What is Structural Rehab?

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What does “Large Pressure Pipe Structural Rehab” mean?

What is “Large”? » Answer: “Large” is 24 inches

What is “Pressure”? » Answer: “Pressure” is 100 psi

What is “Structural”? » Answer: “Structural” is *complicated*

Photo courtesy of Heitkamp

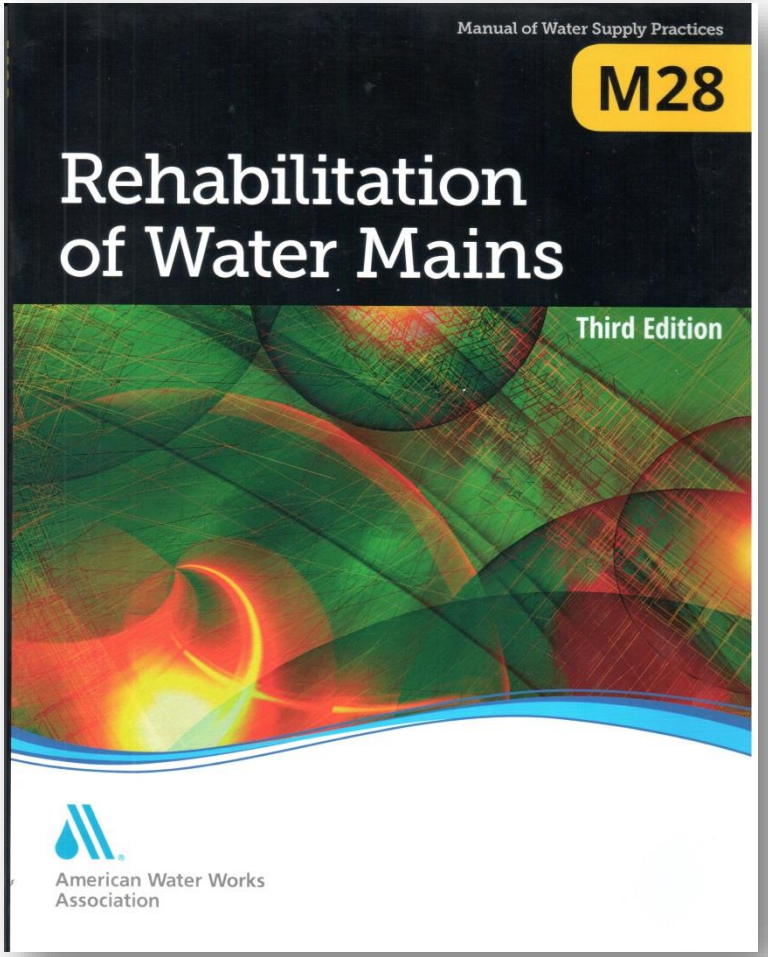
What is “Structural Rehab”?

AWWA Manual M28 – Appendix A

- Class I = Nonstructural
- Class II = Adhered Semi-Structural
- Class III = Non-Adhered Semi-Structural
- Class IV = Fully Structural

Example: Nonstructural Lining

Photo: Hydra Tech, LLC (Source: WRF Report 4367)



What is “Semi-Structural Rehab”?

Semi-structural linings span holes and gaps

- Hole size – not defined
- Minimum pressure – not defined
- Life expectancy – not defined
- Safety factors – not defined

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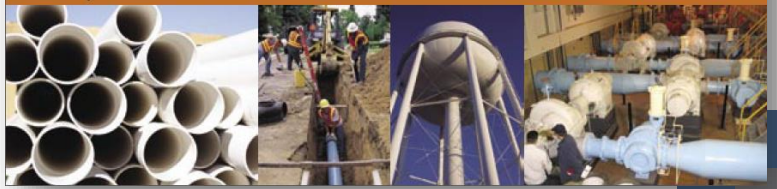
Global Review of Spray-On Structural Lining Technologies

Subject Area: Infrastructure



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What is “Semi-Structural Rehab”?

Semi-str
- » Hole s
- » Minim
- » Life ex
- » Safety

Figure 2.6. Exposed Cement Mortar Lining in 36-inch riveted steel pipeline. (Photo courtesy of Michael E. Grahek)

Virtually anything can be a semi-structural lining

What is “Fully Structural Rehab”?

