



USE OF TRENCHLESS TECHNOLOGIES FOR A COMPREHENSIVE ASSET MANAGEMENT OF CULVERTS AND DRAINAGE STRUCTURES

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16. Abstract DOT's and cities in the US are facing severe and rising needs of renewing heavily deteriorated infrastructure. Further challenges for DOT's are the wide geospatial distribution of infrastructure assets and environmental exposure. While the challenge is well understood, appreciated and addressed, budget allocations and resources limitations represent a major barrier to a comprehensive asset management program. Culverts have the peculiarity of being characterized as both buried pipes in small diameters with no access and worker entry and larger ones with possibility of manual inspection and repair/renewal. As such, asset management procedures for culverts are a complex issue, and can benefit a great deal from an optimal asset management program that incorporates new trenchless technologies. Trenchless technologies are not disruptive to transportation systems and provide safer construction operations for both workers and the general public. If they are used at appropriate application, they provide a new design life to existing culverts and drainage structures that may double or triple the original design life of these assets. However, trenchless technologies are many and some of these methods are new, and while viable, have little field performance history in culverts and transportation systems. Each method has its own capabilities and limitations, and can be applied in certain existing conditions to be effective. Lacking is a comprehensive multi-scale engineering study that would be conducted for decision making at upper management level. Therefore, this project provides a comprehensive study and decision making procedures for asset management using trenchless technologies to address the construction, renewal, renovation, and inspection of culverts and drainage infrastructures.			
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- Assess host line condition & configuration (diameter, grade, sags, collapses, angles, debris, etc.)
- Determine liner pipe diameter for proper fit insertion & hydraulic needs.
- Remove any debris and repair collapses in the host, so the liner pipe may be inserted. No bonding is required, so surface cleaning is not needed.
- Verify sufficient clearance for the liner pipe insertion (measurements or by pulling a mandrel).
- For continuous sliplining: slide butt-fused pipe into the culvert by pulling from the open end.
- For segmental sliplining: slide liner pipes into the culvert by pushing from the open end.
- Bulkhead annulus at the open ends
- Fill annulus with grout (may require blocking or ballast to fix the liner pipe position).

3.2.1.5 QA/QC

- Verify liner pipe is undamaged from insertion and grouting by inspection via walk through or video.
- Verify all joints are fully assembled by inspection via walk through or video.
- Verify liner pipe deflection is $\leq 5\%$ (if some distortion is noticeable).
- If required, leakage test the installed by infiltration, exfiltration or air testing.

3.2.2 Cured In Place Pipe (CIPP)

3.2.2.1 Introduction and Background

Cured-in-place-pipe (CIPP) was the first truly trenchless full pipeline renewal process. Invented in 1970, the first commercial project was completed in the United Kingdom in 1971, and it was introduced into the United States in 1976. In the late 1970s to early 1980s a number of private construction companies were licensed to install this unique technology. With regional education, marketing and occasional installations underway, the CIPP technology became more popular. Owners however, needed a number of additional years to develop confidence for its large-scale use (NASSCO, 2007). As of 2008, it is estimated that over 25,000 miles of CIPP have been installed worldwide.

CIPP is a process by which a deteriorated culvert is lined with a continuous lining composed of a liquid thermosetting resin-saturated material. The lining is cured in the installation by heat and thus a cured in place pipe is obtained. In order to use CIPP as a renewal method the existing pipe should be inspected and cleaned. According to the inspections, a flexible tube should be ordered which will serve the unique project requirements. Once the tube is brought to the job site it should be installed using the inversion method or by using a winch. As a final step, the installed tube should be cured by using hot water, steam or UV light.

3.2.2.2 Product Main Characteristics

There are many different kinds of CIPP products and processes. However, CIPP generally involves manufacturing a fabric tube of the length and diameter of the host pipeline. The wall thickness of the fabric tube is designed depending upon the installation process, end service and physical properties of the finished CIPP laminate. The fabric tube is saturated with a liquid thermosetting resin, inserted into the host pipeline and inflated with air or water pressure. The resin is then cured by one of several different methods (hot water, hot air, steam, UV light or at ambient temperature), resulting in a new tight-fitting plastic pipe within the host pipe. Once the ends are trimmed and any side connections opened, the renewed host pipeline is returned to service.

