between all the joints, and the weight of the ring compresses the gasket to seal the joint. The adjusting rings can also be made with brick or concrete blocks. Installing adjusting rings requires some excavation and restoration around the top of the manhole.

   Precast concrete adjusting rings are available with flat tops or inclined tops. The type of adjusting ring selected should match the surrounding grade at the top of the manhole.

Structural Rehabilitation

Structural rehabilitation of manhole walls is required when they have deteriorated to the point of being unsafe to enter or work inside.

Severe structural deterioration is generally due to corrosion by sulfuric acid produced in the sewer system, poor original construction, ground movement, age, or overloading normally in areas of heavy traffic. Correction of severe deterioration problems is usually done by replacing the manhole or by performing extensive repair work. Whatever corrective measure is decided upon, it should perform the following functions:

1. Remove the causes of deterioration or include means to resist it. This might entail the application of high strength compounds such as hydraulic cement mixed with additives (plaster additives, bonding agents, etc.) to the manhole walls.

2. Ensure manhole safety. If a manhole is severely deteriorated, then the manhole ladder rungs are also suspect. Weak or corroded rungs should be removed and not replaced, or replaced with corrosion resistant rungs.

3. Ensure efficient use of pipe capacity. If the flow is restricted or totally obstructed, corrective measures should be taken to improve the wastewater flow characteristics.

Manhole Repair. Structural repair of manholes involves several steps. The removal of all deteriorated materials from the interior surface is of primary importance. This can be done by waterjetting, sandblasting, applying acid solutions or by using mechanical tools. If a coating is to be applied to the manhole to restore structural integrity, the entire surface should be thoroughly cleaned first. Also, any surface irregularities such as missing bricks or spalled concrete should be patched. Finally, the lining or coating system is applied. Coatings are commonly applied to manhole walls using spray guns, gunite guns, rollers, brushes or hand trowels. If corrosion is a problem, plastic or epoxy coatings are often applied to provide an effective barrier between the concrete and the corrosive atmosphere. Also available are precut polyethylene or fiberglass sheets that can be used to line manhole walls.

Manhole Replacement. When structural deteriorations are too severe or too costly to be corrected by repair methods, the manhole can be partially or completely replaced. When determining if a manhole is more costly to repair than to replace the following replacement factors must be weighed against repair costs:

1. Excavation.

2. Pavement removal and replacement.

3. Traffic disruption.

4. Excavation dewatering requirements.

5. Conflicts with other utilities and structures.

6. Shoring requirements.

7. Maintaining sewage flows.

8. Landscaping or other restorations.

9. Labor, material, and equipment requirements.

Manhole sections are typically replaced with precast concrete sections with tongue and groove joints sealed with a flexible rubber-like gasket material. The manhole sections are easily moved using standard construction equipment with lifting rings precast into each section.

Existing manholes can also be replaced using prefabricated fiberglass plastic manholes. These are corrosion resistant and effective for sealing out groundwater. To prevent uplifting of these lightweight structures concrete bases are normally used. The manhole bench and channel would also need to be replace to match the existing sewer inlet and outlet piping.

Sealing Manhole Walls. When infiltration through structurally sound manholes is a problem, a variety of repair techniques are available for sealing the manhole walls. The most common techniques include:

1. Pressure injecting chemical grouts. This method requires drilling holes through the manhole walls at each point where infiltration is entering the manhole. For best results, chemical grouting should be done during high groundwater conditions so the maximum number of leaks will be visible. Chemical grout is pumped through the previously drilled holes through an injection packer until sufficient grout has been pumped to fill in voids on the outside of the manhole. While pumping the grout, the pressure being exerted against the outside of the manhole walls must be monitored to insure that it does not increase to a point where it can cause damage to the manhole structure. After the pumping stops, the injection hole is filled with hydraulic cement.

2. Install rubber joint seals at leaking precast manhole section joints. These types of joint seals are similar to manhole chimney seals. They are compressed against a leaking joint with stainless steel expansion bands.

Channel and Bench Rehabilitation

Channels and benches at the bottom of manholes often need to be repaired or replaced if they have deteriorated to the point of allowing significant amounts of infiltration to enter the sanitary sewer system through the bottom of the manhole or if the channel needs to be modified to improve the hydraulics through the manhole. Sometimes when the bottom of a manhole deteriorates the structural damage is not visible. Evidence of deterioration may be observed in the form of clear water bubbling up from the bottom of the manhole channel if the defect is severe enough and groundwater levels are high enough.

Manhole channels and benches can be partially or totally removed and then reconstructed. When channel and bench work is being done sewage flows need to be temporarily rerouted. When a channel is reconstructed it is important to allow enough space in the new channel to properly operate sewer maintenance equipment in the future such as sewer cleaning equipment, closed circuit TV cameras, and sewer line grout injection packers. Corrosion resistant materials can be used when reconstructing manhole channels and benches in manholes where corrosion is a problem.