Per M28, Appendix A, Class IV linings must have:

1. Long-term (50-year) internal burst (i.e., “hoop”) strength, independent of the host pipe
2. The ability to survive the failure of the host pipe ~~“due to internal pressure loads”~~

Per M28, Appendix A, Class IV linings need NOT:

1. Resist external pressure loads
2. Have longitudinal/bending strength

The separation of these systems for spanning holes and gaps into two classes is based on their inherent resistance to external buckling forces and dependence on adhesion to the host pipe wall. Class II systems have minimal inherent ring stiffness and depend entirely on adhesion to the pipe wall to prevent collapse if the pipe is depressurized. Class III liners have sufficient inherent ring stiffness to be at least self-supporting when depressurized without dependence on adhesion to the pipe wall.

Class III liners can also be designed to resist specified external hydrostatic or vacuum loads.

Use of Class II or III linings may be indicated where the host pipe is suffering from one or more of the following conditions:

1. Severe internal corrosion leading to pinholes and leakage
2. Leakage from faulty joints
3. Localized external corrosion resulting in pinholes and leakage

Although the liner will not prevent further external corrosion, it will prevent leakage at corrosion holes. This capability guards against the associated effects of that leakage on the exterior of the pipe and the corrosivity and support offered by the surrounding soil.

Class IV Linings

Class IV linings, termed fully structural or structurally independent, possess the following characteristics:

1. A long-term (50-year) internal burst strength, when tested independently from the host pipe, equal to or greater than the MAOP of the pipe to be rehabilitated
2. The ability to survive any dynamic loading or other short-term effects associated with sudden failure of the host pipe due to internal pressure loads

Class IV linings are sometimes considered to be equivalent to replacement pipe, although such linings may not be designed to meet the same requirements for external buckling or longitudinal/bending strength as the original pipe. Also, they may be of smaller internal diameters. Class IV linings can, of course, be used in circumstances similar to those for Class II and III, but their use is essential for host pipes suffering from generalized external corrosion where the mode of failure has been, or is likely to be, catastrophic longitudinal cracking.

Some available renovation technologies can offer both Class II and III and Class IV linings, while a given lining system may be rated as Class IV for MAOP levels up to a threshold value and Class II and III for higher pressures.

Additional Design Considerations

In addition to internal pressure loads, linings may also be required to sustain external buckling loads during periods when the host pipe is depressurized, as well as transient vacuum loads. Some systems (Classes III and IV) can be designed to offer significant inherent resistance to such external loads, while others (Class II) depend solely on adhesion to the host pipe wall. Inherent resistance to external buckling normally varies with increased lining thickness and hence cost. Care should therefore be taken to ensure that such performance requirements are accurately defined.

