Large diameter structures installed in difficult trench conditions using the advantage of long lengths.

CHAPTER 11 Maintenance and Rehabilitation

Most of the following information was compiled by AASHTO-AGC-ARTBA Task Force 17 on Storm Water Management.

GENERAL

Drainage systems should be inspected on a routine basis to ensure that they are functioning properly. Inspections can be on an annual or semi-annual basis, but should always be conducted following major storms. Systems that incorporate infiltration are most critical since poor maintenance practices can soon render them inefficient. Inspection of pipes, covered trenches, and wells can be accomplished with closed circuit television; and still photographs can be obtained by either taking a picture of the monitor, or mounting a still camera alongside the T.V. camera and triggering it electronically. Other more economical alternate methods of inspection are also available. Procedures for maintenance of these systems are discussed in this chapter. It should be stressed that good records be kept on all maintenance operations to help plan future work and identify facilities requiring attention.[1]

BASINS

Infiltration basin surfaces are sometimes scarified to break up silt deposits and restore topsoil porosity. This should be done when all sediment has been removed from the basin floor. However, this operation can be eliminated by the establishment of grass cover on the basin floor and slopes. Such cover helps maintain soil porosity.

Algae or bacterial growth can also inhibit infiltration. While chlorination of the runoff water can solve this problem, it is more practical to make certain that the basin is permitted to dry out between storms and during summer months. Algae and bacteria will perish during dry spells, provided that standing water is dissipated.

Holding ponds or sedimentation basins can be used to reduce maintenance in conjunction with infiltration basins by settling out suspended solids before the water is released into the infiltration basin.

Chemical flocculants can be used to speed up settlement in holding ponds. Flocculants should be added to the runoff water within the settlement pond inlet pipe or culvert where turbulence will ensure more thorough mixing. After suspended matter has flocculated and settled in the pond, the water may be released into the infiltration basin for disposal. Although chemical flocculants may be impractical for general use, they might well be considered in special cases.

Alum (Aluminum Sulfate) is readily available, inexpensive and highly effective as a flocculating agent. It is widely used in water treatment plants. Various trade name flocculation agents are also available.

Cleanout frequency of infiltration basins will depend on whether they are vegetated or non-vegetated and will be a function of their storage capacity, infiltration characteristics, volume of inflow and sediment load. Infiltration basins should be inspected at least once a year. Sedimentation basins and traps may require more frequent inspection and cleanout.

Grass surfaces in infiltration basins seldom need replacement since grass serves as a good filter material. This is particularly true of Bermuda grass, which is extremely hardy and can withstand several days of submergence. If silty water is allowed to trickle through Bermuda, most of the suspended material is strained out within a few metre's, of surface travel. Well established Bermuda on a basin floor will grow up through silt deposits, forming a porous turf and preventing the formation of an impermeable layer. Bermuda grass filtration would work well with long, narrow, shoulder-type (swales, ditches, etc.) basins where a high runoff flows down a grassy slope between the roadway and the basin. Bermuda demands very little attention besides summer irrigation in states having dry summers, and looks attractive when trimmed. Planted on basin side slopes it will also prevent erosion.

Non-vegetated basins should be scarified on an annual basis following removal of all accumulated sediments. Rotary tillers or disc harrows with light tractors are recommended for maintenance of infiltration basins where grass cover has not been established. Use of heavy equipment should be discouraged to prevent excessive compaction of surface soils. The basin floor should be left level and smooth after the tilling operation to ease future removal of sediment and minimize the amount of material to be removed during future cleaning operations. A levelling drag, towed behind the equipment on the last pass, will accomplish this.

Coarse rock or pea gravel is often placed on the bottom of a drainage basin to prevent the formation of a filter cake on the soil, by screening out suspended solids. After a period of operation the aggregate becomes partially clogged, and it is then necessary to remove and clean it, or replace it with new material. This could be done on an annual basis. In as much as basins are usually accessible, this kind of operation is seldom expensive or difficult. The subsequent disposal of silt and other sediments should comply with local area codes.

TRENCHES

The clogging mechanism of trenches is similar to that associated with other infiltration systems. Although the clogging of trenches due to silt and suspended material is more critical than that of basins, it is less critical than the clogging of vertical wells. The use of perforated pipe will minimize clogging by providing catchment for sediment without reducing overall efficiency. Maintenance methods associated with these systems are discussed later in this chapter.

