SPRAYED-ON LINERS

[Plastic Culvert Overview Flowchart] [Structural Defects Flowchart (Plastic)]
[Bedding Deficiencies Flowchart (Plastic)] [Hydraulic Capacity Flowchart (Plastic)]

1. POLYMER BASED COATINGS AND LINERS

1.1. OVERVIEW

Polymer based coatings and liners involve the application of a layer of polymer material by either spincasting (Figure 7) or manual spraying using spray guns (Figure 8). ASCE (2009) defines coatings as applications where only a corrosion barrier is created, and liners as applications where a corrosion barrier and/or a structural repair are provided.

Figure 1. The spincast system uses centrifugal force to apply the material to pipe walls over lengths up to 700 ft (RLS Solutions, 2009)

Figure 2. A spray gun is used for applying the material to pipe walls in man-entry pipes (Warren, 2007)

1.2. MATERIALS USED

1.3. EPOXY

Although spray-on epoxy is mostly used for rehabilitation of potable water pipes, it can also be effectively used to line culverts (Thornton et al, 2005). Epoxy can be applied as protective coatings against corrosion and for eliminating infiltration/exfiltration.

Epoxy coatings are typically100% solids and solvent-free (i.e., they do not require a solvent to keep the binder and filler parts in a liquid suspension form). There are several advantages of such coatings over conventional liquid coatings: they emit zero or near zero volatile organic compounds; they can produce much thicker coatings than conventional liquid coatings without running or sagging; they produce less hazardous waste than conventional liquid coatings; generally they have fewer appearance differences between horizontally coated surfaces and vertically coated surfaces than liquid coated items (Walker and Guan, 1997).

Fiber reinforced polymer composites (FRPCs) contain high performance fibers embedded in a polymer matrix (Figure 95). The matrix serves to provide continuity to the composite, distribute applied loads among fibers, support the slender fibers against buckling, and protect the fibers from physical and environmental damage. FRPC materials have high strength-to-weight ratios, are generally resistant to corrosion, and are lightweight and thus relatively easy to apply (Warren, 2002)

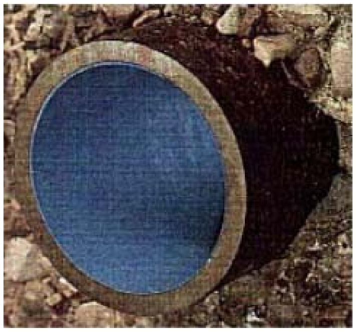

Figure 3. Epoxy-lined pipe (Proline Pipeline Protection, 2008)

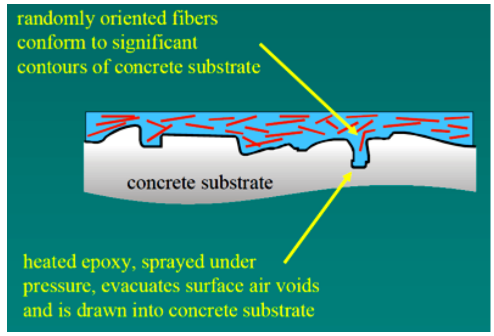

Figure 4. Spraying of fiber reinforced polymer composites (Warren, 2002)

1.4. POLYURETHANE

Sprayable polyurethanes are polyol based products blended with isocyanate. When mixed in a 2:1 ratio (2 parts of "B" polyol to 1 part of "A" isocyanate, proportioned by weight), a rigid coating is produced (permitting up to 4% elongation by ASTM D638) that provides both structural enhancement and corrosion protection. A 1:1 mixing ratio produces a flexible coating (permitting 43% elongation as assessed by ASTM D638) that offers only corrosion protection (Jerry Gordon, Sprayroq, personal communication).

Guan (2003a, 2003b) reviewed the chemistry, history and developments of 100% solids elastomeric polyurethane and 100% solids rigid polyurethane. Most pipe rehabilitation field applications have been traditionally based on 100% solids elastomeric polyurethane, but since the mid 1990s, the trend in North America has been towards the development and use of 100% solids rigid polyurethane coatings.

1.5. POLYUREA

Polyurea coatings and liners are based on isocyanates/amines (Primeaux, 1989). They combine application characteristics such as rapid cure, even at temperatures well below 0°C, and insensitivity to humidity, with physical properties such as high hardness, flexibility, tear strength, tensile strength, chemical and water resistance. The resulting surface offers good weathering and abrasion resistance. The systems are 100 percent-solids, making them compliant with the strictest VOC regulations (Broekaert, 2002).