Manhole Pipe Connections

A common source of infiltration at manholes is at the manhole pipe connection. These connections become defective as a result of differential settling between the manhole structure and sewer pipe. To effectively seal out the infiltration, the area around the manhole base needs to be excavated. Flexible couplings are manufactured to provide a watertight seal between the manhole and pipe. New manhole sections can be purchased with the flexible pipe couplings precast into the manhole barrel. The sewer pipe is inserted into the coupling and secured with stainless steel clamps. Typically, a limited length of new sewer pipe is installed next to the manhole to complete the repair. It is important to compact the bedding material under the pipe and around the manhole base before backfilling to minimize further differential settling.

SEWER PIPE REHABILITATION

General

Damage done to sewer pipes can occur from natural causes or from industrial wastes, overloading, poor design and workmanship. The most common pipe failures are either structural or corrosive in nature, and occur most often in gravity flow pipes. Corrosion failures are usually found in the crown or invert of sewer pipes, in joints where cement mortar was used, and in other areas where various types of acidic corrosion cause impending failure of the materials used in sewer construction. Corrosion of inverts is often caused by the disposal of corrosive or erosive industrial wastes, while external corrosion is evident in pipes buried in soils with an extremely high level of acidity and with a groundwater level that rises above and falls below the pipeline frequently.

Structural sewer pipe failures are generally due to the following causes:

1. Improper pipe bedding. Failure occurs when a pipe is laid in a trench that has a rock bottom, or when it is laid in a trench where rock protrudes. A pipe failure can also occur if the bedding is not placed uniformly in the pipe trench during construction of the sewer line. Also, if improper bedding material is used on steep slopes, fines can be washed downhill through the bedding eventually, causing failure due to non-uniform support beneath the pipe. Pipe sections failing in this manner require replacement and should be bedded properly and backfilled carefully.

2. Failure due to live loads. Pipe laid with insufficient cover may be broken by a surface load imposed on it by traffic or by heavy construction equipment. If adequate cover cannot be placed over the pipe to protect it from traffic loads, the damaged pipe can be replaced with stronger pipe. Also a loading slab or concrete arch can be installed over the pipe to protect it from live loads.

3. Failure due to earth movement. This type of damage is caused by frost-heaving or shifting soil. Pipes damaged in this manner must be rebuilt, preferably below the frost line.

4. Root-growth damage. Where a root has become so large that it has displaced or crushed a pipe, it is usually necessary to dig up the pipe, cut the root, and replace the damaged pipe.

5. Failure due to openings into the sewer. Any opening into a pipe, whether from an open joint or break, will eventually cause a cave-in or collapsed pipe as the surrounding soil supporting the pipe is washed into the sewer with infiltration.

Sewer pipe rehabilitation is required when the sewer line repeatedly shows partial or complete stoppage of flow due to broken or collapsed pipes and offset joints. These failures can cause excessive infiltration to enter into the system as well as further, more serious structural failures of the pipe. Generally, sewers can be repaired from inside the pipe without any or only limited excavation, or by excavating the damaged pipe and replacing it with new pipe.

When selecting a sewer pipe rehabilitation method the following factors should be considered:

1. The physical condition of the existing sewer. Knowledge of the existing sewer condition is needed to determine the best rehabilitation method and the most cost effective solution.

2. Cost. Generally repairing pipes from the inside without excavation is cheaper than the excavation and replacement method.

3. Hydraulic capacity. When selecting a rehabilitation method, the effect on the hydraulic capacity of the sewer must be considered. This is particularly important for sewer lining methods.

4. Types of materials used. When selecting rehabilitation materials, factors such as durability, chemical and abrasion resistance, and strength must be considered.

5. Installation factors such as:

   a. Maintaining sewage flows.
   b. Safety.
   c. Traffic disruption.

6. Effectiveness of each potential rehabilitation choice.

The most common methods used to rehabilitate sewer pipes include:

1. Injecting chemical or cement based grouts through pipes at ground level to stabilize soil and fill voids around the sewer pipe.

2. Chemical joint sealing from inside the pipe.

3. Sewer lining with a variety of materials.

4. Coating the interior surface of the pipe with a mixture of cement and additives.

5. Excavate and replace sewers in spot locations or completely between two manholes.

External Grout Injection

Chemical and cement grouting is done to stabilize soils, fill underground voids or washouts, and to reduce groundwater movement. This is done by pressure injecting grout through a pipe from ground level into underground soils surrounding a sewer pipe. Chemical grouts usually consist of two or more chemicals that react with each other to form a gel or a solid product which creates a plug to fill voids in the soil where the grout has been injected. A chemical mixture often used for external rehabilitation techniques is acrylamide gel.

While chemical grouts are best used on fine soils, cement grouts are more effective in medium sand and coarser soils because of the larger size of the cement particles. Instead of producing a gel as chemical grouts do, cement grouts create suspensions of solid materials in a fluid. These solid particles fill the voids in the surrounding soils. Cement grouts are generally less expensive than chemical grouts.

