TECHNOLOGIES AND METHODS FOR REHABILITATION OF FORCE MAINS

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Purpose Statement: To provide a brief overview of pipeline rehabilitation technologies for the purposes of education and comparison. Further guidance can be sourced by consulting an expert in trenchless technology and representatives of the technologies.

Information provided in this table is relative to sewer force mains applications only.

TECHNOLOGY: SEGMENTAL OR DISCRETE SLIPLINING

Overview	Segmental sliplining involves lining with pipe segments shorter than the section being rehabilitated, where the pipe cross-section remains unchanged during and after installation. This method results in an annular gap between the slipline pipe and the existing pipe, which is typically grouted.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Polyvinyl Chloride (PVC)	Fiberglass Reinforced Polymer Pipe (FRP)		Pipe segments are dropped into an existing pipe through access pits. Then the segments are pushed together progressively into the existing pipeline. Both circular and noncircular sections can be sliplined using spacers to ensure the slipline pipe remains centered within the existing pipe. Annulus grouting may be required following the insertion of the slipline pipe to ensure that the existing pipe structure provides adequate restraint and enhances ring stiffness.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	12 to 84 in.	Class III and Class IV (Semi-Structural and Fully Structural)	140 to 150	PVC: PVC and DI Fittings FRP: Flange adapters, backup rings, MJ adapters	Medium footprint Installation length can reach more than 5,000 LF on a single installation Pressure ratings up to ~300 psi May accommodate 11 1/4-degree deflection dependent upon material, pipe size and annular space Does not require consistent I.D. of host pipe This method of sliplining incorporates grouting the annular space after install To accommodate for grouting a minimum of 38 mm (1.5 in.) annular space is typical, plus the wall of the new pipe, which is designed for the operating conditions

TECHNOLOGY: CONTINUOUS SLIPLINING - LOOSE FIT

Overview	Continuous sliplining uses a long continuous pipe that is pulled through the existing pipe starting at an insertion pit and continuing to a receiving pit. Loose fit pipe has a smaller diameter than the host pipe.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Polyvinyl Chloride (PVC)	Fusible PVC (FPVC)	HDPE	Loose fit sliplining involves pulling a continuous HDPE, PVC, or FPVC pipe, fused or jointed before insertion, into an existing pipeline. The annular space between the slipline pipe and the host pipe is typically grouted.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	4 to 60 in.	Class III and Class IV (Semi-Structural and Fully Structural)	140 to 150	PVC: PVC and DI Fittings HDPE: Flange adapters, backup rings, MJ adapters	PVC, FPVC, HDPE: Large footprint as pipe is fused prior to insertion Installation length per setup can reach more than 7,000 LF on a single pull Operating pressures up to ~300 psi May accommodate 11 1/4-degree deflection dependent upon material, pipe size and annular space Does not require consistent I.D. of host pipe This method of sliplining incorporates grouting the annular space after install To accommodate for grouting a minimum of 38 mm (1.5 in.) annular space is typical, plus the wall of the new pipe, which is designed for the operating conditions

TECHNOLOGY: CONTINUOUS SLIPLINING - MODIFIED LOOSE FIT

Overview	Flexible Fabric Reinforced Pipe (FFRP) is another continuous, loose fit slipliner material consisting of a reinforced hose that is modified prior to insertion into the existing pipe and has a different technical envelope than other loose fit slipliner materials.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Flexible Fabric Reinforced Pipe (FFRP)			The FFRP is factory-manufactured round pipe that is modified into a "C" or "U" shape and coiled onto reels. The installation consists of a continuous supply of modified pipe being winched through the existing pipe and reverted to its manufactured "round" shape by air pressure.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	6 to 20 in.	Class III (Semi-Structural)	140 to 150	Flange end fittings and adapters	Small footprint Installation length per setup can reach over 8,000 LF Pressure ratings can exceed 1,000 psi Can accommodate multiple bends including 90 degree bends Does not require consistent I.D. of host pipe Semi-structural. Does not support external loads.