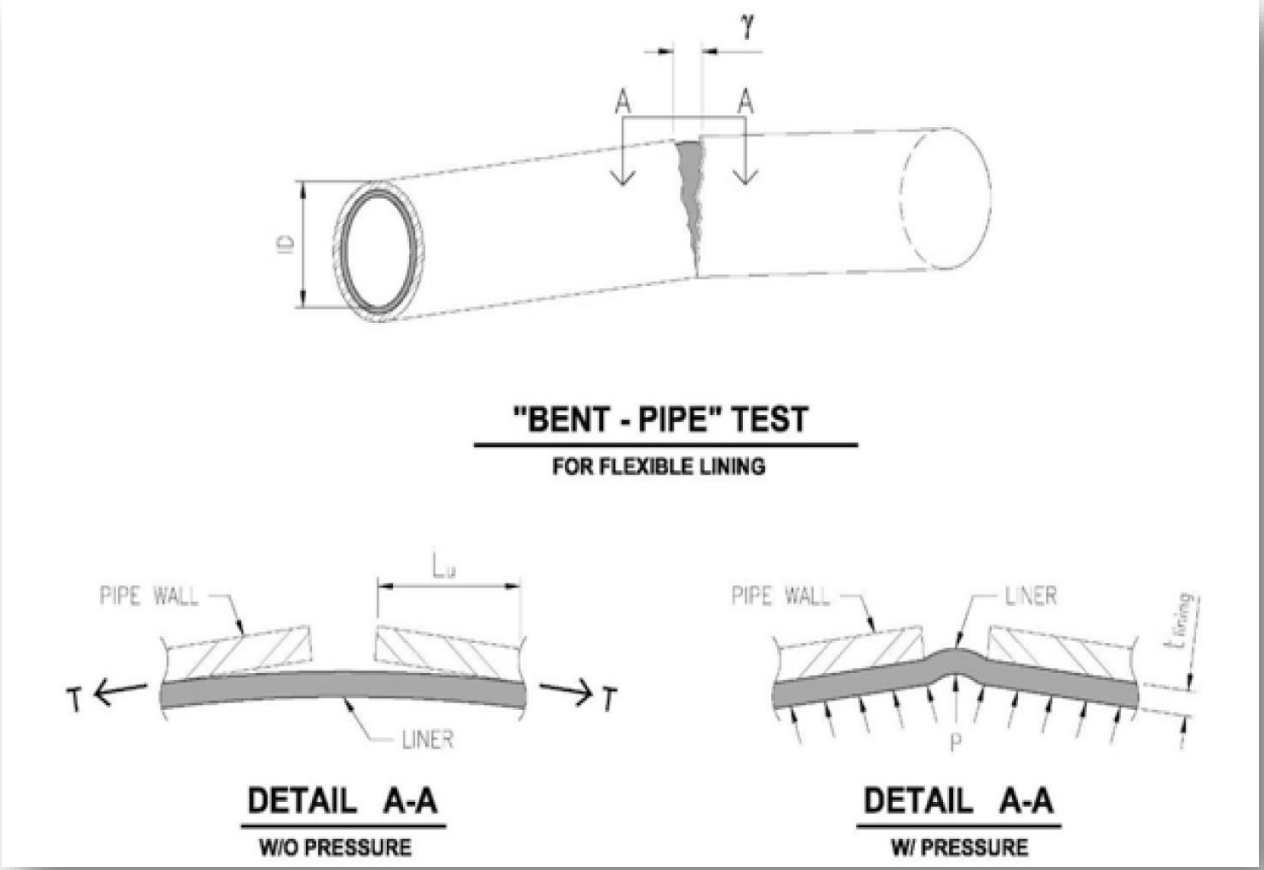
An ability to survive failure of the host pipe is very basic

» Tear-resistance is needed for lining of pipes expected to crack, fracture, or split

Adhered or bonded linings are very likely to tear…

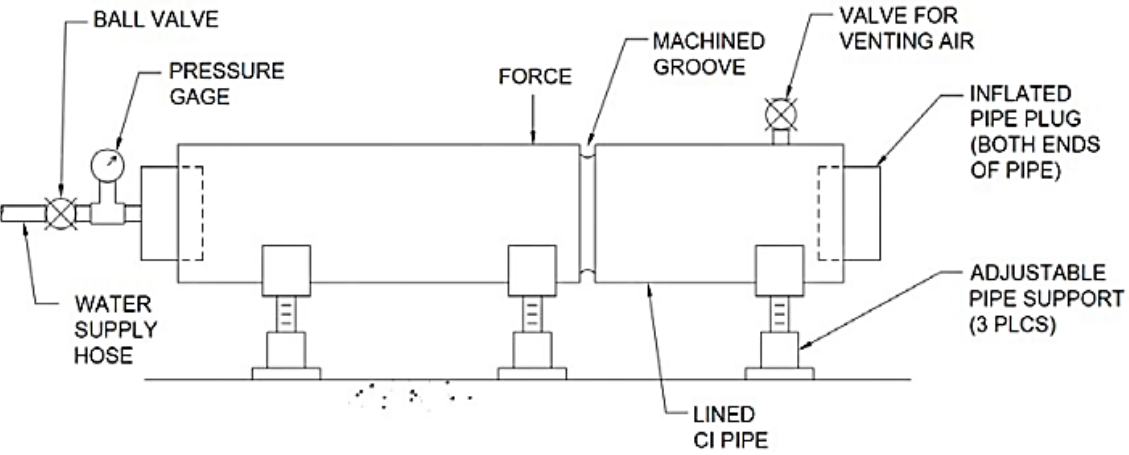
…strains become infinite

From WRF Report 4095 "...Spray-on Structural Linings" (2010)



A liner has less structural value, if it cannot survive a fracture

» The Trenchless Technology Center tested an old cast iron main, with 7mm thick polyurea



Sample extracted from pipe lined in place for American Water in New Jersey.

