SPIRALLY WOUND LINERS

Concrete Culvert Overview Flowchart
Structural Defects Flowchart (Concrete)
Bedding Deficiencies Flowchart (Concrete)
Hydraulic Capacity Flowchart (Concrete)

1. OVERVIEW

Spirally wound liners are fabricated in the field from a continuous thermoplastic strip that has one male and one female edge. During the helical winding process, the male and female edges self-interlock forming a leak tight joint (Figure 24).

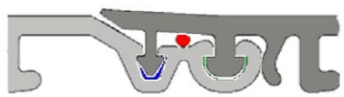

Figure 1. Self-interlocking of male and female edges during helical spiral winding (Jakovac and Raz, 2003)

The process of spiral winding for creating the liner inside the pipe is also utilized by grout-in-place liners (GIPL), which are covered in Section 3.1.6. GIPL liners use however a high-strength structural grout in the annular space between the liner and the host pipe, whereas spirally wound liners covered in this section use non-structural grout or do not require grouting the annular space at all.

2. MATERIALS USED

Strips for winding can be made of either PVC or HDPE. The strips come in a variety of profiles (Figure 25) with external ribs to increase the liner stiffness and to anchor the liner in the cement grout if used for annular space grouting. The PVC strip can be made with steel reinforcement (Figure 26), though this is typically used for larger diameter liners, e.g., 30 in. or more (Jakovac and Raz, 2003).

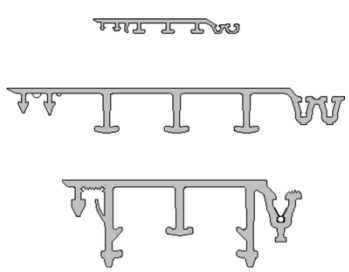

Figure 2. Some examples of winding strip profiles (from Jakovac and Raz, 2003)

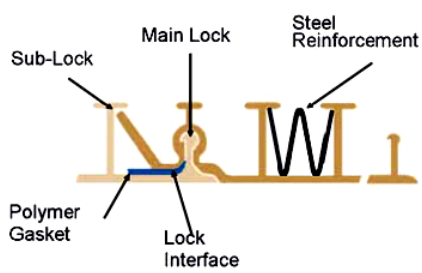

Figure 3. A PVC profile with steel reinforcement (Doherty, 2006)

Based on the location of the winding machine during installation, spiral winding can be classified as either:

- Stationary – A winding machine is positioned at an opened end of the culvert pipe (Figure 27). The machine is a fabricating assembly that consists of a drive tray and various winding cages.
- Mobile – A winding machine traverses the pipe. The machine is circular in shape consisting of a series of hydraulic rams that project radially from the central hub (Figure 28).

Figure 4. A stationary winding machine (Jakovac and Raz, 2003)

Figure 5. A rotating winding machine that traverses through the pipeline (Jakovac and Raz, 2003)

This method may or may not create intimate contact between the liner and the host pipe:

- Fixed diameter liners – Most spiral winding systems create an annular space between the host pipe and the liner, which is grouted, generally using cementitious grouts (Figure 29). The final result is a composite made of spirally wound liner, grout and the host pipe.
- Tight fitting liners (expandable diameter liners) – In a two-step installation process, the liner is first wound into the existing culvert pipe at a diameter smaller than the existing pipe and subsequently mechanically expanded to create a tight fit within the culvert pipe that eliminates the need for grouting (Figure 30). See Section 3.3.3 for additional details.

Figure 6. Fixed diameter liner spirally wound inside a culvert before (left) and after (right) grouting of annular space (Jacquie Jaques, CPT USA, personal communication).

Figure 7. Tight fitting liner is initially wound into the culvert at diameter smaller than the existing culvert pipe (left) and subsequently expanded to closely fit the existing culvert pipe (Jakovac and Raz, 2003)

3. METHOD APPLICABILITY

Spiral winding can rehabilitate circular pipes with diameters from 6 in. to 180 in. (Jaques, 2008a). The maximum drive length is dependent on several variables and project specifics, and is considered to be limited to 650 ft (Sterling et al., 2009). Jacquie Jaques (CPT USA, personal communication) reported shorter maximum drive lengths: up to about 440 ft for fixed diameter liners, about 210 ft for expanded liners, and 175 ft for “close fit” liners installed with a winding machine that traverses the pipeline.