For structural enhancement, the liner is sprayed "high build" (the term typically implies thickness roughly between 0.25 and 1 in.) as the liner is designed to resist soil loads, traffic loads and hydrostatic groundwater pressure. Like cement mortar lining, polyurea lining of this thickness, holds in place as a result of its rigidity and shape, and the adhesion (i.e. surface preparation) is not as critical as with protective coatings (Donald Dancey, Innovative Painting & Waterproofing Inc, personal communication).

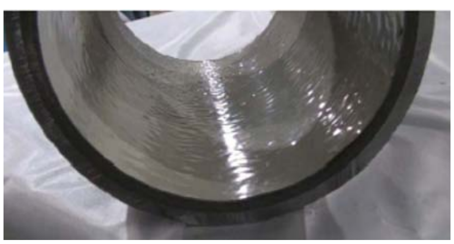

Figure 5. High build polyurea lining in pipe (Joseph, 2009)

1.6. APPLICABILITY

The technology is applicable in all pipe shapes and types (steel, concrete, PVC, cast and ductile iron, asbestos cement, wood, corrugated metal pipes) but the pipes must be completely empty of water, dry and clean (Stephane Joseph, Acuro, personal communication). Spincasting is applicable in small diameter circular pipes, typically in a diameter range between 3 in. and 36 in., and up to 700 ft in distance (RLS Solutions, 2009). In man-entry pipes, the method is applicable in any pipe size and shape, and the installation length is typically limited to 450 ft (Thornton et al, 2005). Safety regulations can also limit the installation length.

1.7. INSTALLATION

1.7.1. EPOXY

Epoxy liners are predominantly installed in man-entry pipes with manual spraying.

One system on the market (two components and 100% solids) is installed with a plural component spray application system, which pre-heats the product, mechanically ratios the two components, mixes and delivers the homogeneously blended product to the spray gun (airless or air-assisted). Application thickness is between 0.06 in. and 0.25 in. per application layer. For quality assurance, at least two coats are recommended. When applying multiple coats, no more than 18 hours at 70°F should be permitted to pass between coats. Recoating is usually performed between 2 and 18 hours after the previous coat. Initial set generally occurs within 6 hours at 70°F. Curing continues for 7 to 14 days (Jim Henke, RLS Solutions, personal communication).

Another system is also using a plural component spray-on system for spraying the material. The epoxy component utilizes a 2 parts base to 1 part activator mix ratio by volume. No thinners are utilized. The coating is applied in thickness up to 0.750 in., and multiple coats can be applied to a max thickness of 1 in. The cure time is about 2 hours at 77°F. Additional coats are applied within one hour (Jane Warren, Warren Environmental Inc, personal communication).

1.7.2. POLYURETHANE

This material is sprayed onto the prepared surface through an airless spray gun using appropriate ratio system for mixing the components (see 3.1.7.2_2b). Application thickness is up to 1 in. or greater. The material begins to gel in about 8 seconds, with a tack free condition after one minute. Within 30 to 60 minutes, the initial cure is completed and the structure is capable of accepting flow. The complete curing continues for the next 4 to 6 hours (Jerry Gordon, Sprayroq, personal communication).

Surface preparation is essential for successful application. The surface must be clean (free of oil, grease, rust) and dry (polyurethanes react to water instantly having bubbling and blistering reaction) (Baron**,** 2007).

1.7.3. POLYUREA

Polyurea is applied in thickness between 0.020 in. and 1 in., though maximal thickness is theoretically unlimited (Stephane Joseph, Acuro, personal communication).

The product cures rapidly with 5 to 8 seconds gel time, 12 to 15 seconds tack free time, and 24 hours return to full service. Application thicknesses from 0.125 to 1 in. can easily be achieved (for a high-built liner). The product can be sprayed directly onto concrete. If substrate is uneven or slightly damp, a primer is recommended (e.g., water blown high density foam that fills voids and creates an even surface) (Donald Dancey, *Innovative Painting & Waterproofing Inc,* personal communication).

1.8. EXAMPLE CASE HISTORIES

1.8.1. EPOXY

Several case histories of applying fiber reinforced polymer composites (FRPCs) for spray-on lining of tunnels, sewer pipes, manholes, and aqueducts are listed on a web site (Warren Environmental, 2009) although no case history of culvert rehabilitation is included among them.

1.8.2. POLYURETHANE

1.8.3. POLYUREA

One case study of polyurea spray-on rehabilitation of PVC pipes is the rehabilitation of a damaged PVC power cable conduit in Tampa, FL. The conduit was damaged while a concrete duct bank was installed under the existing highway (in the process of concrete pouring). The conduit was 8 in. in diameter and was rehabilitated with 0.15 in. thick polyurea lining that was installed robotically using a rotational grouting apparatus (Inspar Robotic Technologies, 2006).