Well-adhered linings are not likely to survive pipe cracking

Lined pipe testing at Louisiana Tech University

Internal failure propagation

Large-pipe liners need to withstand large-pipe type breaks

- Broken wires for PCCP
- Broken bars for bar-wrap pipe
- Longitudinal split for steel?

Testing should mimic real conditions

- Use real (aged) pipe, if possible
- Consider surge events

Also consider:

- Dynamics
- Strain compatibility
- Ductility / eccentricities
- Cyclic loading
- Material deterioration!

Even “hoop strength” requires better definition

$$MAOP = \frac{2 * Fy * t}{D_i * SF}$$

where,

MAOP = max allow operating pressure

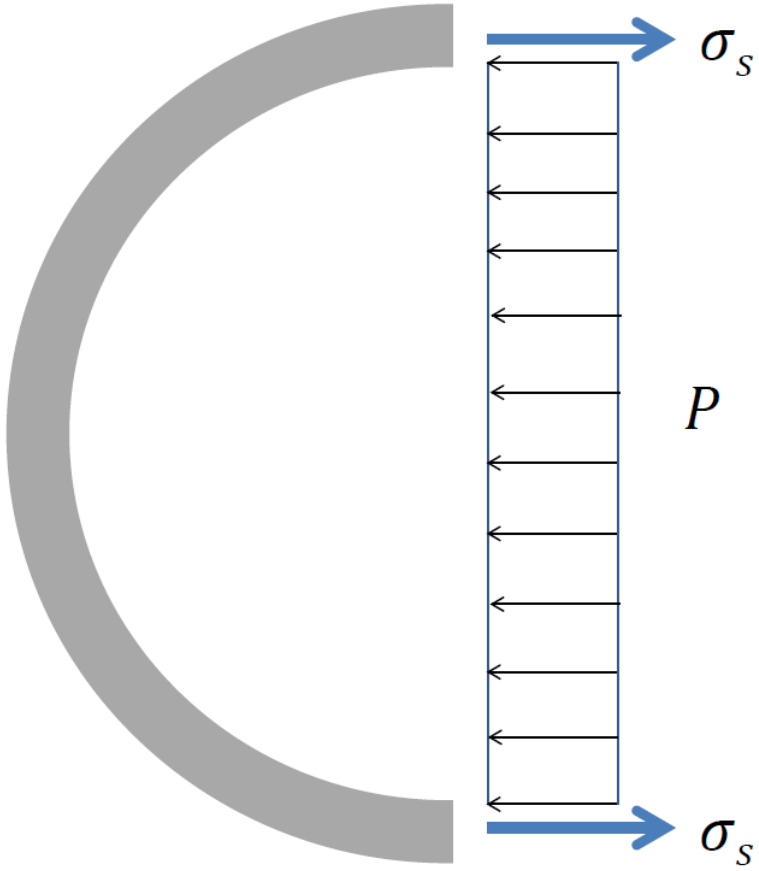
F_y = yield strength

t = pipe wall thickness

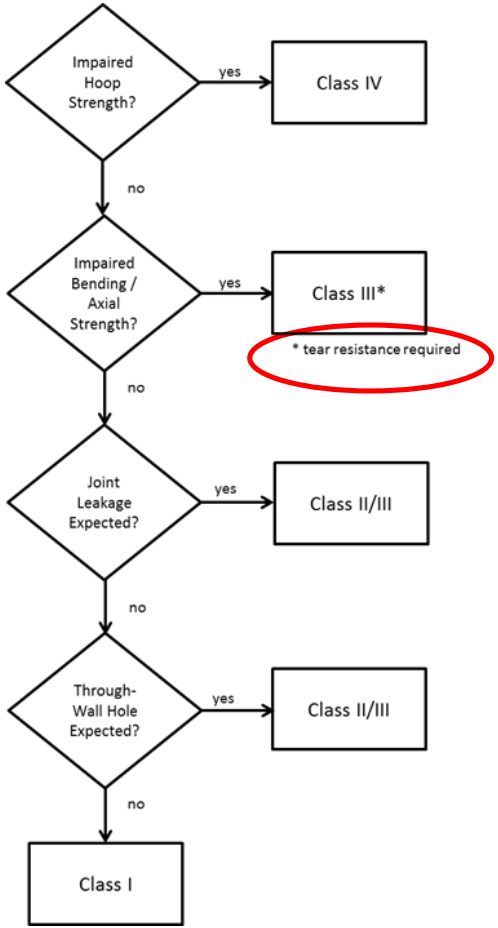
D_i = inside diameter

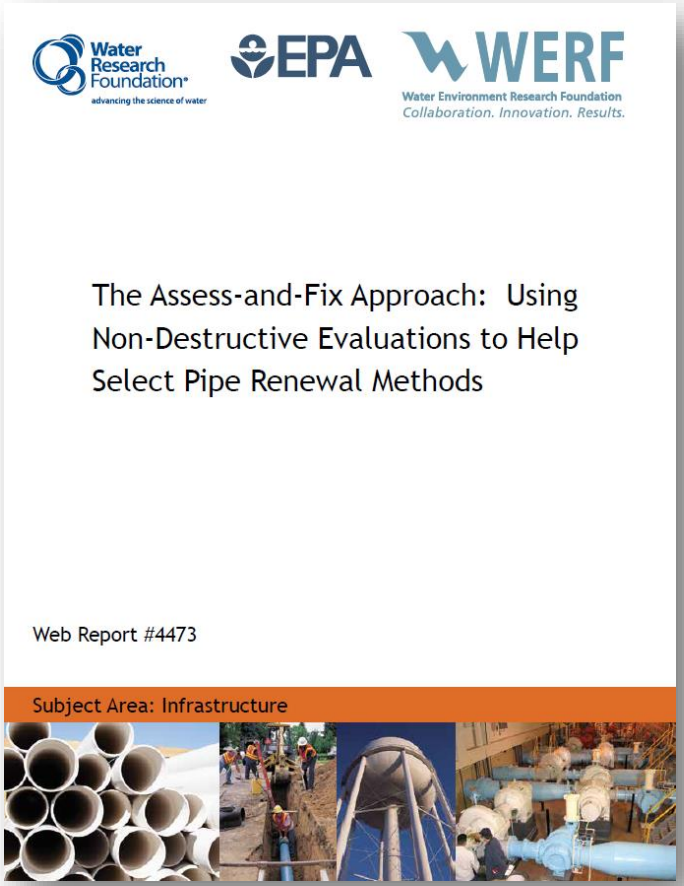
SF = safety factor

This is archaic….and really not applicable to plastic materials



New WRF report fills in many of these gaps





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WRF Report 4473 – Assess and Fix

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Table 6-1 Recommended lining types for various host pipe conditions

Mode	Estimated Future Condition of Host Pipe	Recommended Lining Type			
		Class I	Class II	Class III	Class IV
0	Insignificant structural deterioration	X			
1	Isolated corrosion pits may produce rust hole leaks		X		
2	Leaking joints		X	X	
3	Circumferential break (beam break)			X	X
4	Longitudinal split (burst)				X

The above analysis assumes that Class III and Class IV linings have demonstrated abilities to survive the fracturing of the host pipe while the pipe is pressurized.