Applicability is not limited by culvert pipe type, shape, or condition. Installation can be performed in live flow conditions.

4. CONSTRUCTION ISSUES

4.1. INSTALLATION PROCEDURE

Thornton et al. (2005) outlined the general installation procedure, which involves the following steps:

- Test the air in the pits for the presence of toxic or flammable vapors.
- Clean the existing culvert (e.g., using high-velocity jet cleaners).
- Inspect culverts for protrusions, collapsed or sagged sections, etc, that may hinder liner installation and remove any obstructions found.
- If necessary, setup flow bypass.
- If required or recommended, excavate an insertion pit.
- Position the winding machine (e.g., within the insertion pit) so that the liner can be wound directly into the culvert. Wind the liner placing the required sealant or adhesive within the primary and secondary locks of the locking configuration at the edge of the strip (unless already in place).
- Expand the liner, if required.
- If the job requires profile strips in the form of panels, cut and trim the panels to fit as near as practical to the internal diameter of the existing culvert or to produce the required annulus. Place the panels square with the culvert wall, circumferentially, and lock adjacent panels together as specified by the manufacturer. Seal termination joints with a manufacturer-supplied connecter and approved sealant.
- Inspect the completed installation (CCTV or visually in man-entry pipes).
- Carry out leakage or other testing, if required
- Reconnect connections (if applicable).
- Inject grout into the annular space between the existing culvert and liner through openings in the end seals, at reconnected service connections, or through holes drilled into the liner at appropriate points. Carry out the grouting procedure (apply the grout in a series of lifts/stages or apply the grout continuously)
- Restore flow if bypass was required and initiate site cleanup.

4.2. DIAMETER EXPANSION

Jakovac and Raz (2003) provided detailed descriptions of how spiral winding can produce tight-fit liners. In a two-step installation process, the liner is first wound out into the existing culvert pipe at a diameter smaller than the existing pipe and is subsequently expanded to fit the existing culvert pipe tightly (Figure 31).

For this purpose, a PVC profile is designed with two different types of locks:

- A secondary lock (an assembly lock) prevents the pipe from fully expanding during winding (this is a sacrificial lock that will be opened during the subsequent expansion process)
- A primary lock (a main lock) guides the expansion process and later, together with an adhesive, ensures the tightness of the relined pipe.

This PVC profile also has a hot melt adhesive that is factory applied to the secondary lock (shown blue in Figure 32, Figure 33) and a two-component joint lubricant sealant (silicone or polyurethane) that is field applied to the zone around the main lock (shown green in Figure 32, Figure 33) to act as a lubricant during the expansion process.

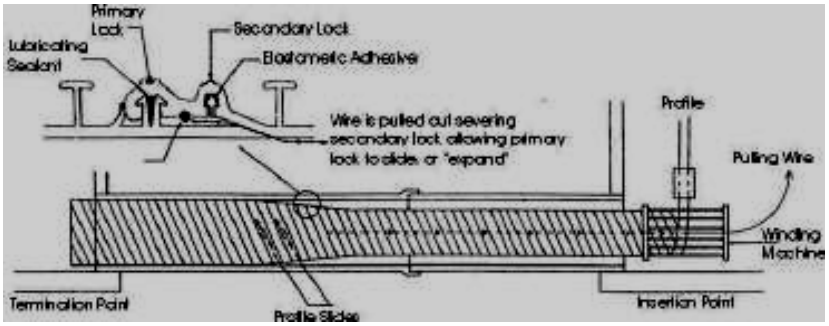

Figure 8. Schematic of spiral-winding process with diameter expansion (PRS Rohrsanierung GmbH, 2008)

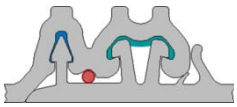

Figure 9. Profile lock before expansion showing wire (red circle) and a sacrificial lock intact (Jakovac and Raz, 2003).

