# SLIPLINING

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## 1. OVERVIEW

Sliplining is a method of rehabilitation in which a new pipe of smaller diameter is inserted directly into the deteriorated culvert by pulling or pushing. Any pipe type used to construct new culverts can also be used for sliplining (Ballinger and Drake, 1995). With this method, the annular space between the host pipe and the newly installed pipe is created, which is typically grouted with a cementitious material.

The method can be categorized into:

- ***Segmental sliplining*** – A liner is being assembled from short pipe segments at the entry point into the existing pipe, from where the liner is being pulled/pushed into the pipe for the length of each added segment.
- ***Continuous sliplining*** - A liner is manufactured as a continuous pipe or assembled in the field prior to insertion (e.g. by fusing HDPE pipes) to match the entire length of the existing pipe.

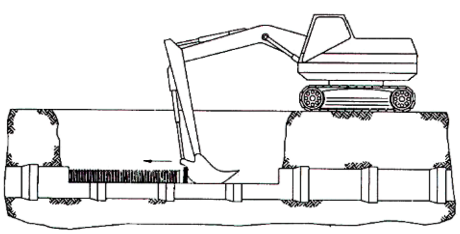

Figure 1. Segmental sliplining (ASTM F 585).

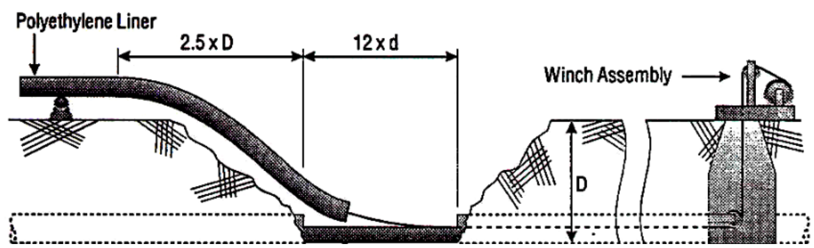


Figure 2. Continuous sliplining (Iseley and Najafi, 1995)

## 2. LINER MATERIALS

A variety of pipe types can be used for sliplining, e.g. reinforced concrete pipe (RCP), plastic pipes (HDPE or PVC, corrugated on the outer surface of the pipe, corrugated on the outside and inside surfaces, or with both surfaces smooth), corrugated metal pipe, and centrifugally cast glass-fiber-reinforced polymer mortar (CCFRPM) pipes (Ballinger and Drake, 1995).

Corrugated metal pipe, pipe arches and structural plate products are available in many sizes for sliplining culvert pipes. In addition, concrete-lined corrugated metal pipes (CLCMP) can be used, for which the concrete lining is plant-applied (Rinker Materials, 1992).

Johnson and Zollars (1992) investigated three different types of PE pipe for sliplining: smooth PE with mechanical joints, smooth PE with fused joints, and corrugated PE pipe. Newton (1999) discussed the practicality of continuous sliplining of failing culverts with polyethylene (PE) pipe showing that some of the major railroads installed this type of liner in the 1990s with very positive results, and described a coupling system for jointing HDPE pipes by “screwing together” bell-and-spigot ends.

CCFRPM pipes are available in a range of sizes from 18 in. to 110 in. in diameter, and standard pipe lengths of 20 ft. Standard stiffness classes (minimum pipe stiffness in psi) used for sliplining are SN 36 and SN 46 (Hobas Pipe USA, 2008).

One patented system uses stainless steel sleeves for continuous sliplining of culverts (LINK-PIPE, 2008c).

## 3. METHOD APPLICABILITY

Circular pipes in a wide range of diameters can be rehabilitated with sliplining, i.e., pipes with ID 4 in. to 63 in. can be repaired with continuous sliplining, and 4 in. to 152 in. pipes with segmental sliplining. Custom shapes are possible with segmental sliplining. Diameter changes may prevent this method. Length is not a limitation, as pipelines over 5,000 ft have been sliplined.

The method is typically limited to straight pipe alignment. However, continuous sliplining can accommodate large radius bends.

The method can be applied in any culvert pipe material and shape. Corrugations on the inside surface do not hinder use of this method. Pipe condition is generally not a limitation, e.g., the pipe can be corroded, deformed, and near collapse.

Sliplining can be performed in live flow conditions and flow bypass is seldom required (Thornton et al, 2005).