The external grouting method is better for stabilizing soils around sewer pipes than for sealing out infiltration. The grout must be injected in areas where known leaks exist. By injecting the grout from above ground, the chance of filling the void around the known leak is not real good. There is also a chance that the injected grout could enter the sewer pipe through the leaks.

<u>Internal Joint Sealing</u>

Internal chemical grouting is the most commonly used method for sealing leaking joints in structurally sound sewer pipes. Although smaller pipes receive more treatment by this method than larger pipes, with special equipment chemical grouting techniques can be applied to large diameter pipes. To seal a leaking joint or radial crack in the sewer system the chemical grout gels are forced out of the pipe through the leaks where they displace groundwater, mix with the soil, and begin to solidify. When the grouts finish solidifying, they form a flexible barrier around the pipe against incoming groundwater or exfiltrating wastewater. Chemical grouts which are used for sealing joints include urethane base gels and foams, acrylate base gels, and acrylamide base gels. Chemical grouts can also be applied to manhole walls, wet wells in pumping stations, and small holes.

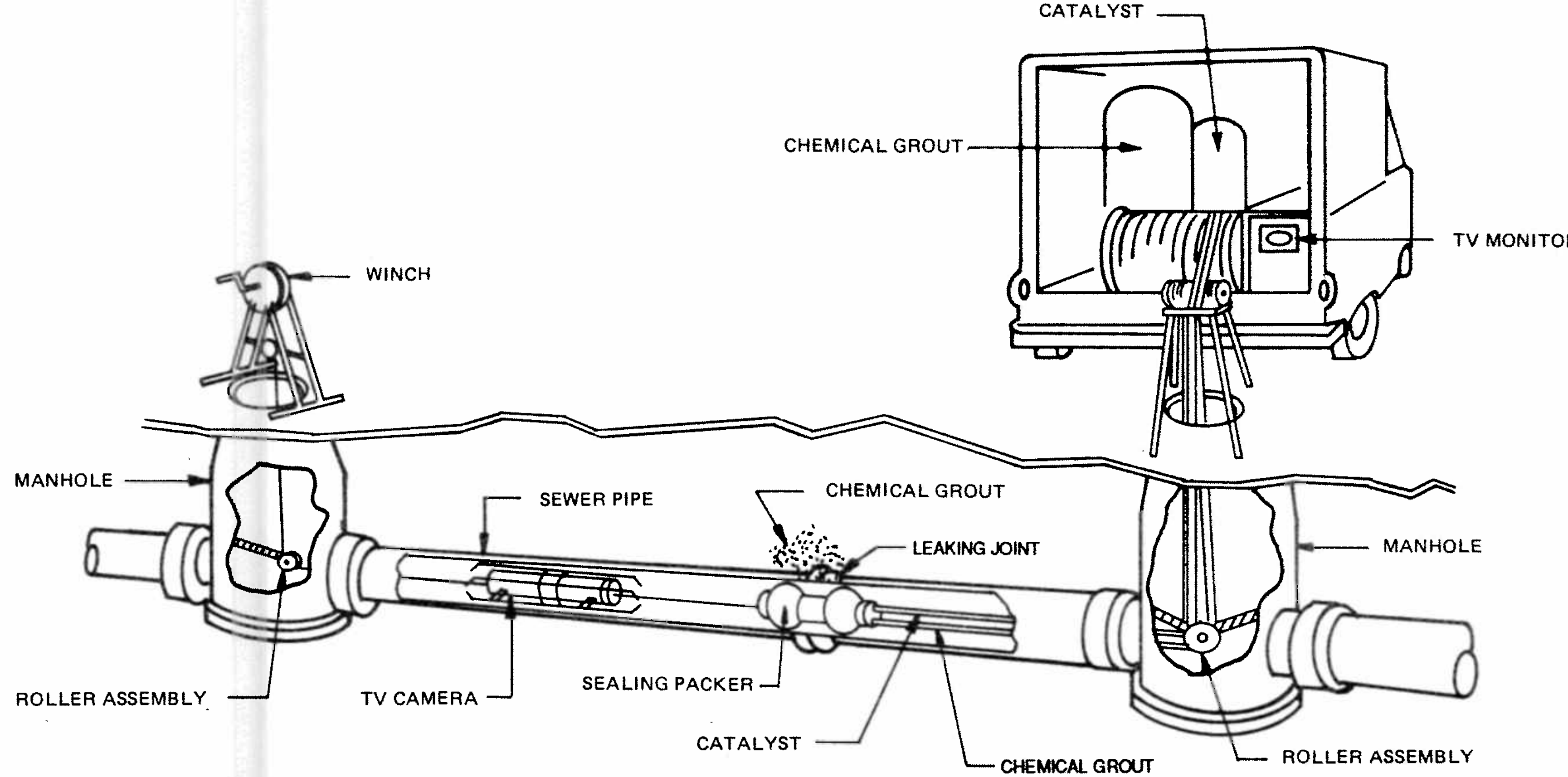
Before a sewer pipe can be chemically grouted, the sewer must be cleaned and roots removed. The structural integrity of the pipe must also be analyzed. The inside pipe walls must be smooth enough to allow proper operation of the chemical grouting equipment. To determine the estimate of chemical grouting cost, the pipe size and percentage of joints requiring sealing must be taken into account.