1.9. ADVANTAGES AND LIMITATIONS

The main advantage of polymer-based coatings and liners is the ability to provide protection against corrosion. Some also provide structural enhancement. No excavation is required.

The main limitation is that the culvert must be completely free of water and flow bypass may be required. An extensive surface preparation is essential for successful application with some systems.

2. QA/QC CONSIDERATIONS FOR SPRAYED-ON LINERS

NASTT (2006a) outlined QA/QC issues for coatings and lining (cementitious, epoxies, urethanes and ureas). Referenced were material standards, most important installations issues (surface preparation, variables such as weather, safety, confined spaces, product viscosity, moisture tolerance, etc), and measures to ensure proper application (training of qualified applicators and proper equipment). The importance of testing and inspection of applied coatings and linings was recognized.

Muenchmeyer (2004) discussed elements of a QA/QC program that can minimize or prevent coating failures (Table 1), and outlined key specification issues and customer acceptance criteria. Good verifiable quality controls and testing documentation during construction were identified as critical components for the long term success of corrosion protection coatings. The paper also discussed warranties and the importance of regular project inspections.

Table 1: QA/QC for polymer coating (based on Muenchmeyer, 2004)

Quality assurance plan	Quality control plan
▪ Complete description of the project site and structure condition specifying precautions, if applicable	▪ Written verification that all QA requirement have been met
▪ Defined QA criteria	▪ Documentation that all safety requirements have been implemented
▪ Defined QC verifications during construction	▪ Verification of coating materials submittals, delivery and use
▪ Proposed safety plan for the work execution	▪ Pre-construction inspection of surfaces documenting their condition
▪ Schedule for product sampling	▪ Inspection of equipment for surface preparation and coating application (applicability, operational condition, and manufacturer's approval)
▪ Required submittals and certifications for the project and on the products to be used	▪ Documentation of environmental and service condition (temperature, humidity, pH, flow, infiltration, etc)
▪ Training certifications for the Applicator	▪ Inspection and verification of surface preparation
	▪ Measurements of film thickness of applied coating
	▪ Inspection of film continuity (visual and holiday testing)
	▪ Adhesion testing
	▪ Inspection and documentation of post-inspection repair procedures
	▪ Re-testing requirements of areas found to be deficient and repaired
	▪ Other test requirements recorded and verified by the inspector

Muenchmeyer (2005) evaluated a failure of coatings installed in one rehabilitation project in 1996, and described lessons learnt for future applications. The project included the use of epoxy coating in approximately 50 large diameter manholes (the conclusions apply to coatings in general), which failed soon after the 5-year warranty expired for the following principal reasons: 1) the coating was installed with non-uniform thickness that varied between 0.06 in. and 0.30 in. (thinner non-monolitic areas failed), and 2) the exposed aggregate was in many areas left un-coated and the pinholes were not repaired thus leaving underlying concrete to corrode at more rapid rate. Prior to the 5-year warranty expiration, the coatings were inspected by non-experienced inspectors who did not identify any problems. Among the lessons learnt are: 1) experienced inspectors and regular annual inspections are essential (extended warranty has no value otherwise), and 2) good field advice should be considered (the applicator indeed recommended a cementitious coat prior to epoxy coating that the owner disregarded).

3. STANDARDS AND SPECIFICATIONS

Morgan (2000b) listed shotcrete guides and specifications.

AWWA C602 covers cement-mortar lining of pipelines from 4 in. to 144 in. in diameter.

ACI 506.2 provides a useful basis (but only limited guidance) for the preparation of detailed specifications for a variety of different shotcrete constructions

ACI 506R provides detailed information on materials and properties of both dry-mix and wet-mix shotcrete. Most facets of the shotcrete process are covered, including application procedures, equipment requirements, and responsibilities of the shotcrete crew.

European Specification for Sprayed Concrete (EFNARC, 1996a) deals with concrete or mortar which is pneumatically placed onto a surface. Both wet and dry processes are covered. The appendix covers the admixtures for sprayed concrete: definitions, specifications, requirements, reference concrete mixes and test methods. EFNARC (1996b) covers the execution of spraying of concrete or mortar. EFNARC (1999) provide a commentary on the Specification by giving an explanation of the requirements.

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Plastic Culvert Overview Flowchart

Structural Defects Flowchart (Plastic)

Bedding Deficiencies Flowchart (Plastic)

Hydraulic Capacity Flowchart (Plastic)