## 4. CONSTRUCTION ISSUES

### 4.1. INSTALLATION PROCEDURE

The following are steps that are normally required for the sliplining process (modified from Thornton et al., 2005, and Ballinger and Drake, 1995):

- Inspect the culvert (diameter changes along the culvert barrel, connecting pipes, protrusions, roots, sediment)
- Determine diameter of sliplining pipe and material
- Clean and clear the culvert, if required
- Divert and/or control water passing through the culvert (setup flow bypass), if required
- Make excavations if required
- Make any repairs in the existing culvert structure that may be necessary prior to sliplining. Repair embankment as well by identifying voids and grouting behind the culvert.
- Construct a guide way on the invert of the culvert, if required to facilitate the sliplining of sections into the existing culvert.
- Install pipe segments or continuous liner into the host culvert pipe
- Upon completion, a 24-hours relaxation period is recommended
- Inspect the installed slipliner pipe (CCTV or man-entry visual inspection)
- Perform leakage or other testing, as required
- Reconnect and stabilize terminal connections. Grout the annular space.
- Restore flow (remove bypass pumping) if applicable, and perform the site cleanup.
- As necessary, complete the project by constructing or modifying head- and wing-walls on the ends of the culvert.

If corrugated pipes or pipe arch sections are used for sliplining of corrugated culverts, either timber skids or a concrete “sidewalk” should be installed in the invert so that the liner may be slid into position. They may not be needed if the culvert is less than 150 ft long and the culvert is 36 in. or less in diameter (Ballinger and Drake, 1995).

When sliplining long culverts or if the insertion is expected to be difficult (e.g., there are offset joints or other irregularities in the existing culvert), conically shaped mechanical pulling heads can be used that enable easier gliding of the liner inside the culvert (Figure 3). For HDPE liners, a less sophisticated but cost-effective approach is to fabricate a pulling head out of a few extra feet of liner (Figure 4). The leading edge of the HDPE liner has evenly spaced wedges cut out, and the remaining ends are collapsed towards the center and fastened together with bolts, threaded rods or metal straps and attached to a cable (Kanters, 2007).

Figure 3. Conically shaped pulling head for sliplining (Kanters, 2007)

Figure 4. Pulling head for sliplining field-fabricated out of the HDPE pipe (Kanters, 2007)

CSPI (2004) outlined steps in relining procedure using corrugated steel pipe and corrugated steel pipe arch.

### 4.1.1. Assembling Continuous Liners

Each slipliner product has its own joint design. Heat fusion is a method for joining sections of smooth wall and some corrugated HDPE pipes. After aligning the two ends (Figure 5), pipe sections are connected by welding (Figure 6).


Figure 5. Aligning two pipe sections before welding (D. A. Van Dam, 2008)


Figure 6. Welding HDPE liner sections from inside the pipe (D. A. Van Dam, 2008)

Some HDPE products have integral threads that allow sections to be easily joined without special equipment. A coupling system for joining HDPE pipes by "screwing together" bell-and-spigot is shown in Figure 7. Some HDPE pipes come with a (patented) "snap" joining system (Figure 8) in which two sections of solid wall HDPE pipe, ranging in length from 2 ft to 50 ft and having male and female ends, are aligned and "snapped" together using chains and pressure from the excavator (Snap-Tite, 2008).


Figure 7. Thread-Loc joint for joining HDPE pipes (KWH Pipe, 2008b)

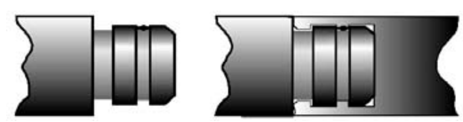

Figure 8. Male end of pipe (left) and a connected joint completed by snapping (right) (ISCO Industries, 2005)

Other types of pipe typically use gasketed or glued bell-and-spigot joints, or a restrained joint mechanism (Figure 9). Figure 10 and Figure 11 show how stainless steel sleeves are assembled into a continuous liner.

Figure 9. "Ring-and-pin" gasketed joint (Potter, 2009).

Figure 10. On-site assembly of continuous liner from stainless steel sleeves (LINK-PIPE, 2008c).

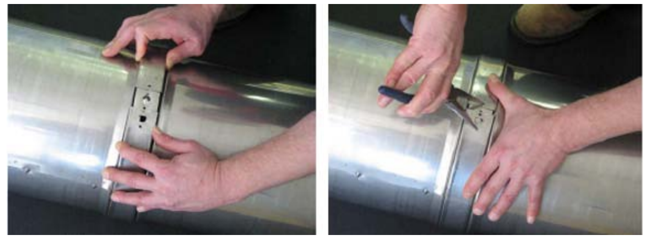

Figure 11. Connecting stainless sleeves into a continuous liner (LINK-PIPE, 2008c).