In small and medium sized pipes up to about 48 inches in diameter, it is common to air test all joints within a sewer reach. All joints failing the air test are grouted. This method minimizes the potential for groundwater to migrate and leak into other unsealed joints.

When using the air test and grout method to seal the interior of a pipe, the primary equipment necessary is a closed circuit TV camera and monitor, and a joint sealing packer. The TV camera equipment is used to locate the pipe joints and to monitor the grouting process. The packer is used to apply grout under pressure at the location of sewer leaks. After a sewer joint has been identified by the TV camera, the packer is positioned over the joint and tested for airtightness. If the joint fails the air test, chemical grout is pumped through the packer into the leak until either a specified maximum volume of grout has been pumped or until a specified pressure is measured. Figure 6-1 shows a typical chemical grouting set up using a joint sealing packer and closed circuit TV camera equipment.

Chemical grouting can be done when sewers are flowing partially full. Maximum flow depths for effective chemical grouting have been recommended by the National Association of Sewer Service Companies (NASSCO) and they are:

1. For 6-12 inch pipes the flow depth should not exceed 25 percent of the pipe diameter.



REFERENCE: FROM HANDBOOK FOR SEWER SYSTEM EVALUATION
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, DEC. 1975.

FIGURE 6-1. TYPICAL ARRANGEMENT FOR CHEMICAL GROUTING

2. For 15-24 inch pipes the flow depth should not exceed 30 percent of the pipe diameter.

3. For 27 inch pipes and larger the flow depth should not exceed 35 percent of the pipe diameter.

When flow depths exceed the recommended maximum depth of flow values the sewer flow must be restricted or bypassed around the section during grouted. When restricting sewer flows care must be taken so that wastewater does not backup and overflow onto private property.

The advantages of using chemical grouts to seal leaking joints include:

1. They are less costly than other internal rehabilitation methods.

2. The application time is only a few hours.

3. The operation causes little traffic disruption.

4. Because of its internal application procedure, there is no interference with other underground utilities.

5. No excavation is required.

6. No surface restoration is required.

7. In sewers where depths of flow are small, sewer flows do not need to be rerouted.

The disadvantages and limitations of chemical grout joint sealing are listed below:

1. The process requires temporary rerouting of sewer system flows when the depth of flow is greater than the recommended maximum values.

2. Toxicity problems sometimes occur.

3. Chemical grouting does not improve structural strength.

4. Is not applicable when the pipe is cracked longitudinally, crushed, or broken.

5. Joints are not sealable if they are badly offset or misaligned.

For grouting large diameter pipes, pressure grouting or manual placement of oakum soaked with grout may be used. Grouting sealing rings or predrilled injection holes can be used to pressure grout. Sealing rings are placed over the defective joint and inflated to isolate the joint. Sealing grout is then pumped into the small void between the pipe wall and the face of the ring.

With the chemical grouts available today, sewer joint grouting when done properly can provide a very effective seal against infiltration of groundwater and exfiltration of wastewater at the joint that is grouted. Unless grouting is done over a large area of the sewer system, the overall effectiveness of infiltration reduction may be limited. When random joints are grouted between manholes or when random sections of the sewer system are air tested and grouted there is a possibility that groundwater will migrate to unrehabilitated areas of the sewer system and enter through other defects.

Cement Mortar Lining

The application of coatings to the inside surface of a sewer pipe is used to rehabilitate cracked or damaged sewers and also to protect pipelines from internal corrosion. One such coating is a 1:2 portland cement mortar coating applied at thicknesses greater than one-quarter inch. For sewer pipes less than 24 inches in diameter, no reinforcing is required. For sewer pipes greater than 24 inches, reinforcement is installed using spirally-wound reinforcing rod. All diameters, however, require cleaning, temporary rerouting of sewer flows and dewatering of the line before the cement mortar can be applied.

Three processes are commonly used in the application of cement mortar:

1. The centrifugal process utilizes a variable speed winch which pulls a revolving mortar dispenser through the pipe. Its use is most economical on pipes greater than 24 inches in diameter, but can be used on 8 to 144 inch pipe. The process is slower than others, but the coated line can be opened for use within 24 hours after application.

2. The reinforced centrifugal lining process uses less steel than other processes and conforms to the inside contour of the pipeline. The applications are the same as for the centrifugal process.

3. The manual process is used on smaller pipes, from 4 to 16 inches in diameter, that have few service connections. This process requires frequent excavations, has high cost and cannot be done quickly.