Although CIPP is used for storm sewers, water lines, and industrial and other process piping, historically it has principally been used for sanitary sewer renewal. CIPP is routinely used for manhole-to-manhole installations in sanitary sewers. While excavation is typically not required for small to medium sized sanitary sewers, larger sewers (48 inch equivalent diameter or larger) may require removal of a portion of the manhole or excavating a pit or shaft.

A large majority of CIPP installed as of 2008 has used the hydraulic pressure of water to install the CIPP tube and heated water to cure heat-initiated resin. During the hot water cure cycle, small amounts of organic chemicals such as styrene can leach into the cure water. This hot water cure process is quite acceptable in sanitary sewers because the waste process water can safely be discharged to the sanitary sewer system. However, this waste process water should not be discharged to the environment. Thus, if water is used to install and cure CIPP for culverts or storm sewers, the waste process water must either be pumped to an adjacent sanitary sewer system or hauled to a suitable disposal site. Depending on the project location and logistics, this process can be cost prohibitive. Many rural culverts are long distances from water sources and suitable cure water disposal sites. As a result, water must be hauled to the job site, used during the installation, and then collected and hauled away from the job site to a suitable disposal location. These additional costs can yield a project not cost-effective.

3.2.2.3 Advantages and Limitations

The main advantage of this type of lining is to have a lining without joints thereby eliminating the future joint defects and having a corrosion and abrasion resistant invert. The shape of the structure to be lined with a CIPP does not have to have a circular shape and CIPP can be used in the pipes with bends. However, the existing flow should be bypassed and the cost can be high due to specially produced tube and carefully monitored curing process.

Advantages of CIPP include:

- Grouting is not necessary.

- Smooth interior surface enabling an increase in flow capacity.
- Lining noncircular shapes is possible.
- Lining can be accomplished even in the presence of bends.
- Design life of 50 – 100 years.
- Corrosion resistant.
- Relatively quick installation.
- A structural solution.
- Small cross-section reduction with increased flow capacity.

Limitations of CIPP include:

- The tube is custom made for each project.
- Existing flow must be diverted.
- Successful installation depends highly on the curing process.
- It can be expensive.
- Must divert any pipe flow.

3.2.2.4 Method Installation Description

CIPP installation and cure methods that do not use large amounts of water are better suited for the renewal of many storm sewers and culverts. If large amounts of water are not used in the process, water does not have to be trucked to and away from the job site.

Three different types of installation processes are discussed below. Each uses pressurized air to install and/or inflate the CIPP tube and steam, hot air, UV light or simply ambient temperature to cure the resin once the CIPP tube is in place. There are a large number of CIPP products, processes and installers available in the North American market, and each is slightly different with varying technical envelopes. However, considering that the scope of this manual includes open-ended storm sewers and culverts with an equivalent diameter range of 12 – 144 inches, CIPP products and processes are available for storm sewers and culverts in the equivalent diameter range of 12 –108 inches. Of course CIPP is available for sewers smaller than 12-inch diameter, but that is outside the scope of this report (ASCE, 2008).

Table 3-2 Main characteristics of CIPP

<i>Method</i>	<i>Diameter range (in)</i>	<i>Maximum installation (ft)</i>	<i>Resin</i>	Liner material
Inverted with air	12 -108	3000	Polyester and vinyl ester resins	Polyester felt material, fiberglass reinforced or similar
Winched at place	12 - 100	1500	Polyester and vinyl ester resins	

3.2.2.4.1 Invert with Air

Wall thickness design and installation of CIPP utilizing the inversion process is described in ASTM F 1216 (ASTM. 2007). Once the host pipeline has been cleaned and prepped, the CIPP tube is saturated with liquid thermosetting resin, a polyester resin for storm sewers and culverts. This commonly called wet out process typically occurs in a factory setting but can also take place at the job site if the wet out tube is too large or heavy to transport. Once the wet out tube is on the job site, the installation process can begin.

