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TECHNOLOGIES AND METHODS FOR REHABILITATION OF GRAVITY SEWER PIPELINES

Prepared by: NASSCO's Pipe Rehabilitation Committee

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 gravity sewer applications only.

TECHNOLOGY: CURED IN PLACE PIPE (CIPP)

Overview	Cured-in-place pipe ("CIPP") lining is a widely used trenchless technology used to repair localized damage, or rehabilitate pipelines manhole-to-manhole or in longer segments. This method involves inserting a resin-saturated tube into the existing pipe and curing it in place under ambient conditions, by applying a heat source, or by photoinitiated reaction through exposure to UV or LED light. Classified as a close-fit liner that conforms tightly to the host pipe creating a new, seamless pipe, offering renewed structural integrity, increased durability, and protection against further deterioration.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	Tube - felt, fiber reinforced felt, or fiber reinforcement	Thermoset resin - polyester, vinyl ester, silicate, or epoxy		Installation methods include inversion (ASTM F1216), pulled-in-place (ASTM F1743), pulled-in-place glass reinforced/UV cured (ASTM F2019), pushed- or pulled-in place sectional repair (ASTM F3541). Cure methods include ambient, application of a heat source (i.e., circulated hot water, controlled steam), or by photoinitiated reaction (i.e., exposure to UV or LED light).

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	2 in. to 120 in.	All types of host pipe material and shapes.	Typically 500 to 1,000 LF with longer lengths dependent upon diameter and pipeline configuration.	Bends: can navigate multiple 45- and 90-degree bends Pipe material and diameter transitions: can be used where slight changes in diameter or misalignment, or transitions between pipes of the same diameter but different materials exist	Flow must be diverted or bypassed. Existing pipeline must be clear of obstructions, crushed or collapsed pipe, and reductions in the cross-sectional area of more than 40% to ensure proper installation of the liner. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance found in ASCE MOP 145; ASTM F1216-24a; ASTM F2019-22; and ASTM F3541-22. Wall thickness (typically 3.0 mm to 20 mm) determined by design calculations using project specific assumptions, and the initial and long-term retention of flexural properties of the CIPP system selected.	Per ASTM F1216-24a / ASTM F1743-25 / ASTM F3541-22: Minimum flexural strength - 4,500 psi; flexural modulus - 250,000 psi Per ASTM F2019-22: Minimum flexural strength - 15,000 psi; flexural modulus - 725,000 psi Chemical resistance: ASTM F1216-24a, Appendix X2; ASTM F1743-25, Section 7.2; ASTM F2019-22, Section 5.2.7; ASTM F3541-22, Appendix X2; ASTM D5813-04(2025)	Installation Practices: ASTM F1216, ASTM F1743, ASTM F2019, ASTM F3541, ASTM F2994 Material Specification: ASTM D5813

TECHNOLOGY: FOLD AND FORM PIPE LINING (FFPL)

Overview	Fold-and-form pipe is made from a thermoplastic material that is heated, folded, and coiled onto a reel for transport to the job site. Installation is performed through existing manholes or small access points. Once winched into the existing pipeline, the liner is typically heated using steam, causing it to revert to its original shape and form. Classified as a close-fit liner, FFPL is a new, structurally independent, corrosion resistant pipe.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	Polyvinyl Chloride (PVC)	Polyvinyl Chloride (PVC-A)	HDPE	The folded liner is first conditioned (i.e., softened) using non-pressurized steam. It is then pulled into place inside the host pipe using a winch. Once in position, the liner is re-rounded and expanded to form a close-fit to the host pipe through a thermforming process. This involves a controlled combination of pressurized steam and compressed air, applied under specific temperature and pressure conditions. After expansion, the pipe is cooled using pressurized chilled compressed air, ensuring it becomes rigid after returning to its original shape.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	4 in. to 48 in.	All types of host pipe materials in cylindrical pipelines, provided the host pipe can maintain its shape and will not collapse under the steam and pressure used during installation.	400 to 1,000 LF Diameter and reel size dependent.	Bends: can navigate bends up to 30 degrees Pipe material and diameter transitions: can be used where slight changes in diameter or less than 12.5% offset joints, or transitions between pipes of the same diameter but different materials exist	Flow must be diverted or bypassed. Existing pipeline must be clear of obstructions, crushed or collapsed pipe, and reductions in the cross-sectional area of more than 16% to ensure proper installation of the liner. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance found in ASCE MOP 145; ASTM F1947-21a; ASTM F1867-22 Wall thickness: 0.114 in. to 0.60 in. determined by design calculations using project specific assumptions, and the mechanical properties of the FFPL system selected.	Per ASTM F1867-22 and ASTM F1871-24: Minimum tensile strength and modulus - 3,600 psi and 155,000 psi; minimum flexural strength and modulus - 4,100 psi and 145,000 psi; heat deflection - 115°F Per ASTM F1947-21a and F1504-21e1: Minimum flexural modulus - 280,000 - 320,000 psi dependent upon PVC cell classification; ASTM F1504: minimum impact energy and pipe stiffness - diameter dependent see Table 1 and 2	Installation Practices: PVC-A - ASTM F1867; PVC - ASTM F1947 Material Specification: PVC-A - ASTM F1871; PVC - ASTM F1504