### 4.1.2. Insertion of Slipliner

Duncan (1984) described insertion of a slipliner made from corrugated structural plate arch in one case study where a 240 ft length of failing pipe arch culvert (structural steel plate with span of 14 ft and rise of 9 ft 8 in.) was sliplined with corrugated structural plate arch (10-gauge, span of 11 ft 10 in., rise of 7 ft 3 in). A guide was constructed to help assemble the slipliner pipe from plates and roll it in place. The guide was made from a 1.5 ft × 8 ft channel iron, set to grade every 10 ft and anchored to the culvert every 3.5 ft (Figure 12). A pit in front of the cut-off wall enabled a protective coating (asbestos-bonded asphalt coating) to be manually applied underneath the pipe (Figure 13). The pipe was assembled by bolting together bottom plates first to create the bottom half, and then bolting to it three top plates already assembled on the ground. Rollers were bolted to the pipe every 12 ft (Figure 14). Brackets were installed in the culvert's pipe bottom and the walls, and the slipliner pipe was pulled through the culvert.

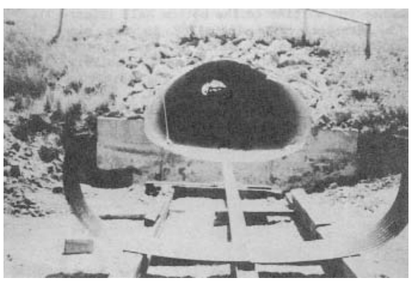

Figure 12. Guide for rolling (Duncan, 1984)

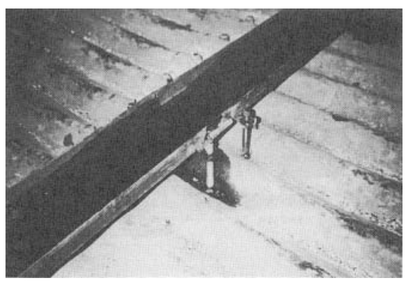

Figure 13. Assembly area and channel guide in place (Duncan, 1984)

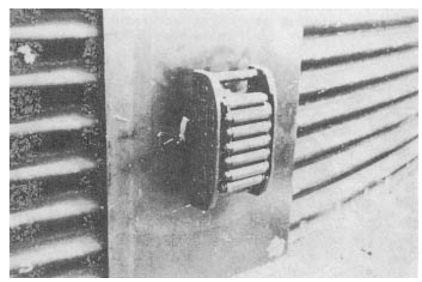

Figure 14. Roller system (Duncan, 1984)

### 4.1.3. Grouting of Annular Space

In sliplining installations, grouting the annulus between the liner and host pipe provides support to the liner pipe that comes from the host pipe that has settled well in the soil. Grouting can increase the structural differential-pressure capability of the polyethylene pipe by up to four-fold. (Phillips Driscopipe Inc, 2002.).

Jenkins and Kroll (1981) studied soil and cement encapsulation of PE pipe to determine the benefit derived in buckling resistance. They showed that cement grout can improve capability of the pipe by a factor of five. Buckling resistance of pipe contained by compacted soil was found 2-3 times greater than that of free standing pipe resistance. They also pointed out that when the annual space is not completely filled with grout, even if the liner pipe cannot generally deform even under much larger loads, the local distortion of the pipe still occurs at the loading point. For that reason, the grout support must be complete, i.e., at least 80% of the circumference must be grouted in order to achieve a higher buckling resistance. When undesirable point loads are avoided in a grouted pipe, the grout in the annulus protects the liner pipe and thus enhances the durability of the pipe.

Zhao et al. (2003) presented the effect of the grout on the performance of slipline pipe based on a three-year study on the performance of a sliplined water main in the City of Ottawa, Canada (Table 1). They also stated that the decision on annular space grouting is mainly based on its impact on construction and cost. Grouting the annulus also minimizes the buckling potential due to water accumulation in the annulus and freeze-up when the pipe is installed within the frost susceptible depth in cold regions.