Although there are many different combinations of CIPP tube types and installation equipment available, in nearly all cases the beginning of the CIPP tube is turned inside out and attached to some type of inversion device. Air pressure is added to a sealed chamber causing more of the CIPP tube to turn inside out or invert. As the inversion process continues the inverting face of the CIPP moves through the host pipeline. When the tube is half inverted or half way into the host pipeline, the last of the wet out tube moves into the inversion device. Depending upon the type of installation being utilized, at this time a rope may be attached to the end of the CIPP tube. In addition, hoses may also be attached to deliver air and steam throughout the CIPP tube once it is fully inverted (ASCE, 2008).

As the inversion continues, tension is maintained on the previously attached rope (often called a hold-back rope) to control inversion rate, and the inverting face continues to move to the termination point. This rope and any previously attached hoses have now traveled through the entire length of the host pipeline.

With the inversion process, resin saturated felt is pressed up against the host pipe. Because of this, care must be taken to prevent liquid resin from flowing into the receiving stream or downstream storm sewer.

Most air-inverted CIPP tubes are cured with steam. In this case steam is either discharged into the attached hoses or directly into the CIPP tube. Once a previously determined cure schedule has been satisfied, the now cured product is cooled with air. Once cool, the ends are trimmed, any side connections are reinstated and the storm sewer or culvert can be placed back into service.



Figure 3-2 CIPP Inversion with air pressure.
(Source: Hydro Tech Inc.)

3.2.2.4.2 Pull-in and Inflate

Wall thickness design and installation of CIPP utilizing the pull-in and inflate process is described in ASTM F 1743 (see reference 7). Once the host pipe has been cleaned and prepped, the polyester resin saturated CIPP tube is pulled into the host pipe. Once the pull-in process is completed, the CIPP tube is inflated with air. In order for this process to work, the CIPP tube must have a coating or bladder on the inside that allows the tube to be inflated. The CIPP tube must also have a coating on the outside to allow the tube to be impregnated with resin, and also to protect the saturated tube during the pull-in process. Because the resin is contained between an outer and inner membrane or coating during the installation process, the chance that any liquid resin will escape into the environment is minimized (ASCE, 2008)..

Once the CIPP tube is pulled-in and inflated with air, it can be cured with UV light, steam or hot air. Once cooled, the ends are trimmed, any side connections are reinstated and the storm sewer or culvert can be placed back into service.



Figure 3-3 Pull and Inflate process (NASSCO, 2007).

3.2.2.4.3 Pull-In and Invert Through

Wall thickness design and installation of CIPP utilizing the pull-in and invert-through process is described in ASTM F 1743 (see reference 7). Two CIPP tubes are required for this process. Once the host pipeline has been cleaned and prepped, the CIPP tubes are saturated with liquid thermosetting polyester resin or wet out. Typically the bulk of the finished wall thickness, and, thus, resin is placed in the tube that is pulled-in (Tube A). The inverted tube (Tube B) may include a thin layer of fabric to be wet out. Or, it can simply be a bladder material with no fabric, requiring no wet out (ASCE, 2008).

First, Tube A is pulled into place. Tube B is then inverted with air through Tube A. Inversion of Tube B is as described in “Invert with Air”. This process inflates Tube A and holds it in place tight against the host pipeline. Steam is then introduced to cure the resin. If Tube B included a fabric material that was wet out, Tube A and Tube B cure together forming one laminate. If Tube B is simply a bladder material with no wet out

fabric, it is typically extracted and discarded. With this process the resin is contained between an outer and inner membrane or coating during the cure process thus minimizing the chance that any liquid resin will escape into the environment.

