GROUT-IN-PLACE LINERS

[Plastic Culvert Overview Flowchart](#) [Structural Defects Flowchart (Plastic)](#)

[Bedding Deficiencies Flowchart (Plastic)](#) [Hydraulic Capacity Flowchart (Plastic)](#)

1. OVERVIEW

Grout-in-place liners (GIPL) are made of thermoplastic liner tubes (PVC or HDPE) that are installed with anchors (e.g., V-shaped studs) on the outside of the liner, which serve as a spacer to the inner surface of the host culvert pipe thus creating annular space that is filled with high-strength cementitious grout. The grout is the primary structural element.

2. MATERIALS USED

The liner tube can be a studded HDPE liner (Figure 1) inserted by inversion or winching in, PVC strip installed by spiral winding (Figure 2), or soft panels (PVC, HDPE, etc) installed by slipforming (Figure 3).

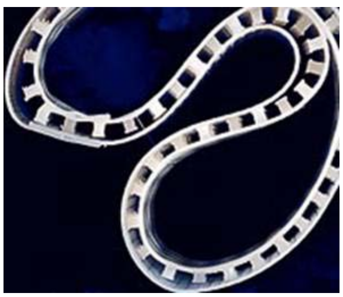

Figure 1. Studded HDPE liner (Whittle, 2007)

Figure 2. Winding a PVC strip (Whittle, 2008)

Figure 3. Slipforming with PVC sheets (Whittle, 2008)

Paterson (2000) stated that studded HDPE liners can be installed as three different systems:

- The basic system contains a single HDPE liner. The height of studs determines the thickness of annular space, which is typically between 0.4 in. and 0.75 in.
- A preliner system that also includes a smooth HDPE liner, which is usually required in areas near or below the groundwater level to ensure dilution-free grouting.
- A double system that incorporates another HDPE liner to create a larger void space around the existing culvert pipe wall that will be filled with structural grout, thus increasing the structural capacity of the lining system. Double-liner systems are used in applications requiring additional structural load-bearing capacity and high-security containment.

Grouts used with grout-in-place liners have adequate mechanical locking to the host structure and the liner tube, low shrinkage and bleeding, little segregation in water and high compressive strength, e.g., 2,800 psi after 7 days of curing and 4,900 psi after 21 days with PVC GIPL (McAlpine, 2009). Compressive strength of grouts used with HDPE GIPL is higher (Whittle, 2008) and can exceed 13,000 psi after 28 days (Cooper, 2000).

Grout-in-place HDPE liners may have a “self-cleaning invert” feature due to a special floor texturing that causes micro turbulences: during periods of increased flow in the pipe, any deposits are swept-up from the liner surface, directed to the flow centre and transported downstream (Whittle, 2008; Trolining GmbH, 2008).

3. APPLICABILITY

Grout-in-place liners can rehabilitate circular pipes from 6 in. to 120 in. or larger, however the method is applicable to any geometry.

The method can be applied in any culvert pipe material and shape. Pipe condition is generally not a limitation, e.g., the pipe can be deformed and near collapse.

Spiral winding machines with a custom form frame can rehabilitate both circular and non-circular pipelines and are typically used in medium to very large diameter pipelines, e.g. 36 in. to 12 ft ×15 ft and larger. The pipeline can have curved alignment with radius of curvature at least 7 times pipe diameter (Tackenberg, 2007).

Installation lengths can go up to 625 ft (Sterling et al, 2009).

4. CONSTRUCTION ISSUES

4.1. HOST PIPE PREPARATION

The following are the steps involved in preparing the host pipe (Whittle, 2008): inner dimensions of host pipe are measured, inner surface condition inspected, the pipe is cleaned, and rebar repaired as necessary.