Table 1: Pros and cons of grouting the annular space in sliplining (modified after Zhao et al, 2003)

| Advantages of using the grout | Disadvantages of using the grout |
|---|---|
| ▪ Increases the buckling resistance of the liner pipe | ▪ Increased construction cost and longer installation time |
| ▪ Increases the load carrying capacity | ▪ Potential collapse of liner pipe during grout injection |
| ▪ Can be used to control load-sharing between liner and host pipe | ▪ Requirement for blocking of all openings that may allow grout to escape during pouring |
| ▪ Eliminates sharp loading edges on the liner pipe from failed host pipe | ▪ Requirement for a proper grout injection procedure |
| ▪ Reduces longitudinal movements due to differential temperatures, thus minimizing shear-off potentials at lateral connections | |
| ▪ Increases the service life | |

Duncan (1984) provided recommendations on how to position the holes for grouting the annular space: at 3 and 9 o'clock positions at 8 ft intervals along the sliplining pipe, and at 11 and 1 o'clock positions at 4 ft intervals. Also, to facilitate filling under the bottom of the arch culvert, grout holes should be at 5 and 7 o'clock positions at 4 ft intervals.

Grouting of the annular space between the pipes must be continuous with no voids (a few small voids can be tolerated) to achieve the improved structural support that is needed. The Phillips DriscoPipe (1991) design manual showed the importance of complete grouting for sliplining with plastic pipe. The maximum external pressure differential on unsupported liner will increase when the gap between liner and original culvert is eliminated. For example, based on liner design theory at that time, Phillips DriscoPipe (1991) indicated that service life of ungrouted HDPE SDR 26 pipe is 50 years for 9 ft of water head. However, when the same pipe is properly grouted into an existing pipe, it can withstand 36 ft of external groundwater.

Stephens (1996) provided useful guidelines for grouting the annular space of sliplined pipe (test shown was modified by authors):

- The grout design should specify mix design (proportions of constituents), density of slurry (cement, cement/flyash and water) and density of grout (after dispersant is added), viscosity, initial set time, 24-hour and 28-day compressive strengths, shrinkage, stability, and "bleed" (fluid loss).
- Initial set-up time is extremely important. The grout mix must remain fluid and not thicken for a period of at least two hours (see Figure 17). Grout should be tested in accordance with ASTM C939.
- Fly ash based lightweight grouts are not recommended for slipliner grouting if the grout would be exposed to excessive water infiltration before it sets.
- If the existing pipe has deflected from a straight alignment, there is the possibility that trapped air will result in discontinuous grout.
- Grout injection should start at the upstream end of the pipe and progress toward the downstream end so as to more easily displace water and debris. Suitable injection tubes must be inserted at the upstream end (e.g, as shown in Figure 15). Vent pipes installed at the downstream end should be 150% larger than injection tubes to minimize the potential for clogging.
- In the field, every batch of grout should be tested for density and viscosity.
- Any suspected voids in the soil must be pressure grouted prior to inserting the slipliner.
- Maximum grout injection pressure must not exceed the slipliner manufacturer's recommendations.

For evaluating the proposed grout mix, the following need to be considered (Stephens, 1996): (1) condition of the pipe wall beneath the corroded layer, (2) groundwater infiltration; (3) porosity of the corroded portion of pipe (for fluid loss considerations, see Figure 16), (4) the length of runs, type of pipe to be used, OD of slipliner pipe, pipe stiffness, maximum injection pressure allowed, weight of pipe filled with water (if flotation or misalignment are not allowed), and (5) the joint deflection limit of the slipliner pipe if flotation is expected.

Figure 15. Grout tubes and slipliner pipe inside existing culvert (D. A. Van Dam, 2008)

Figure 16. A corroded pipe can cause thickening of the grout (Stephens, 1996)

Figure 17. A collapsed 18 in. welded steel pipe in a 36 in. steel casing attributed to too quick grout set-up time (Stephens, 1996)

### 4.2. OTHER ISSUES

### 4.2.1. Flammability of Polyethylene (PE) Slipliners

North Dakota DOT incurred severe damage to some polyethylene (PE) liners installed in culverts due to ditch fires. Katti et al. (2003) investigated options to address the flammability of these liners. The research reviewed several coatings that could be applied to the inside of PE liners, as well as CIP liners and centrifugally cast glass-fiber-reinforced polymer mortar **(**CCFRPM) pipes. The CCFRPM pipe was found to be the best solution, provided it was fitted with concrete end caps to ensure resistance to fire.