Gunite Lining

Another coating material often used is reinforced shotcrete, or gunite. Gunite is a mixture of fine aggregate, cement, and water applied by air pressure using a cement ejector. Compared to cement mortar, gunite is denser and stronger. Like cement, gunite improves a pipeline's structural integrity. In fact, the greater the structural deterioration, the more effective the gunite process is compared to cement mortar linings. Gunite adheres well to other concrete and brick sewers and is more corrosion resistant than normal concrete. Its finish, when troweled, is similar in smoothness to cement mortar linings, and can improve a pipeline's flow characteristics.

Gunite is ideal for extremely deteriorated large sewers where persons and equipment can work without restriction. Long lengths of sewers may be effectively renewed with little excavation and minimal traffic disruption. Safety precautions must be observed whenever personnel enter the sewer system.

Installing gunite takes more time than installing a cement mortar lining. It can be applied under low wastewater flows. However, installing gunite is more effective when sewer flows are temporarily rerouted and the pipeline is dewatered totally. For pipelines carrying corrosive or aggressive wastewater, special aggregates and high alumina cements may be used. Welded wire mat or small diameter rod reinforcing is used for structural gunite applications.

Sliplining

Sliplining of pipelines is another versatile rehabilitation procedure. The sliplining procedure involves inserting a flexible liner pipe of slightly smaller diameter into an existing circular pipeline and then reconnecting the service connections to the new line. Sliplining an existing pipeline segment, where applicable, can usually be done in less time and at a considerably lower cost than conventional excavation and sewer replacement.

Sliplining is used to rehabilitate extensively cracked sewer pipe, especially ones in unstable soils. It is also used to rehabilitate deteriorating pipe installed in a corrosive environment, pipes with massive and destructive root intrusion problems, and pipelines with relatively flat grades.

One of the advantages of relining over replacement is that it requires minimal excavation and.limits traffic disruption. Sliplining also avoids the extensive dewatering that may be required for open trench construction. With sliplining, dewatering is limited to the insertion pit and excavation of the service connections. Sliplining can be installed in pipelines having moderate horizontal or vertical deflection caused by shifting soils. The flexibility of the sliplining allows for a normal amount of future settlement or deflection.

Before an existing sewer line can be lined with flexible pipe, it must be cleaned and inspected internally. The internal inspections are required to identify the location of all service connections, severely misaligned joints, collapsed pipe, and any other obstruction that will not allow the liner to be installed. If an obstruction is identified that will not allow the liner to be installed, it must be repaired by excavating prior to lining the pipe.

A pit must be excavated at the end where the liner pipe will be inserted into the existing pipe. The dimensions of the pit excavation are based on the diameter and material properties of the liner pipe. Each size and type of liner will have a maximum bending radius that must be considered when digging the liner insertion pit. Shoring and bracing may be necessary depending on the depth and soil conditions.

The liner is commonly pulled through the existing sewer pipe using a winch assembly set up at an existing manhole.

During the lining process, sewage flows can be allowed to pass through the annular space between the existing pipe and the liner. If the hydraulic capacity of the annular space is not adequate to handle the sewer flows temporary bypassing of sewer flows around the section being lined is necessary.

After the liner has been installed, the service connections must be connected to the liner. This is normally done by excavating the service connection at the .sewer main and using a heat fusion saddle or a strap-on saddle to make the connection.

After the service connections have been reconnected, the annular space between the new liner and existing pipe can be sealed off partially or completely. If there is a chance that the old pipe will collapse and possibly damage or collapse the liner, the annular space should be filled completely with either sand or grout. If it is not necessary to fill the entire annular space between the liner and old pipe the annular space at the two ends should be sealed off.

Figure 6-2 shows a typical sliplining set up.