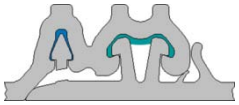

Figure 10. Profile lock after expansion showing no wire and the sacrificial lock opened (Jakovac and Raz, 2003).

The profile is wound from an “entry end” to an “exit” end of the host culvert pipe, with a high tensile strength steel wire in between primary and secondary lock (red circle in Figure 32). Once the spiral liner pipe has reached the exit end of the host pipe, the steel wire is pulled out. This uncouples the secondary lock and allows the liner pipe to be expanded. Expansion is carried out by fixing the end of the liner pipe (at the exit end) to prevent it from rotating and continuously winding the liner from the other end. This results in a circular pipe that is designed to be structurally self supporting.

4.3. GROUTING OF ANNULAR SPACE

With most spiral winding systems, annular space is created between the host pipe and the liner and grouting is required. Generally, non-structural cementitious grout is used, e.g., 300 psi compressive strength, installed in accordance with section 500-3 of the Greenbook (BNI, 2009), because the liner is designed to be structural and the grout is only required to provide a load path from the existing pipe to the liner and not to enhance the strength of the liner. With tight fitting liners, grouting is not required unless: (1) excessive sections of pipe are missing, (2) significant offset of the joints exist in the host culvert pipe (i.e., 12.5% of ID or 1 in., whichever is greater), or (3) pipe ovality exceeds 5% (Jaques, 2008a).

Grouting of the annular space is carried out through grout pipes that are either installed from the surface prior to liner winding (Figure 34) or drilled through the installed liner (Figure 35). Grouting can also be performed through the bulkhead (Figure 36).

Figure 11. Surface grouting through installed grout pipes prior to liner installation (Jaques, 2008a).

Figure 12. Grouting through grout ports drilled through the installed liner (Jaques, 2008a)

Figure 13.Grouting through the bulkhead (Jaques, 2008a)

5. EXAMPLE CASE HISTORIES

California DOT (Caltrans) used spiral winding to rehabilitate two culverts under Highway 101 in San Jose, CA, in 2007 (Vitorelo, 2008). The culverts were reinforced concrete pipes, 18 in. and 30 in. in diameter, and with total length of 230 ft. The culverts were broken and leaking, and sags formed in the

freeway pavement above the pipes. The 18 in. culvert had a gaping 8 in. hole that was spewing water with a force equal to a 15 ft water head. The spiral winding spanned the hole and sealed the leak.

6. QA/QC CONSIDERATIONS

ASCE (2009) outlined QA/QC measures applicable for spiral winding. The profile strip used for winding must be marked on the surface with a code number identifying the manufacturer, plant, date, and profile designation. Structural grout should be sampled and tested as designated by the owner (e.g., compressive strength test, bleed test, shrinkage test, and flowability test). The installed liner should be inspected by direct visual inspection or with CCTV. The manual also outlined acceptance and delivery, and time and cost considerations.

7. STANDARDS AND SPECIFICATIONS

ASTM D1784 covers rigid PVC compounds and chlorinated PVC compounds for use in extruded or molded form, including piping applications. (Material standard)

ASTM F1697 and **ASTM F1735** covers the requirements and test methods for materials, dimensions, workmanship, stiffness factor, extrusion quality, and a form of marking for extruded PVC profile strips for machine-made field fabrication of spirally wound pipe liners (Product standards).

ASTM F1698 and **ASTM F1741** describe procedures for the rehabilitation of sewer lines and conduits 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 (Installation standards)

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

8. ADVANTAGES AND LIMITATIONS

The main advantages of spiral winding are that it eliminates the need for excavation, pipe storage on site, and bypass flow (for most applications). Installation is quick and quiet, and this method has the ability to accommodate large radius bends and diameter changes. The method does not involve chemical processes and is more likely to be environmentally safe (no Styrene and potentially contaminated process waters to dispose off).

The main limitations of spiral winding are the need for grouting of the annular space (unless diameter expansion has been applied), the reduction in flow area (although flow capacity is often recovered or even increased due to smooth interior surface of the liner pipe), and the ends of the relined pipe require watertight sealing. The method is applicable in circular pipes only.

9. REFERENCES

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