WELLS

The same clogging and chemical reactions that retard basin and trench infiltration can affect wells to an even greater extent. One problem unique to wells is chemical encrustation of the casing, with consequent blocking of the perforations or slots in the well casing. Alternate wetting and drying builds up a scale of water-soluble minerals, which can be broken up or dissolved by jetting, acid treatments or other procedures.

Some agencies restore well efficiency by periodic jetting, which removes silt and fines. Jetting consists of partially filling a well with water, then injecting compressed air through a nozzle placed near the bottom of the shaft (refer to 4. Compressed Air Jet, of this chapter). Dirt or sand that has settled in the shaft or has clogged the casing perforations is forced out the top of the well. Wells cleaned in this manner will operate fairly efficiently for several years, providing that drainage was good initially.

Clogging due to silt and suspended material is much more critical in cased wells than in basins. Filters or sedimentation basins and special maintenance procedures will help prevent silting up of wells. Underground sediment traps in the form of drop inlets are frequently used with small wells, but these inlets do little more than trap the heaviest dirt and trash, allowing finer suspended matter to flow into the well. Larger settling basins hold water longer for more efficient silt removal, and provide some temporary storage volume at the same time.

Sand and gravel or other specially selected filter materials used in "gravel packed" wells cannot be removed for cleaning if they should become clogged. Nor can well screens that become partially or totally clogged by corrosion, bacteria, or other deposits, be removed for repair. Generally, the only practical solution to the problem is to drill another well and abandon the inoperative one. Problems of clogging of gravel packing (and well walls) can often be minimized by using sediment traps and by treating the water to remove substances that will clog the soil, the gravel packing, or the well screen. Problems of corrosion of well screens can be eliminated by using slotted PVC pipes for well screens. Furthermore, the PVC is not attacked by acids or other chemicals that are sometimes used for flushing wells to remove deposits that clog the gravel packing or the walls of wells.

It is important that those maintaining infiltration facilities that employ wells be knowledgeable of the kind of materials used in screens and other parts of the systems that could be damaged by acids and other corrosive substances. The importance of regular well maintenance cannot be over stressed. Periodic cleaning and redevelopment is essential, and chlorination or other chemical treatments may be necessary if biological growth or encrustation impedes drainage. Should there be any signs of bacterial groundwater contamination, a 5-10 ppm dosage of chlorine should be added to the wells in question.

When infiltration well systems are being designed, preference should be given where practicable to the use of filter materials that would facilitate

Exterior coatings are protected during installation by use of lifting lungs or slings.

maintenance. If aggregate filter material is mounded over the infiltration well, designers should realize that it will be necessary to periodically remove the upper part of the filter material and clean it or replace it with clean material. In some situations this may not be practical. When cased, gravel-packed wells are used, it would be impractical to use a fine aggregate filter although some designers make use of a bag constructed of filter fabric, which is fitted to the top of a well to trap sediment. When the inflow rate has decreased to the maximum tolerable amount, the bag is removed, and cleaned much as a vacuum cleaner bag is cleaned, or a new filter bag is inserted. Consideration should also be given to back flushing the well system using methods similar to those defined in earlier sections of this chapter.

CATCH BASINS

Catch basins should be inspected after major storms and be cleaned as often as needed. Various techniques and equipment are available for maintenance of catch basins, as discussed in the next section. Filter bags can be used at street grade to reduce the frequency for cleaning catch basins and outflow lines. Filter bags have been used successfully in Canada and various parts of the United States.

Whatever the problems, fittings are available to solve them.

METHODS AND EQUIPMENT FOR CLEANOUT OF SYSTEMS[2]

Various types of equipment are available commercially for maintenance of infiltration systems. The mobility of such equipment varies with the particular application and the equipment versatility. The most frequently used equipment and techniques are listed below.

1. Vacuum Pumps

This device is normally used to remove sediment from sumps and pipes and is generally mounted on a vehicle. It usually requires a 900 to 1400l holding tank and a vacuum pump that has a 250mm diameter flexible hose with a serrated metal end for breaking up caked sediment. A two-man crew can clean a catch basin in 5 to 10 minutes. This system can remove stones, bricks, leaves, litter, and sediment deposits. Normal working depth is 0 to 6m.