4.2. INSTALLATION OF HDPE GROUT-IN-PLACE LINERS

Cooper (2000) provided details of the installation procedure. These liners and preliners are factory manufactured based on measured dimensions of the host pipe. The sheets are formed into cylinders and welded along their axial length to create a double-weld seam. If a preliner is used, it is folded and winched in first, and re-rounded to conform to the walls of the host pipe using a 5 psi air pressure. A studded liner is winched in place (Figure 4) inside the preliner and similarly re-rounded. Once both liners are in place, the open ends of all liners are sealed together using extrusion welding. After the annulus is sealed, the inflatable plugs are placed at the ends and the interior filled with water and pressurized. The grout is mixed to consistent water/cement ratio and viscosity within a specified range, and injected/poured under controlled head into the annulus between the liner and preliner through grouting ports (Figure 5). The injector is sampled throughout the injection process for proper water/cement ratio and viscosity, and evidence of expansion/swelling. After the grout injection has been completed, the hydrostatic pressure inside the liner is maintained while the grout cures to its nominal strength. The installed liners are inspected with CCTV. The translucent nature of some HDPE liners allows easy inspection.

Figure 4. Winching in a studded HDPE liner PVC (Whitle, 2007)

Figure 5. Grouting and air release ports installed after the annular space between the HDPE liner and preliner has been sealed (Whittle, 2007)

4.3. INSTALLATION OF SPIRALLY WOUND PVC LINERS

4.3.1. INSTALLATION USING A WINDING MACHINE

Tackenberg (2006, 2007) outlined the basic installation process using a winding machine:

- Install winding machine
- Wind the liner
- Remove winding machine and install internal bracing
- Inject grout
- Remove bracing

In the pre-installation phase, inner dimensions of the host pipe are measured, inner surface condition inspected, any obstructions and projecting points mitigated, and the pipe cleaned. Hydroblasting is recommended to remove buildup of grease and other foreign matter from the walls as well as all loose tiles and aggregate. Inverts need to be in good condition or repaired if necessary for the winding machine to run smoothly. Although the installation can be done in live flow conditions, a project with unpredictable flow levels may require a flow diversion.

The winding machine is assembled on the ground and inserted into the pipe (Figure 6). It has a custom form frame designed for the interior dimensions of pipe and a roller system that travels around the frame (Figure 7). Hydraulic motors are used for pulling in the winding profile (strip) and locking it into place. After winding, a bracing form (Figure 8) is installed as a support for the grout and to maintain clearance between the host pipe and the liner. The support jacks prevent the profile from floating or collapsing during the injection of the grout. Typically one support jack is needed every 7 ft, so this step is the most time consuming step during the installation. Bulkheads are constructed at the upstream and downstream sections and the grout is injected.

Figure 6. Winding machine with a custom form frame (Tackenberg, 2007)

Figure 7. A close view at the winding machine (Tackenberg, 2006)

Figure 8. A bracing form (installed and centered) before the grouting (Tackenberg, 2006)

4.3.2. MANUAL INSTALLATION

Spirally wound grout-in-place PVC liners can also be manually installed in man-entry pipes. McAlpine and Anderson (2005) discussed cleaning, lining and grouting of large diameter pipe. The PVC liner is delivered on site in coils. The liner has “T” shaped ribs on one side (the ribs provide a mechanical anchor for the PVC liner as the annular gap would be filled with suitable grouts) and smooth surface on another (to form the flow surface). The liner is taken into the pipe’s interior by simply pulling it from the inside of the bound coil. One end of the liner, usually at an upstream starting point, is formed into a circular hoop of desired diameter. The edge joints of adjacent windings are joined together by a second “joiner” strip that is inserted with an air hammer (Figure 9). The joiner strip has a co-extruded rubber gasket that forms a compression seal making the joint watertight.

Figure 9. Hammering a profile locking strip in place (Danby Pipe Renovation, 2007)

Prior to strip winding, steel welded wire mesh can be placed inside the pipe to serve as annulus spacers.

The annular space is subsequently filled in with grout. Because the PVC liner is a relatively low stiffness formwork, the grout must be placed in lifts of limited vertical rise. Drilling holes in the liner at the desired height can control the lift heights.

4.4. LINING WITH PVC PANELS

In man-entry non-circular pipes, ribbed plastic panels can be used for lining. The panels can be made to match any shape of the host culvert pipe. The panels are typically 12 in. wide and can be made to match specific job requirements (the length is practically limited by the ability of trucks to deliver them on site, e.g., up to 50 ft). The panels are placed inside a pipe and locked together on the edges (snapped) to form a continuous liner.