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thods

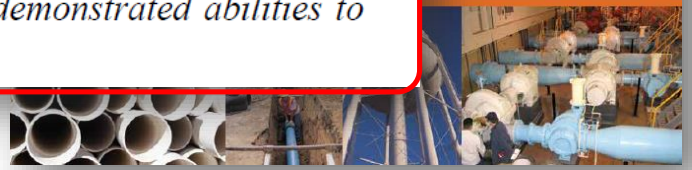

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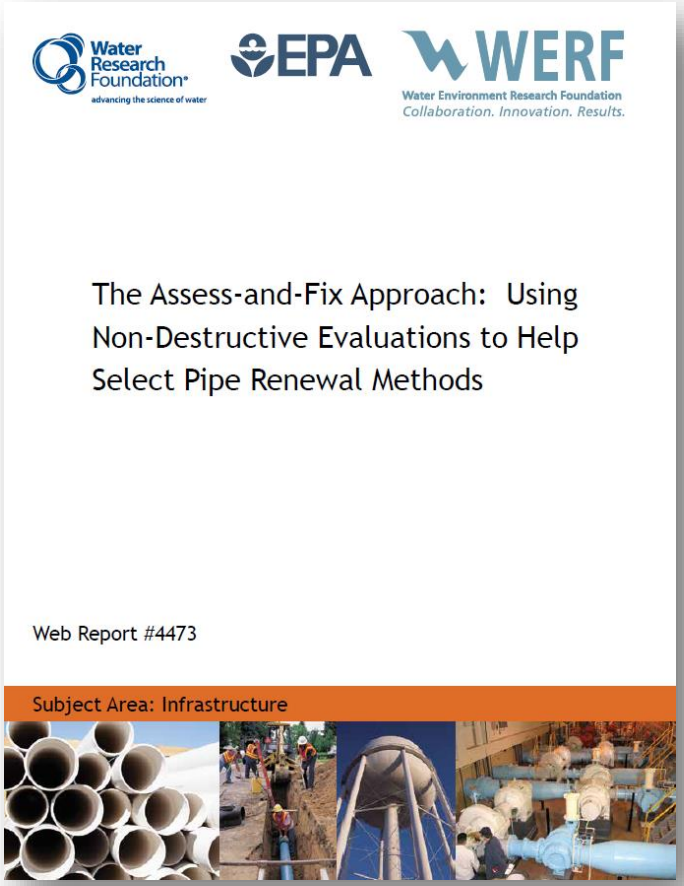
Table 6-2 Recommended criteria for Assess-and-Fix rehabilitation design

Design Variable or Parameter	Criteria
Yield or bending strength of polymeric material	100,000-hour strength, as determined by 10,000-hour tests performed per ASTM D1598, and analyzed per ASTM D2837 or ASTM 2992
Safety factor against surge-caused rupture	Customer selected, but not less than 1.1
Safety factor against leakage or other low-consequence failure	Customer selected, but not less than 1.1
Safety factor against rupture or other high-consequence failure	Customer selected, but not less than 1.25
Other safety factor considerations	Higher SF for high-consequence failures Higher SF for more brittle materials
Internal pipe pressure for analysis of lining material	Hydrostatic test pressure or maximum expected operating pressure
Interaction between host pipe and lining	Pipe strength and lining strengths are NOT additive, unless strain incompatibilities are addressed (see discussion below)
Size of rust hole for Mode 1 Failure	1.2 x predicted hole size (or larger)
Size of joint gap for Mode 2 Failure	0.2 inches (or larger)
Size of crack opening for Mode 3 Failure	0.2 inches (or larger)
Development of water-tight envelope	Lining system must be sealed at all discontinuities, including corporation stops, other lateral connections, and lining interruptions
Adhesion or lack of adhesion	Systems that rely on adhesion should be able to demonstrate adhesion Systems that rely on lack of adhesion (for tear resistance) should be able to demonstrate lack of adhesion and tear resistance



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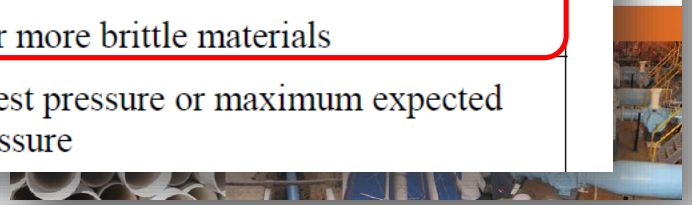

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Conclusions – “Structural lining” is not clearly defined

- Owners must do their homework
- AWWA M28 and WRF 4473 provide guidance
  - Committees are working too
- Testing / analysis is required
  - Water-tight envelope
  - Survival of host-pipe failure
  - Consider all real conditions

Pipe rehab is great! ….when properly applied

Questions?