2. Waterjet Spray

This equipment is generally mounted on a self-contained vehicle with a high pressure pump and a 900 to 1400l water supply. A 76mm flexible hose line with a metal nozzle that directs jets of water out in front is used to loosen debris in pipes or trenches. The nozzle can also emit umbrella-like jets of water at a reverse angle, which propels the nozzle forward as well as blasting debris backwards toward the catch basin. As the hose line is reeled in, the jetting action forces all debris to the catch basin where it is removed by the vacuum pump equipment. The normal length of hose is approximately 60m Because of the energy supplied from the water jet, this method should not be used to clean trench walls that are subject to erosion.

3. Bucket Line

Bucket lines are used to remove sediment and debris from large pipes or trenches (over 1200mm diameter or width). This equipment is the most commonly available type. The machine employs a gasoline engine driven winch drum, capable of holding 300m of 13mm wire cable. A clutch and transmission assembly permits the drum to revolve in a forward or reverse direction, or to run free. The bucket is elongated, with a clam shell type bottom which opens to allow the material to be dumped after removal.

Buckets of various sizes are available. The machines are trailer-mounted, usually with three wheels, and are moved in tandem from site to site. When a length of pipe or trench is to be cleaned, two machines are used. The machines are set up over adjacent manholes. The bucket is secured to the cables from each machine and is pulled back and forth through the section until the system is clean. Generally, the bucket travels in the direction of the flow and every time the bucket comes to the downstream manhole, it is brought to the surface and emptied.

4. Compressed Air Jet

The compressed air jet is normally used to clean and remove debris from vertical wells. This equipment requires a holding tank for water and the removed debris, a source of water supply (if the well is above the groundwater level), an air compressor, two 6mm air lines, a diffusion chamber, and a 100mm diameter pipe to carry the silty water and other debris to the surface. The well should be partially filled with water, if required, and the compressed air injected through a nozzle near the bottom of the well. As the silty water enters the diffusion chamber (to which the other air line is connected) it becomes filled with entrained air and is forced up the 100mm disposal pipe and out of the top of the well by the denser water entering the bottom of the diffusion chamber intake. Normal working depths are typically 0 to 20m.

5. Surging and Pumping

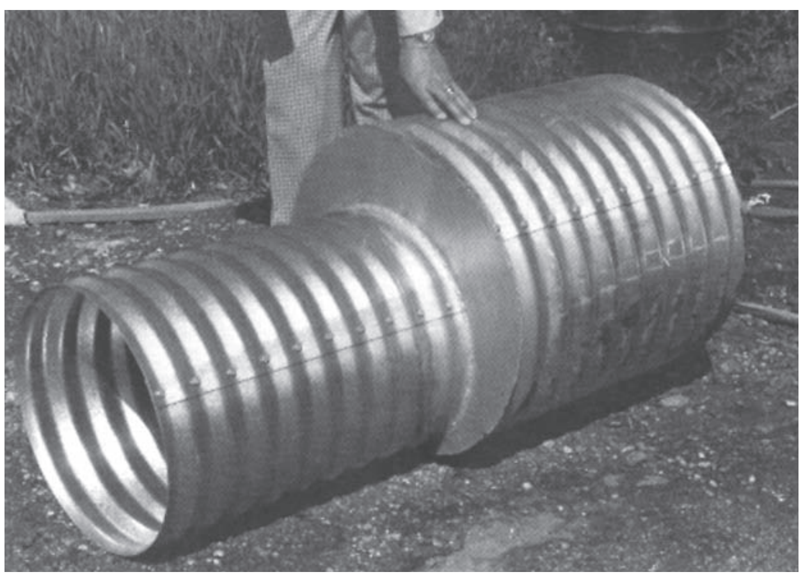
This procedure is another means of removing silt and redeveloping a well. The process involves partially filling the well with water and then pumping a snug-fitting plunger up and down within the casing. This action loosens silt and sediment lodged into the packing and the immediately adjacent soil, and pulls it into the well. Surging is immediately followed by pumping silt-laden water from the bottom of the well. If the well is situated in clay soil or if clay materials have been washed into the well, the surging and air jetting methods will be more effective if sodium polyphosphate is added to the water in the well prior to cleaning or redeveloping. A 2-5 ppm concentration of this chemical will deflocculate clay particles in the well and the immediately surrounding soil, and the clay can then be pumped or jetted out very easily. The depth is limited by the pumping capacity available.