Figure 10. Flat and "corner" PVC panels installed in the invert and in sharp corners of a low-rise arch culvert (Danby Pipe Renovation, 2007)

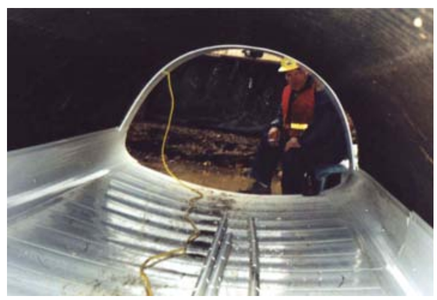

Figure 11. Arch PVC panels complete the slipforming (Danby Pipe Renovation, 2007)

5. QA/QC CONSIDERATIONS

Whittle (2008) stated that quality controls for grout-in-place relining must ensure consistent wall thickness, consistent design modulus (elastic modulus), and consistent corrosion resistance (chemical composition).

Key quality assurance checks for GIP HDPE liners in the field include water tightness of all joints and seams, monitoring of grout properties at ambient temperatures, and monitoring humidity changes. Key quality control tests in the field are viscosity, water-to-cement ratio, weight, temperature, and changes in volume (expansion or contraction during curing). Prism specimens should also be poured for post-construction strength tests in a laboratory (Grant Whittle, Ultraliner Inc, personal communication).

6. STANDARDS AND SPECIFICATIONS

6.1. PVC LINERS

ASTM D1784 covers rigid PVC and chlorinated PVC compounds for use in extruded or molded forms like pipe and fitting applications (Material standard).

ASTM F1697 covers requirements and test methods for materials, dimensions, workmanship, stiffness factor, extrusion quality, and a format for marking for extruded PVC profile strips used for field fabrication of PVC liners used in host pipes ranging in diameters from 6 in. to 180 in. and for similar sizes of non-circular pipelines such as arched or oval shapes and rectangular shapes (Product standard).

ASTM F1735 covers the requirements and test methods for materials, dimensions, workmanship, extrusion quality, and form of marking for extruded PVC profile strips used for field fabrication of PVC liners for existing man-entry (36 in. to 144 in.) sewer and conduit rehabilitation (Product standard).

ASTM F1698 describes the procedures for the rehabilitation of sewer lines and conduits of man-entry sizes (36 in. to 144 in. in vertical dimension) by the installation of a field-fabricated PVC liner. After installation of the liner, cementitious grout is injected into the annular space between the liner and the existing sewer or conduit. Rehabilitation by this installation practice results in a rigid composite structure (PVC/grout/existing pipe) (Installation standard).

ASTM F1741 describes the procedures for the rehabilitation of sewer lines and conduits 6 in. to 180 in. in diameter by spiral winding of an extruded thermoplastic strip into the existing pipeline. The procedures using stationary installation equipment and the traveling installation equipment are covered (Installation standard).

6.2. HDPE LINERS

North American standards that will cover these liners are in development, but have not yet achieved consensus peer review. The following are applicable European standards:

- DWA-M 143-10 (Sewer rehabilitation with studded liners)
- ATV M127, Part 2 (Structural design)
- DIN EN 1610 (Tightness test)
- DIN EN 295 (Abrasion resistance)
- DIN EN 196 (Grout properties)
- DVS 2225 (Liner manufacture by hot wedge welding method)
- ISO 1133 (Physical properties of HDPE)
- ISO 527 (Mechanical properties of HDPE)
- DVGW W 270 (Suitability for drinking water application)

7. EXAMPLE CASE HISTORIES

8. ADVANTAGES AND LIMITATIONS

The main advantages of grout-in-place relining are the ability to rehabilitate culverts with practically any size and shape, ability to accommodate bends, the fact that no excavation is required, this system results in a full structural rehabilitation, and the method is often cost competitive with other methods especially in large diameters and non-round geometries (lower mobilization costs and shipping costs as no refrigeration of materials is required).

The main limitation is the cost of structural grout if the liner is designed with considerable thickness. The required thickness can be reduced if the liner is designed as a composite structure with the host pipe, but this requires good surface cleaning of the existing culvert pipe, e.g., high pressure water jetting. Reduction in flow area depends on the liner thickness and can be significant. However, reduction in hydraulic capacity due to reduced cross-sectional area is typically at least partially mitigated by an improved Manning's *n* value. Also, the method can't be applied with flow in the pipe and therefore a bypass may be needed.

9. REFERENCES

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