Consider using this process for an 84-inch culvert. Assuming a wall thickness design of 36 mm, a typical scenario would be a 33 mm thick Tube A and 3 mm thick Tube B. The 33 mm Tube A is first pulled into the culvert, the 3 mm Tube B is then inverted through Tube A and then the two tubes are cured together achieving the desired thickness.

This process is advantageous for difficult to access locations. Tube A can be lowered in with a crane and pulled-in with a cable and winch. Air inverting the 3 mm thick Tube B is much easier and does not require the large set-up area when compared to inverting a 36 mm tube.

Once cured and cooled, the ends are trimmed, any side connections are reinstated and the storm sewer or culvert can be placed back into service.

3.2.2.5 QAI/QC

The contractor installing the CIPP should take quality assurance measures during the installation process to ensure that quality controls listed in the contract documents are met. This process is more easily accomplished if the contractor has a permanent quality program in place.

The testing requirements to determine if the installed CIPP meets the performance requirements of the contract documents are typically listed in the technical specifications. Also, the basic testing requirements outlined in ASTM F 1216, ASTM F 1743 and ASTM D 5813 are applicable to storm sewers and culverts. These include:

- **Workmanship:** This includes a visual inspection for dry spots, lifts, delaminations or other defects. This inspection is by closed-circuit-television (CCTV) for small pipes or a walk-through on larger storm sewers or culverts.
- **Flexural Properties:** Flexural strength and flexural modulus are determined from a CIPP sample collected at the jobsite. These values should meet or exceed the values specified.
- **Wall Thickness:** The in-place wall thickness should meet or exceed the specified minimum wall thickness including any +/- tolerances.
- **Chemical Resistance:** Although chemical resistance properties are not as important in a storm sewer or culvert as compared to a sanitary sewer, the materials installed should meet the requirements of the chemical resistance test in ASTM F 1216.

- **Tensile Strength:** Tensile strength testing is not required for CIPP used to renew storm sewers, culverts or sanitary sewers. Tensile testing is required only for pressure CIPP.

Conformance to performance-based requirements is a true indication of the installed CIPP's ability to perform satisfactorily over the expected design life of the project. Strict means and methods specifications can be restrictive and exclusive because there are several types of CIPP installation methods and numerous CIPP installers in the marketplace.

Inspector's qualifications and responsibilities also determine how the final CIPP installation performs. The inspector must become thoroughly familiar with the contract documents for the project and most importantly the detailed specifications. The detailed specifications guide the inspector to the areas where the trenchless project must be inspected, recorded, documented, tested and otherwise verified to ensure that the product is being installed as specified (NASSCO, 2007).

Among some of the quality control procedures, it is recommended by the ASTM D5813 that for each inversion designated by the owner, a specified number of CIPP samples must be required. The sample should be cut from a section of the CIPP at the termination point that has been inverted through. If the CIPP is used to repair large diameter culverts, the sample should be fabricated from material taken from the tube and the resin/catalyst system used and cured in a clamped mold placed in the tube when circulating heated water is used and in the silencer when steam is used (NASSCO, 2007).

The finished CIPP should be continuous over the entire length of the culvert and be free of dry spots, lift, and de-lamination. If these conditions are present, the CIPP will be evaluated for its ability to meet the applicable requirements of the contract documents. Where the CIPP does not meet the requirements of the contract documents or specifically stated requirements of the specifications, the affected portions of CIPP will be removed and replaced with an equivalent repair (NASSCO, 2007).

3.2.3 Spiral Wound Pipe

3.2.3.1 Introduction and Background

The Spiral Wound Lining System utilizes a rigid plastic profile that is closely formed inside an existing pipe by interlocking the continuous strips of plastic profile using a specially designed winding machine or by manually locking the successive wraps of profile utilizing a jointing strip. The system is able to rehabilitate circular shape pipes as well as non circular shape pipes such as box culverts and horseshoe shapes (ASCE, 2008).

All the materials and equipment required to carry out a spiral wound project can, if required, be entered into the existing pipeline through manholes. The equipment is