6. Fire Hose Flushing

This equipment consists of various fittings that can be placed on the end of a fire hose such as rotating nozzles, rotating cutters, etc. When this equipment is dragged through a pipe, it can be effective in removing light material from walls. Water can be supplied by either hydrant or truck.

7. Sewer Jet Flushers

The machine is typically truck-mounted and consists of a large watertank of at least 4500l, a triple action water pump capable of producing 7000 kPa or more pressure, a gasoline motor to run the pump, a hose reel large enough for 150m of 25mm inside diameter high pressure hose, and a hydraulic pump to remove the hose reel. In order to clean pipes properly a minimum nozzle pressure of 4100 kPa is usually required. All material is flushed ahead of the nozzle by



Increaser, prefabricated in CSP, reduces the overall total installed cost.

spray action. This extremely mobile machine can be used for cleaning areas with light grease problems, sand and gravel infiltration and for general cleaning.

REPORTED PRACTICE

In 1973 a questionnaire was mailed to the maintenance engineers of 50 southern cities. Replies were received from the following cities:

ALABAMA	GEORGIA	TENNESSEE	FLORIDA
Huntsville	Atlanta	Jackson	Jacksonville
Anniston	Macon	Chattanooga	St. Petersburg
Tuscaloosa			Sarasota
Mobile			Pensacola
Florence			Bradenton

Thirteen of the fourteen used both concrete pipe and CSP for storm sewers. Periodic inspections were made in 10 of the cities to determine the need for cleaning and the useful life remaining in their storm drains. The following systems were used to clean concrete storm sewers:

Hand and water jet 5
Ropes, buckets, fire hose 1
Water jet and vacuum hose 1
Rodder with cutting edge and water 5
Myers Machine 2

Ten of the cities used the same cleaning procedures for corrugated steel pipe. The other 4 used rodding and flushing only.

In maintaining storm sewers the following solutions to the problems shown were reported:

Joint Separation
Grout joints 6
Pour concrete collar 5
Replace 2
Hydraulic cement 1

Invert Failure
Replace—6
Concrete invert—8

Structural Failure
Replace 12
Repair 2

Four cities threaded a smaller diameter pipe within existing structures. Pressure grouting was typically used to fill the void between the new pipe and existing structure.

For sizes smaller than 800mm, pull through devices for inspection and repair must be used. For high volume roads or expensive installations, a minimum size of 800mm is recommended to permit access by maintenance personnel.

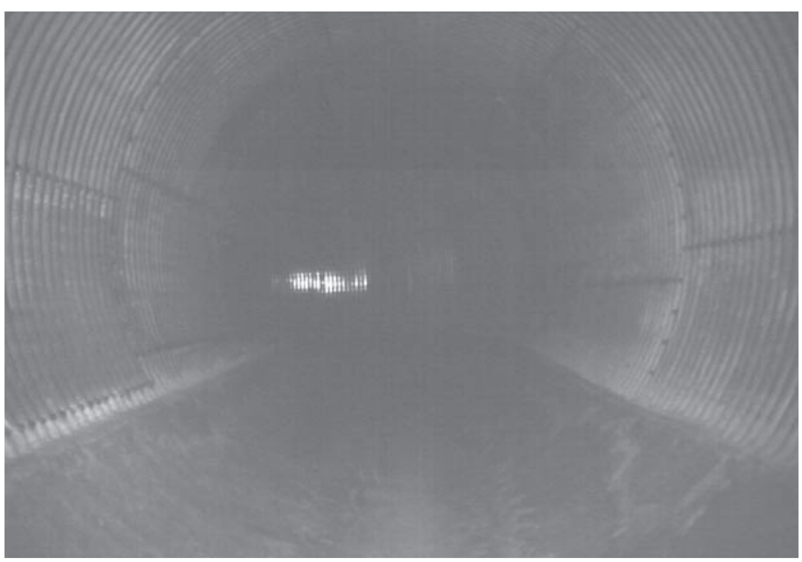
REHABILITATION [3]

Rehabilitation of America's infrastructure is a major undertaking now being addressed by federal, state, and local governments. While the magnitude of rehabilitation may at times appear enormous, rehabilitation often is very cost effective when compared to the alternative of new construction.