TECHNOLOGY: FIBER REINFORCED POLYMER LINING (FRPL)

Overview	Fiber reinforced polymer lining is applied using a wet-layup method generally used to repair localized damage or sections of large diameter pipe. The lining consists of a polymer and a reinforcing fabric that can be used to restore structural integrity, provide corrosion protection, and enhance flow efficiency.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	Fabric - carbon fiber or glass fiber	Polymer - epoxy		Installation involves applying resin-saturated reinforced fiber fabric to the interior surface of a cleaned and prepared host pipe. After thorough surface preparation, including cleaning, drying, and priming with a compatible polymer, the dry reinforced fiber sheets are saturated with a polymer, typically an epoxy resin, and applied by workers to the pipe walls in overlapping layers that conform to the pipe geometry. Air bubbles are removed, and the fabric is compressed against the substrate to ensure adhesion. The composite is then allowed to cure under controlled environmental conditions.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	30 in. and greater, dependent on access for workers and equipment.	Host pipe materials such as concrete, brick or masonry, steel or ductile iron, and clay that are suitable for adhesive bonding required by FRPL. Most shapes can be lined with FRPL, although corrugated pipe or highly deformed pipes can be less suitable.	No fixed maximum, although installation length is limited by access for workers and equipment, and the ability to control environmental conditions.	Bends: only limited by worker and equipment access Pipe material and diameter transitions: only limited by worker and equipment access	Flow must be diverted or bypassed. Worker entry required. Surface preparation and control of environmental conditions are critical to ensure adhesion to the host pipe required by FRPL. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance found in ASCE MOP 145; AWWA C305 provides guidance when carbon fiber reinforced polymer lining is used on PCCP pipe. Wall thickness ranges based upon the number of layers applied with each layer ~1.0 mm thick. Wall thickness is determined by design calculations using project specific assumptions, and the initial and long-term retention of mechanical properties of the system selected.	No predefined minimum structural requirements; each application is determined based on the condition of the host pipe and the intended service environment.	NASSCO Performance Specification Guideline for Rehabilitation of Sewers Using Fiber Reinforced Polymers.

TECHNOLOGY: PIPE BURSTING

Overview	Pipe bursting is a trenchless method used to replace or upsize existing cylindrical pipelines. During this process, a bursting head is pulled through the old pipe, fracturing and displacing the existing pipe as it moves forward. Simultaneously, a new pipe is pulled in behind the bursting head, taking the place of the old one. This method is particularly effective when the existing pipeline is too deteriorated for other rehabilitation techniques. Pipe bursting is the only trenchless technology that can be used for upsizing pipelines to meet increased capacity demands.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	Most common replacement pipe: HDPE, FPVC	Other replacement pipe: Ductile Iron, Steel, Polypropylene, Fiberglass Reinforced Polymer Mortar		Static pipe bursting uses a hydraulic pulling machine to pull a bursting head through the existing pipe while simultaneously pulling in the new pipe. Pneumatic pipe bursting uses a pneumatic hammer to fracture the existing pipe while advancing the bursting head and pulling in the new pipe.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	4 in. to 48 in.	Pipe material determines the appropriate bursting method and the type of bursting head or slitter tools to be used. Only cylindrical pipes are suitable for pipe bursting.	Typically, 300 to 600 LF. Length of pull limited by diameter, soil conditions, bends, and other factors.	Bends: limited to long radius, typically less than/equal to 15°. Pipe material and diameter transitions: can be used without significant limitations and suitable for pipelines in poor structural condition. Upsize pipe: 1-3 pipe sizes, dependent upon soil conditions, depth of cover, existing pipe material, diameter, and other factors.	Flow must be diverted or bypassed. Soil conditions, bury depth, tight or multiple bends, and access can limit capabilities of utilizing bursting as an option. The length of a pull can be limited by equipment capabilities. Not suitable for non-cylindrical pipe, or pipeline runs with multiple service connections. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance: refer to guidelines on the replacement pipe material to meet project specific considerations. For pipe upsizing and pipe diameters greater than approximately 15 inches in diameer, there is increase risk issues, including soil deformation a(heave and settlement)t the ground surface Wall thickness dependent upon replacement pipe material selected.	No predefined minimum structural requirements; each application is determined based on the condition of the host pipe and the intended service environment.	Installation Practices: International Pipe Bursting Association Guideline for Pipe Bursting; NASSCO Pipe Bursting Gravity Sewer Mains with HDPE Pipe, pipe bursting equipment manufacturer guidelines. Material Specification: specific to replacement pipe material being used including, ASTM F714, ASTM D3350, ASTM D1248.