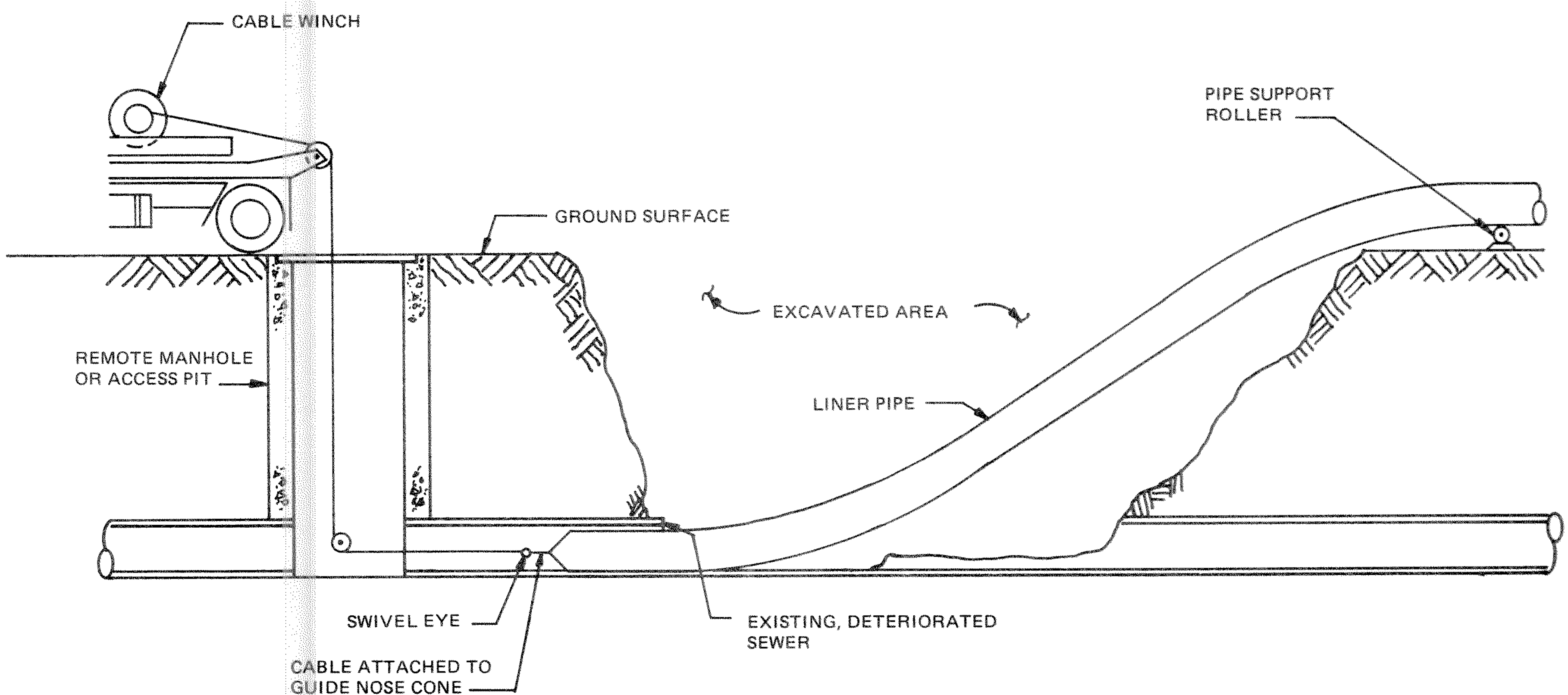


FIGURE 6-2. TYPICAL ARRANGEMENT FOR SLIPLINING

There are several different types of liner materials, polyethylene being the most common material used. Many of the common materials are listed here:

1. Polyethylene pipe (extruded). This material is available in low, medium, and high density and provides excellent corrosion and abrasion resistance. It's application is suitable for pipes 8 to 48 inches in diameter.

2. Polyethylene pipe (spiral-welded). Similar to extruded polyethylene pipe, this material differs essentially in that it can be inserted in pipes 12 to 144 inches in diameter.

3. Polybutene pipe is a good choice for pipes where extra protection is required against excessive temperatures and aggressive industrial wastes. It can be applied in pipes up to 24 inches in diameter.

4. Reinforced plastic mortar pipe is used to reline extensively cracked, corroded, and severely deteriorated sewers 18 to 108 inches in diameter. It can generally be inserted while sewage is flowing.

5. Reinforced thermosetting resin pipe is lightweight and high in strength, but has high cost and limited flexibility. It provides a smooth interior which improves flow characteristics. Pipes 8 to 144 inches in diameter are suitable for this relining material.

6. Polyester resin lining is inserted from an existing manhole without the need for special excavations. Installation is quick and labor requirements are low.

7. Fiberglass reinforced cement liners provide good resistance to abrasion and have high strength, although the installation procedure requires many workers and is slow. It is applicable to pipes greater than 42 inches in circular, oval, rectangular, elliptical, ovoid, and v-shaped sewers.

Inversion Lining

Inversion lining of sewers is another method that can be used to rehabilitate an existing sewer with little if any excavation. The inversion lining procedure involves the installation of a resin impregnated flexible felt tube which is inverted into the existing sewer utilizing hydrostatic pressure. After the lining is in place, the resin is cured to form a hard watertight lining. Inversion lining is a patented process and is only available through licensed contractors.

The inversion lining process is commonly done to sewer sections between manholes but has been done to longer sections including several manholes. Before beginning the inversion lining process, the sewer line must be cleaned and inspected. Any obstructions located must be removed. Sewer flows must be plugged or rerouted during the inversion lining process. The water service to each building that discharges to the sewer section being lined should be shut off during the lining process since the liner will temporarily plug all service connections.

After the liner has been allowed to cure, the service connections are opened using, a remotely controlled cutter in conjunction with a closed circuit TV camera.

The ends of the inversion liner must also be cut and trimmed at the manholes after curing is complete. The flow channel in the manholes may require minor adjustment to provide a smooth flow transition from the channel to the lined sewer.

Figure 6-3 shows the inversion lining process.

Pipe Replacement

The option to excavate and replace damaged pipe cannot be ignored. This option may produce the most effective rehabilitation results despite its high cost. If pipe size enlargement, change in grade, or realignment is needed, in addition to pipe defect corrections, replacement is a good choice. Many times pipe replacement can be used if the cause of deterioration in the existing sewer is known. By knowing the cause of deterioration in the existing sewer, the replacement sewer can be installed with properties such as corrosion resistance and strength that will reduce the chances of the same type of failure from occurring in the replacement sewer.