Storm sewers and highway culverts represent a significant portion of the infrastructure. The American Concrete Institute (ACI) recently has addressed the problem of rehabilitating existing concrete structures of all types. Methods of rehabilitating corrugated steel pipe (CSP) structures are outlined here. Generally, CSP structures can be rehabilitated to provide a new, complete service life at a fraction of the cost or inconvenience of replacement.

All of the methods described herein require a complete inspection and evaluation of the existing pipe to determine the best choice. With CSP, rehabilitation often requires merely providing a new wear surface in the invert. Typically, structural repair is unnecessary. However, if the pipe is structurally deficient, this does not rule out rehabilitation. Repair methods can be utilized and the structures restored to structural adequacy and then normal rehabilitation procedures performed. Even with 25% metal loss, which occurs long after first perforation, structural factors of safety are reduced by only 25%. When originally built, CSP storm sewers often provide factors of safety of 4 to 8—far in excess of that required for prudent design.

This section deals mainly with the repair of corrugated steel pipe and/or steel structural plate or the use of CSP as a sliplining material.



Concrete inverts can solve abrasion problems.

Methods of Rehabilitation

- In place installation of concrete invert.
- Reline existing structure.
  Slip line with slightly smaller diameter pipe or tunnel liner plate
  Inversion lining
  Shotcrete lining
  Cement mortar lining

In Place Installation of Concrete Invert

For larger diameters where it is possible for a person to enter the pipe, a concrete pad may be placed in the invert. Plain troweled concrete may be satisfactory for mild conditions of abrasion and flow. For more severe conditions a reinforced pavement is required.

Figure 11.1 shows one method of reinforcing the pad and typical pad thickness. The final design would be in the control of the Engineer and would obviously depend upon the extent of the deterioration of the pipe.

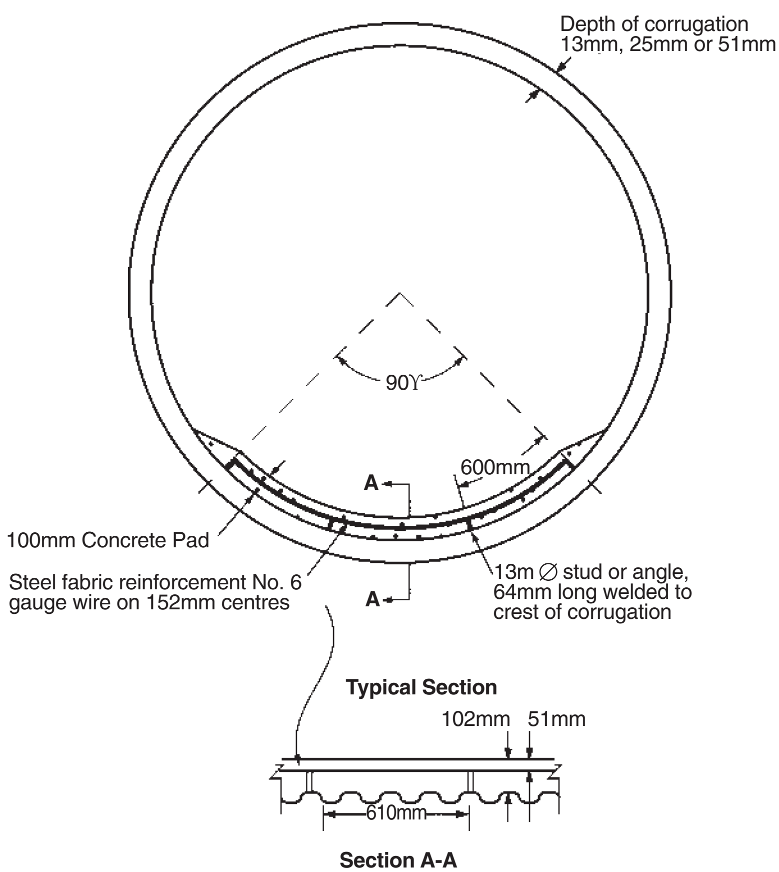


Figure 11.1

Relining Materials

The selection of the reline material is dependent upon the condition of the pipe line to be rehabilitated and the diameter and/or shape.