TECHNOLOGY: SPRAY-IN-PLACE PIPE (SIPP) USING POLYMERICS

Overview	Spray-in-place polymer (SIPP) is a trenchless method for rehabilitating large diameter gravity sewer pipelines suffering from corrosion, wear, and other forms of deterioration. Polymeric materials are sprayed or spincast onto the interior surface of the pipeline. These materials bond to the existing pipe structure, creating a seamless, durable, corrosion resistant lining.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	Polyurethane	Epoxy	Hybrid polymers	After thorough cleaning and surface preparation of the host pipe, the selected polymeric material is metered and pumped into the existing pipeline using specialized equipment. Application is made by worker-entry or robotic devices spraying or casting the polymer onto the cleaned and prepared surfaces of the host pipe.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	30 in. and greater, dependent on access for workers.	Host pipe materials such as concrete, brick or masonry, steel or ductile iron, and clay that are suitable for adhesive bonding required by SIPP. Robotic application may have limitations on host pipe shape.	No fixed maximum, although installation length is limited by access for workers and equipment, and the ability to control environmental conditions.	Bends: only limited by worker access and equipment capabilities Pipe material and diameter transitions: only limited by worker and equipment access	Flow must be diverted from all surfaces to receive SIPP, and bypassed when required for worker safety. Surface preparation and control of environmental conditions are critical to ensure adhesion to the host pipe required by SIPP. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance: refer to SIPP manufacturer guidelines to meet project specific considerations. Applied thickness typically 0.125 to 0.250 in. (125 to 250 mils) determined by existing surface profile, bond to host pipe, mechanical and physical properties of the polymer system selected.	Adhesion or bond to existing substrate may be quantified as specified by pull-off strength or substrate failure. Minimum initial and long-term mechanical properties required when used in design for structural renewal.	Installation Practices: AMPP, NACE and SSPC standards provide guidance on cleaning and surface preparation. NACE RPO188-99, ASTM D4787, D7234, and D4541 provide guidance on post-application quality control testing.

TECHNOLOGY: SPRAY-APPLIED PIPE LINING (SAPL) USING CEMENTITIOUS

Overview	Spray-applied pipe lining (SAPL) using cementitious mortars is a trenchless method of pipeline rehabilitation that forms a new, structurally independent pipe within the existing pipe. The mortar is mixed on-site and delivered pneumatically into the pipeline, where it is applied using either centrifugal casting or shotcrete techniques. Installation is performed through manholes or access shafts, and with the right equipment, extended distances up to 6,000 feet can be lined, making it ideal for long pipeline sections.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	Portland Cement	Geopolymer	Reinforcements not typically required. On occasion steel, welded wire or mesh maybe used.	After cleaning and surface preparation of the host pipe, the selected material is pumped into the existing pipeline and applied using centrifugal casting or shotcrete hand spray, with or without hand troweling for finishing.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	30 in. and greater, dependent on access for workers and equipment capabilities.	Host pipe materials such as concrete, brick or masonry, and clay that are suitable for bonding required by SAPL. Robotic application may have limitations on host pipe shape.	Typically 500 to 1,000 LF, with longer lengths possible using specialized equipment.	Bends: only limited by worker and equipment access Pipe material and diameter transitions: only limited by worker and equipment access	Flow must be diverted from all surfaces to receive SAPL, and bypassed when required for worker safety. Surface preparation and control of environmental conditions can be critical for proper application and cure of applied material. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance found in ASTM F3706-24; NASSCO Spray-Applied-Pipe-Liner (SAPL) Installation for Gravity Pipelines - Mortar Based Systems Performance Specification Guideline. Refer to SAPL manufacturer guidelines to meet project specific considerations. Minimum thickness 1 in. to 2 in. determined by pipe diameter, design, physical and mechanical properties of the material selected.	Per ASTM F3706-24: (28-day) Minimum compressive strength - >8,000 psi; minimum flexural strength - >800 psi; minimum tensile strength - >700 psi; bond strength - >2,500 psi; and shrinkage - <0.02%.	Installation Practices: ASTM F3706; NASSCO Spray-Applied-Pipe-Liner (SAPL) Installation for Gravity Pipelines - Mortar Based Systems Performance Specification Guideline Material Specification: ASTM Test Methods C39 and C78 for determining mechanical properties