TECHNOLOGY: CONTINUOUS SLIPLINING - CLOSE FIT

Overview	Continuous sliplining uses a long continuous pipe that is pulled through the existing host pipe starting at an insertion pit and continuing to a receiving pit. Close-fit pipe is folded or reduced to facilitate installation, then reverted to provide a compression fit to the existing pipe. Close fit sliplining is also referred to as compressed fit or swagelining when using a continuous HDPE pipe.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	HDPE	Flexible Reinforced Plastic Hose (FRPH)		The installation consists of a continuous supply of pipe that is slightly larger than the I.D. of the existing pipe that is temporarily compressed or reduced in diameter during insertion into the host pipe. After installation the new pipe rebounds back outward, fitting tightly against the host pipe wall.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	HDPE: 16 to 63 in. FRPH: 4 to 54 in.	Class III and Class IV (Semi-Structural and Fully Structural)	140 to 150	Flange adapters, backup rings, MJ adapters	Small footprint when installing FRPH which is wound on a reel Large footprint as HDPE pipe must be strung out in its entirety Installation length per setup can reach up to 5,000 LF on a single pull dependent upon installation method Class III solution accommodating internal pressure up to 58 psi when using FRPH Class IV pressure up to 126 psi when using HDPE Class IV solution accommodating both internal pressure and external loading when using HDPE May accommodate 11 1/4-degree deflection when using HDPE; 45-degree when using FRPH Reduces internal diameter a minimum of 13 mm (0.5 in.) or greater when using HDPE; 20 mm (0.8 in.) or greater when using FRPH

TECHNOLOGY: CURED-IN-PLACE PIPE (CIPP)

Overview	Cured-In-Place Pipe (CIPP) consists of a resin-saturated tube (liner) that is inserted into the existing pipe and cured to produce a new pipe within the host pipe. AWWA/ANSI Standard C623 Cured-In-Place Pipe (CIPP) Rehabilitation of Pressurized Potable Water Pipelines, 4 in. (100 mm) and Larger can be referenced for the rehabilitation of potable water mains using CIPP.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Tube - fiber reinforced felt, or fiber reinforcement	Thermoset Resin - epoxy or vinyl ester		The tube is saturated with a thermoset resin and installed into the existing pipe either by directly inverting the liner into position using water or air pressure (ASTM F1216) or by pulling the liner into the host pipe using a winch (ASTM F1743). Once in place and properly inflated, the liner is cured by circulating hot water or controlled steam, or by exposure to UV light (i.e., photoinitiated reaction).	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	6 to 72 in.	Class III and Class IV (Semi-Structural and Fully Structural)	140 to 150	Hymax couplings and mechanical end seals used at CIPP termination.	Medium footprint Installation length per setup subject to diameter and thickness (up to 1,200 LF) Pressure ratings up to 250 psi - larger diameter, lower MAOP Can accommodate 45-degree and sweeping 90-degree bends Class IV solution accommodating both internal pressure and external loading Resin impregnation (wet-out) of the tube may be in a factory setting, or on-site (over-the-hole) Lining thickness is 4 to 15 mm (0.2 to 0.6 in.)

TECHNOLOGY: SPRAY-IN-PLACE POLYMER (SIPP)

Overview	Spray-in-place polymer (SIPP) involves applying a polymeric resin to the cleaned and prepared interior walls of the force main. AWWA/ANSI Standard C620 Spray-In-Place Polymeric Lining for Potable Water Pipelines, 4 in. (100 mm) and Larger can be referenced for rehabilitation of potable water mains using polymeric resins.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Polyurethane	Epoxy	Polyurea	After thorough cleaning and surface preparation of the existing pipe, the selected polymeric material is metered and pumped using specialized equipment for application by either worker-entry or robotic devices, which spray or cast the polymer onto the interior surfaces of the host pipe. The material is applied in one or more coats to form a continuous liner.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	4 in. and larger	Class I to Class III (Non-Structural to Semi-Structural)	140 to 150	End seals are typically not required for SIPP applications because of their adhesion to the existing pipe surfaces.	Small footprint Application length per setup subject to diameter and thickness (typically up to 1,000 LF) Not rated for internal pressure (dependent on host pipe) May require multiple layers to achieve desired thickness Cleaning and surface preparation of host pipe wall is critical Lining thickness is 40 to 500 mils (1 to 13 mm, or up to 0.5 in.)