If the line has deteriorated to the point where it is deficient structurally, then your choice would necessarily have to be one of a material having full barrel cross section and possess sufficient structural capability to withstand the imposed dead and live loads.

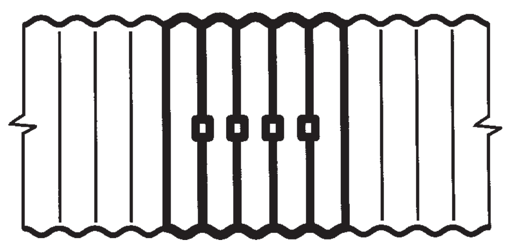
If you do not need to provide structural support, then you may direct your attention only to the repair of the invert in most cases.

The following is a discussion of reline materials and methods of installing them. It is the Engineer's responsibility to select the material and method of relining dependent upon the pipeline's rehab requirements.

Sliplining

If downsizing of the existing line is not a concern then the use of standard corrugated steel pipe AASHT0 M-36, ASTM760 or CAN3-G401-93 may be used and provided in lengths which would facilitate insertion. A hydraulic advantage may be gained by using helical corrugated steel pipe or spiral rib pipe if the existing pipe is annular corrugated.

If sufficient clearance exists between the liner pipe and the existing line the sections may be joined by the use of a silo rod and lug type coupling band. See Figure 11.2.



Rod & Lug

Band is secured by rod around band connected by lugs

Figure 11.2

The use of an internal expanding type coupling band is recommended to connect the sections if there is insufficient clearance on the outside of the liner pipe. See Figure 11.3.

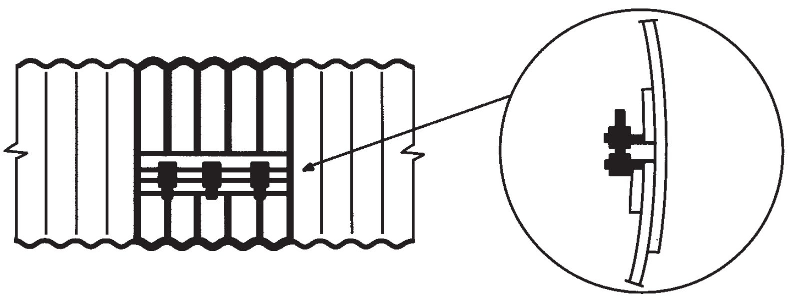


Figure 11.3 Internal Type

An alternative to the use of the conventional angles or lugs and bolts is to use sheet metal screws in conjunction with an installation jig.

If the owner desires to maintain maximum hydraulic capacity of the line then the use of a smooth lined corrugated steel pipe is recommended.

Choices of this type of pipe include:

1. 100% Asphalt Lined
2. 100% Cement Mortar Lined
3. Double Wall CSP
4. Spiral Rib CSP

Figure 11.4 shows a typical section of a corrugated steel pipe fabricated for sliplining.

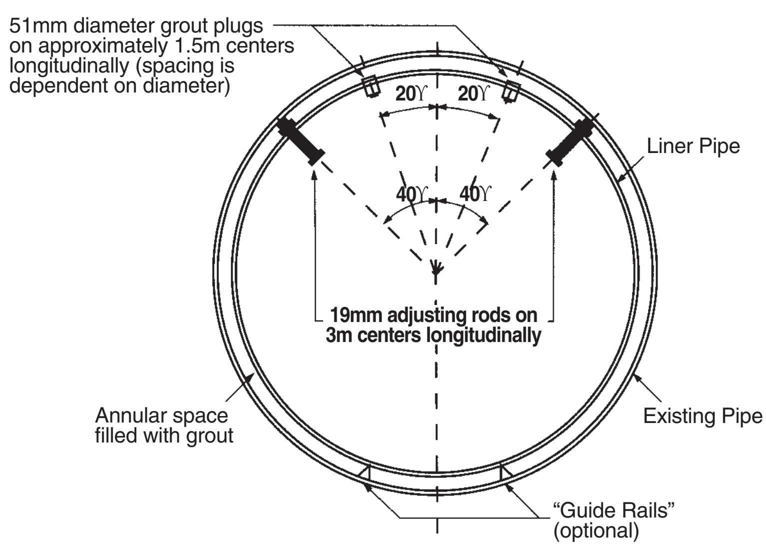


Figure 11.4 Typical Section

Inversion Lining

Inversion lining is accomplished by using needle felt, of polyester fiber, which serves as the "form" for the liner.