The possible benefits of pipe replacement include:

1. Increased hydraulic capacity.
2. Correct misalignment of grade or.line.
3. Concurrent repair of service connections.
4. Elimination of direct sources of stormwater entry.
5. Removal of incidental infiltration and inflow sources.
6. Increased pipeline service life.

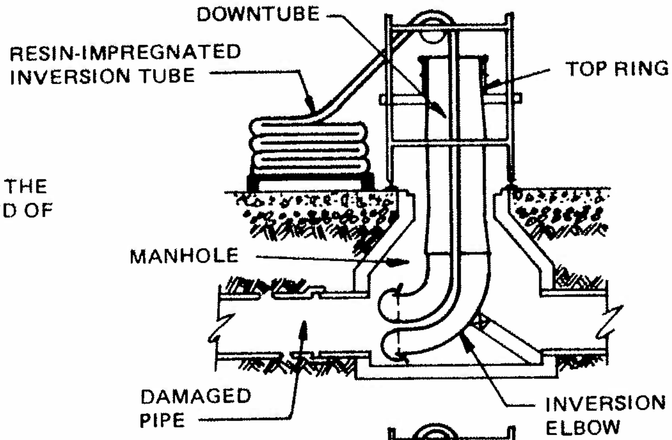
Before selecting the option of sewer replacement, the disadvantages must be considered. The major disadvantages include:

1. High cost relative to other rehabilitation techniques.
2. Need for pavement removal and replacement.
3. Traffic disruption for extended periods of time.
4. Potential damage to existing buildings, utilities, and large trees.
5. Excavation requirements such as dewatering and shoring.
6. Rerouting sewer flows.

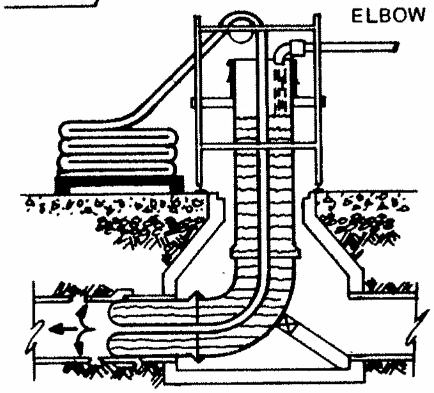
Service Connection Repairs

Service connections, the pipes which branch off the sewer main and connect building sewers to the public sewer main, can be a significant source of inflow and infiltration, if they possess excessive defects. These can include cracked, broken, or open jointed pipes. Several patented methods exist for rehabilitating service laterals including variations of the standard chemical grouting method using specialized TV cameras and grout packer and

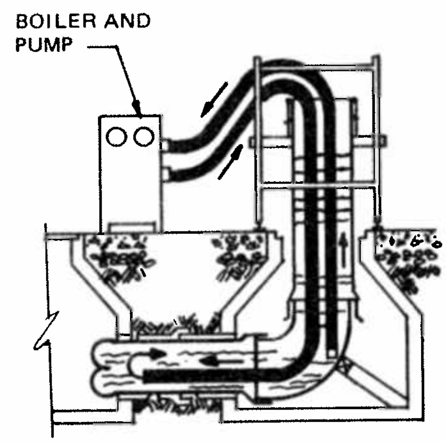
THE INVERSION TUBE IS LOWERED THROUGH THE DOWNTUBE AND BANDED TO THE BOTTOM END OF THE INVERSION ELBOW.



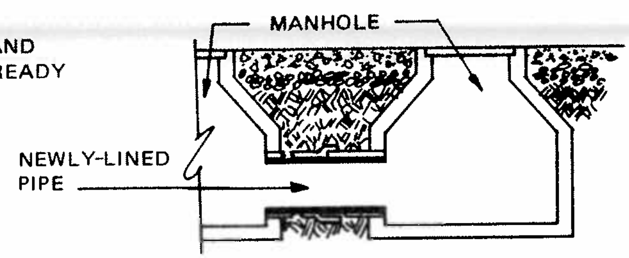
WHEN WATER IS ADDED TO THE DOWNTUBE ITS WEIGHT PUSHES THE INVERSION TUBE THROUGH, AND TIGHT AGAINST, THE OLD PIPE.



WHEN THE INVERSION TUBE IS FULLY EXTENDED THE WATER IS SLOWLY HEATED, CURING IT TO A ROCKHARD, PERMANENT, PIPE-WITHIN-A-PIPE.



AFTER THE NEW INVERSION TUBE HAS CURED AND ITS ENDS CUT FLUSH WITH THE OLD PIPE, IT IS READY FOR IMMEDIATE USE.



REFERENCE: "ENGINEERING DESIGN GUIDE," INSITUFORM OF NORTH AMERICA, INC., 1985.

FIGURE 6-3. THE INVERSION LINING PROCESS

inversion lining. The option to replace service lateral piping is also available for consideration. The costs of these methods vary depending on difficulties encountered.