TECHNOLOGY: SPRAY-APPLIED PIPE LINING (SAPL)

Overview	Spray-applied pipe lining (SAPL) using geopolymer materials may be appropriate to provide corrosion protection in large-diameter concrete sewer force mains where pressure is moderate and surge is controlled.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Geopolymer			After cleaning and surface preparation of the host pipe, the selected material is pumped into the existing pipeline and applied using either centrifugal casting or shotcrete hand spray, with or without hand troweling for finishing.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	36 to 120 in.	Class II and Class III (Non-Structural to Semi-Structural)	125 to 135	New connections performed in traditional manner (saddles, spools, etc.) No end seals required at coating termination.	Medium footprint Installation Application length per setup subject to diameter and thickness (typically up to 700 LF) Not rated for internal pressure (dependent on host pipe) Relies on adhesion to host pipe Cleaning and surface preparation of host pipe wall is critical Lining thickness is 25 to 100 mm (1 to 4 in.)

TECHNOLOGY: WET LAY-UP OF FIBER REINFORCED POLYMER

Overview	The wet lay-up of fiber reinforced polymer consists of application of a composite that includes a polymer and a reinforcement material. AWWA/ANSI Standard C305 CFRP Renewal and Strengthening of Prestressed Concrete Cylinder Pipe (PCCP) can be referenced for rehabilitation of potable water PCCP pipe using carbon fiber reinforced polymer (CFRP).				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	Epoxy	Fiberglass Fabric	Carbon Fiber Fabric	The installation is accomplished through the manual wet lay-up method, also known as the hand lay-up technique. The reinforcement fabric is impregnated with resin at the site and then applied to the interior surface of the pipe in a specific sequence, both circumferentially and longitudinally. This technology requires worker entry for application.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	36 to 120 in.	Class III and Class IV (Semi-Structural and Fully Structural)	140 to 150	New connections performed in traditional manner (saddles, spools, etc.) No end seals required at coating termination	Small footprint Installation is hand applied and subject to confined space entry Pressure ratings can exceed 450 psi Can accommodate bends Class IV solution accommodating both internal pressure and external loading Does not require consistent host pipe inside diameter Reduces internal diameter a maximum of 13mm (0.5 in.) Can be used externally

TECHNOLOGY: PIPE BURSTING

Overview	Pipe bursting is a technology that uses static or pneumatic methods to burst, fracture, or split the existing pipeline, displacing it into surrounding soils while pulling a new pipe through the same path as the existing pipeline. A unique characteristic of pipe bursting is the ability to upsize the diameter and thus capacity of the existing pipeline. AWWA/ANSI Standard C602 Pipe Bursting of Potable Water Mains, 4 in. (100 mm) to 36 in. (900 mm) can be referenced for potable water applications.				
Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method	
	HDPE	Polyvinyl Chloride (PVC)	Fusible PVC (FPVC)	A bursting head is pulled through the existing pipe, fracturing it outward into the surrounding soil while simultaneously installing a new pipe behind it. The process typically requires launch and receiving pits, temporary bypass pumping, and a pulling system to guide the bursting head and replacement pipe along the existing alignment. This technology makes sense for pipelines constructed of consistent materials, relatively straight alignment, and consistent depths of bury and bedding, with parallel separation from other utilities.	
Technical Envelope	Diam Range	Structural Classification	Hazen Williams Coefficient (typical values)	Connections (ARVs), Terminations and End Seals	Comments
	4 to 48 in.	Class IV (Structural Replacement, Upsize I.D. / Capacity)	140 to 150	PVC: PVC and DI Fittings HDPE: Flange adapters, backup rings, MJ adapters	Large footprint Installation length per setup can reach up to 2,000 LF Pressure rating dependent on replacement pipe May accommodate up to a 22 1/2-degree deflection Can enable pipe diameter upsizing Does not require consistent I.D. of host pipe. Class IV solution accommodating both internal pressure and external loading