The use of this method requires that the pipe be taken out of service during the rehabilitation period. One side of the felt is coated with the polyurethane membrane and the other is impregnated with the thermosetting resin.

The felt variables include denier, density, type of material, method of manufacture (straight or cross lap), and length of fiber. The physical properties of the felt and chemicals must be determined for the specific project and in cooperation with prospective contractors.

The liner expands to fit the existing pipe geometry and therefore is applicable to egg-shaped, ovoids, and arch pipe.

Inversion lining has been utilized on lines from 100 to 2700mm in diameter. It is normally applicable for distances of less than 60m or where groundwater, soil condition, and existing structures make open excavation hazardous or extremely costly. Inversion lining with water is generally confined to pipelines with diameters less than 1500mm and distances less than 300m. Normally, air pressure is utilized for inversion techniques on larger diameter pipe. Compared with other methods, this process is highly technical. Other technical aspects include resin requirements, which vary with viscosity, felt liner, ambient temperatures, and the filler in the felt content; the effects of ultraviolet light on the resin and catalyst; and safety precautions for personnel and property.

Shotcrete Lining

Shotcrete is a term used to designate pneumatically applied cement plaster or concrete. A gun operated by compressed air is used to apply the cement mixture. The water is added to the dry materials as it passes through the nozzle of the gun. The quantity of water is controlled within certain limits by a valve at the nozzle. Low water ratios are required under ordinary conditions. The cement and aggregate are machine or hand mixed and are then passed through a sieve to remove lumps too large for the gun.

When properly made and applied, shotcrete is extremely strong, dense concrete, and resistant to weathering and chemical attack. Compared with hand placed mortar, shotcrete of equivalent aggregate-cement proportions usually is stronger because it permits placement with low water-to-cement ratios. For relining existing structures, the shotcrete should be from 50 to 100mm thick depending on conditions and may not need to be steel reinforced. If used, the cross-sectional area of reinforcement should be at least 0.4% of the area of the lining in each direction.

The following specifications should be considered:

1. "Specifications for Concrete Aggregates" ASTM C 33.
2. "Specifications for Materials, Proportioning and Application of Shotcrete" ACI 506.
3. "Specifications for Chemical Admixtures for Concrete" ASTM C 494.

Cement Mortar Lining

Cement mortar lining is particularly well suited to small diameter pipe which is not easily accessible.

The cement mortar lining is applied in such a manner as to obtain a 13mm minimum thickness over the top of the corrugations. Application operations should be performed in an uninterrupted manner. The most common practice uses a centrifugal machine capable of projecting the mortar against the wall of the pipe without rebound—but with sufficient velocity to cause the mortar to be densely packed in place. See Figure 11.5, which shows a typical set-up for this process.

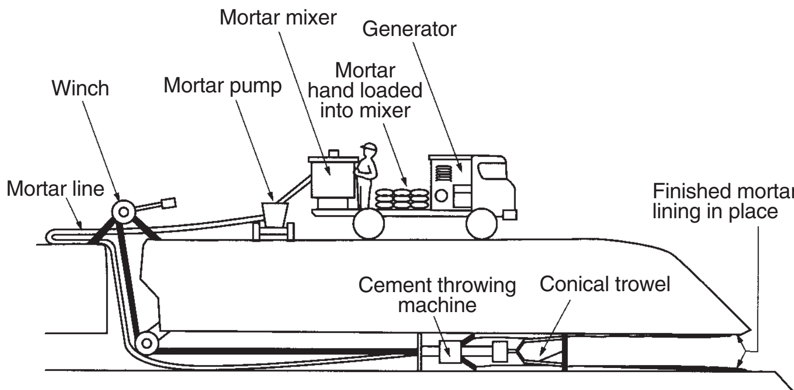


Figure 11.5 Cement Mortar Lining

General

Numerous patching compounds are commercially available. Compounds such as epoxies, which are used in bridge and paving repair, can be used. Both plain and reinforced concrete can be used. A number of the above procedures are applicable to both concrete and steel pipe. However, use of welding and mechanical fasteners for repair is applicable only to steel pipe. Thus, the ease of maintenance associated with steel sewers is a major factor in economical sewer design.

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