TECHNOLOGY: SLIPLINING

Overview	Sliplining is a method that involves inserting a new, smaller-diameter pipe, the liner, into the existing, damaged pipeline. This liner restores the pipeline's structural integrity, ~~improves flow capacity,~~ and extends the overall lifespan of the system. Various materials are used for the liners, depending on factors like pipe size, system requirements, and environmental conditions. The liner can be installed in either continuous lengths or segmented sections.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	HDPE	PVC	Fiberglass Reinforced Plastic (FRP)	Entry and exit pits are required to accommodate the insertion of the new pipe (liner) and winching equipment. After the host pipe is cleaned to remove obstructions, the liner is either pulled through the host pipe using a winch or hydraulic jacking system, or pushed into the host pipe, typically for smaller diameters or shorter distances. After the liner is in place, the annular space may be filled with a flowable grout.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	8 in. to 100 in.+, depending on liner material, access, and other project specific conditions.	Host pipe should be cylindrical and still structurally stable to support liner insertion and grouting of annulus.	Typically, 300 to 1,000 LF with continuous sliplining, and 100 to 300 LF with segmental sliplining. Dependent on access, insertion method, pipe diameter, work area for lay-out of liner pipe.	Bends: typically can not be accommodated, may be possible with segmental sliplining. Pipe material and diameter transitions: typically can not be accommodated, may be possible with segmental sliplining. Bypass of existing flow may not be required.	Flow diversion or bypass may be required. Host pipe must be intact and structurally stable to withstand liner insertion and grouting, with straight or fairly straight alignment, and unobstructed. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance - refer to liner pipe manufacturer or plastic pipe association guidelines (e.g., PPI and Uni-Bell PVC Pipe Assn.), liner pipe is selected based on project specific considerations. Design guidance found in MOP 145. Wall thickness dependent upon liner pipe material selected.	No predefined minimum structural requirements; each application is determined based on the condition of the host pipe and the intended service environment.	Installation Guide: ASTM F585; refer to manufacturer guidelines. Material Specification: specific to liner pipe material being used including, ASTM F714, ASTM D3350, ASTM D3262, ASTM D2996, ASTM D3517

TECHNOLOGY: SPIRAL WOUND LININGS

Overview	Spiral wound linings consist of a continuous strip, or panel, of plastic material that is mechanically interlocked during installation. The strips are spirally wound into the host pipe and interlocked, either manually or using specialized machinery, with access typically through existing manholes. The interlocked strips are installed to form either a tight fit to the host pipe or, if an annular space is present, the gap is filled with grout. This technique can restore structural integrity, improve flow capacity, and reduce disruption, often eliminating the need for bypass pumping during installation.

Materials and Rehabilitation Method	Material 1	Material 2	Material 3	Rehabilitation Method
	PVC	HDPE	Grout, typically cementitious	Depending on the diameter of the host pipe, a continuous strip of plastic material is spirally wound creating a new pipe using a stationary or traverse winding machine, with access provided through existing manholes. The profile edges of the plastic strips interlock to form a mechanical seal. The interlocked strip forms either a tight-fit to the host pipe, or when annular space exists, is grouted in place, restoring structural integrity and improving flow capacity. The type of grout used depends on the dimensions of the pipe and project conditions. Alternatively, manually wound liners use manual force to lock the profile edges of the plastic strips or panels that are then grouted in place.

Technical Envelope	Diam Range	Host Pipe Material and Shape	Maximum Length	Capabilities	Limitations
	8 in. to 200 in.+ (machine wound); 36 in. and greater (manually wound)	All types of host pipe material. Cylindrical pipelines can be lined in all sizes, while non-cylindrical pipelines can be lined in pipes 36 in. and larger.	Typically, 200 to 700 LF. Larger diameters allow for longer installations up to 1,500 LF or more.	Bends: 15° or less possible in larger diameter pipes, depending on access and liner stiffness. Pipe material and diameter transitions: +/- 15% change in diameter may be possible. Bypass of existing flow may not be required.	Flow diversion or bypass may be required. Host pipe must be intact and structurally stable to withstand liner insertion and grouting, with straight or fairly straight alignment, and unobstructed. The line and grade of the existing pipeline will remain.

Performance	Design	Structural Requirements	Reference Standards
	Design guidance found in ASCE MOP 145; ASTM F1741-25; ASTM F1698-21 Wall thickness (typically 6 mm to 12 mm) determined by design calculations using project specific assumptions, and the mechanical properties of the liner system selected.	No predefined minimum structural requirements; each application is determined based on the condition of the host pipe and the intended service environment.	Installation Practices: ASTM 1741 (machine wound); ASTM F1735 (manually wound); ASTM F1698 (manually wound or panels) Material Specification: ASTM F1697

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