Summary of Sewer Rehabilitation Methods

A summary of the various sewer rehabilitation methods and their applications is given in Table 6-1. Table 6-2 indicates typical service lives for common sewer system repairs in Northeastern Illinois.

TABLE 6-1. SUMMARY OF MOST COMMON SEWER REHABILITATION METHODS

Method	Application	Advantages	Disadvantages
Chemical Grouting	* Leaking, structurally sound sewer pipes. * Can be used to seal open joints and some cracks. * Used to control infiltration and inflow.	* Cheaper than replacement * Minimal traffic disruption. * No excavation required. * Grouting can be done during low sewer flows. * Existing utilities and buildings not affected.	* Grout packers difficult to seal where surface is not smooth. * Does not improve structural integrity. * Grouts can shrink if they dehydrate. * Infiltration reduction may not reach predicted values due to migration of groundwater. * Questionable service life. * Not effective for sealing widely separated or badly misaligned joints.
Cement Mortar Linings	* Used to line interior of cracked or damaged sewers. * Can be applied to sewers subject to internal corrosion.	* Improves structural conditions of the sewer. * Minimal traffic disruption. * Minimal excavation required. * Existing utilities and buildings not affected. * Provides some protection against corrosion.	* Sewer flows must be temporarily rerouted. * Application surface must be relatively dry. * Quality control is difficult. * Dewatering may be required to control infiltration while lining.
Gunite Lining	* Used to structurally repair large diameter sewers.	* Can improve pipeline flow characteristics. * Improves structural condition of the sewer. * Higher strength than cement mortar linings. * Requires little if any excavation. * Can be applied to various shaped pipes. * Minimal traffic disruption. * Existing utilities and buildings not affected. * Provided some protection against corrosion.	* Temporary rerouting of sewer flow and pipeline dewatering is required for best results. * Control of infiltration during gunite lining is required. * Not applicable to small diameter pipes. * Quality control is difficult.
Sliplining	* Used to repair cracked or deteriorated sewer pipes.	* Cheaper than excavation and replacement. * Minimal excavation. * Minimal traffic disruption. * Can use corrosion resistant liner pipe. * Existing utilities and buildings not affected in general. * May increase hydraulic capacity. * Low flows tolerated during lining process.	* May decrease hydraulic capacity. * Not applicable for pipelines with short radius bends, badly misaligned joints or sewer sags. * Only good for circular pipes. * Expensive for deep sewers. * Grouting of annular space may be required. * Excavation of service connections commonly required.

TABLE 6-1 (cont.). SUMMARY OF MOST COMMON SEWER REHABILITATION METHODS

Method	Application	Advantages	Disadvantages
Inversion Lining	* Can be applied to any type and shape pipe. * For pipelines with minor structural defects.	* Ideal for sewer repairs under busy streets, buildings or large trees. * Minimal if any excavation required. * Quick. * Service connections can be reopened without excavation. * Bends and minor pipe alignments are not a problem. * Pipe capacity not affected significantly. * Minimal traffic disruption.	* Can only be done through a few licensed contractors. * Very expensive for small jobs. * Temporary rerouting of sewer flows required.
Pipe Replacement	* For pipelines with major structural defects. * For increasing capacity. * For installing new pipelines with properties to reduce the chance of future deterioration.	* Can increase pipeline capacity. * Substitute modern pipe material for outdated material. * Increases service life. * May be best method for reducing infiltration and inflow.	* Most expensive type of repair. * Disrupts traffic for long periods of time. * May affect buildings and other utilities. * Dewatering and shoring requirements are likely. * Rerouting sewer flows is required.

TABLE 6-2. TYPICAL SERVICE LIVES FOR SEWER SYSTEM REPAIRS

DEFECT	REPAIR METHOD	SERVICE LIFE[1] (YEARS)
MANHOLE DEFECTS		
Leaking cover - flowing water	gasket cover/insert dish	10-20
Leaking cover - ponded water	bolted waterproof cover and frame	20
Leaking frame to	butyl rubber rope gasket	5-10
manhole joint and	bolt on rubber boot	10-20
leaking adjustment	bonded rubber seal	5-15
Manhole wall leaks		
brick and block	external grout	5-10
	internal grout	3- 5
precast	tuck point	3- 5
Manhole pipe connections	tuck point	3- 5
Structurally defective manhole	replace	20
SEWER LINE DEFECTS		
Random leaking joints	air test and grout	3- 5
Cracked pipes	lining	20
	spot replacement	20
	manhole to manhole replacement	50
Defective service connections	spot replacement	20
ILLEGAL CONNECTIONS		
Storm inlet/Catch basin	disconnect	20
Storm sewer cross connection	disconnect	20
Defective service line	replace	20
Abandoned service line	plug	20

[1]Service lives are typical for Northeastern Illinois.

Source: Attachment G to a December 5, 1986 memorandum distributed by the Metropolitan Sanitary District of Greater Chicago.