## 5. QA/QC CONSIDERATIONS

PPI (1995) prepared *Guidance and Recommendations on the Use of Polyethylene (PE) Pipe for the Sliplining of Sewers*, which describe the specifications, design considerations, and installation procedures for continuous sliplining utilizing polyethylene liners.

Goodwin et al. (1997) provided guidelines for writing specifications for successful sliplining.

Indiana DOT’s standard specifications (INDOT, 2009) require a Quality Control Plan (QCP) to be submitted to the engineer for acceptance at least 15 days prior to the start of sliplining, which must include, as a minimum, identification of the QC representative by name and documentation verifying the QC representative’s experience; the contractor’s method for cleaning and preparation of the existing pipe; method for joining, welding, or fusing the pipe joints; the personnel who will be welding or fusing the liners and their certification; the method and frequency of destructive and non-destructive testing on the welded or fused joints; the initial testing of the first joint, weld or fusion at each liner installation location; the corrective action that will be taken if defective or non-passing joints are found; the grouting process including the daily calibration process procedures for the grout generating equipment; inspection of bulkheads; specific job mix of the grout concentrate; the grouting procedure to ensure complete filling of voids; the corrective action to be taken if the grout compressive strength does not meet specifications; and the corrective action if the installation of the grout causes damage or deflection to the liner.

As grouting work is typically sub-contacted and the quality of grouting contractors can vary considerably, Caltrans (2003) recommends a list of submittals and calculations that the grouting sub-contractor should be required to forward to the project engineer.

## 6. STANDARDS AND SPECIFICATIONS

**ASTM D2657** describes the general procedures for making joints with polyolefin pipe and fittings by means of heat fusion joining techniques (material standard, continuous sliplining).

**ASTM D3212** covers joints for plastic pipe systems intended for drain and gravity sewage pipe at internal or external pressure less than 25 ft head using flexible watertight elastomeric seals. Test requirements, test methods, and acceptable materials are specified (material standard, segmental sliplining).

**ASTM D3262** covers machine-made glass-fiber-reinforced thermosetting-resin (fiberglass) pipes (Material standard).

**ASTM D4161** covers axially unrestrained bell-and-spigot gasket joints including couplings required for machine-made "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe systems, 8 in. through 144 in. (material standard, segmental sliplining)

**ASTM D6783** covers the testing and requirements for polymer concrete pipes. This specification is suited primarily for pipes to be installed by direct burial and pipe jacking but may be for sliplining as well (material standard, segmental sliplining).

**ASTM F585** describes the design considerations, material selection considerations, and installation procedures for the rehabilitation of sanitary and storm sewers by the insertion of polyethylene pipe through the existing pipe, along the previously existing line and grade (installation standard).

**ISO/TR 10465-1** describes the procedures for underground installation of flexible GRP pipes (Installation standard).

NASTT (2006f) outlined QA/QC issues for thermoset pipe (e.g., CCFRPM) that can be installed by sliplining. QA/QC should address the component products (the resin, the fillers and the reinforcing agents), the design (thickness, host pipe configuration, corrosion resistance, hoop strength and fit), and installation (joint fit, installation method, lateral restoration and grouting).

Additional standards and specifications associated with sliplining are listed in Thornton et al. (2005).

## 7. EXAMPLE CASE HISTORIES

### 7.1.1. Sliplining with RCP

### 7.1.2. Sliplining with Metal Pipe

### 7.1.3. Sliplining with HDPE

### 7.1.4. Sliplining with CCFRPM

## 8. ADVANTAGES AND LIMITATIONS

The main advantages of sliplining are simple installation, the ability to rehabilitate practically any pipe size, the variety of sliplining pipes on the market, and no need for flow bypassing in most cases. Thus, sliplining often offers an economical rehabilitation option for culverts. The method is capable of accommodating large radius bends. The method does not involve chemical processes and may be environmentally safe relative to other procedures (there is no Styrene, disposal off potentially contaminated process waters).

The main limitations of sliplining are the need for excavation of pits (although with shorter culvert lengths, digging of access pits may be avoided), and the grouting of the annular space (which is generally required). Other limitations often quoted are the reduction in flow cross-sectional area (although flow capacity could be recovered, or even increased, due to smooth interior surface of slipliner pipe) and the need for a sufficient work area (this can be significant). Numerous joints can be created with segmental sliplining, whereas with continuous sliplining the number of joints can be limited to only few.

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