“Inliner-“ and “Close Fit” Technologies - Potentials and Advantages for Water Pipe Rehabilitation

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NODIG Pipe Rehabilitation, Inliner, Close Fit

Introduction

The access to drinking water is a very precious good on earth. Even in regions which are rich of water in natural deposits, there are problems with efficient water tapping and supply. In many cities more than 50 % of the water is lost on the way to its end customer, a fact which is often caused by leaking pipes. Based on the Global Water Supply and Sanitation Assessment 2000 Report the water losses are often 50 % higher then the water extraction. In Asia und Latin America the losses because of leaking pipes are in average 42 %, in Africa 39 % and in North America the loss is still 15 %.

The conventional replacement of pipelines by excavation is very expensive, time-consuming and noisy and it generally involves considerable disruptions of traffic in urban areas. This is the reason for the steadily increasing demand for No-Dig technologies worldwide and why trends are shifting to the development of innovative solutions for water pipe – systems based on NO DIG technologies during the last years.

Based on the experience of big projects in Budapest (Hungary), Vienna (Austria) or Bydgoshsz (Poland), the latest trends for “Inliner-“ and “Close Fit” systems used for the rehabilitation of pressure pipes will be explained in this paper. Information about the preliminary works as cleaning and CCTV (Closed Circuit Television) inspection, the selection process for the materials and systems utilised. The paper concludes with critical issues of rehabilitation and possible strategies for future enhancements.

Potentials

Once a supply main has been identified as failing to meet its service requirements, the method of replacement or renewal will need to be evaluated and verified. Though popular, open-cut methods can create considerable inconveniences to customers, businesses, residences, and traffic. In urban areas these inconveniences can also become very costly. As a result, trenchless technologies have attracted the attention of the water supply industry as an alternative to open-trench methods. Trenchless technologies can substantially reduce direct rehabilitation costs and do diminish the inevitable collateral damage on all residential and commercial parties within the instant environment of the job site as the open cut area is reduced to minor access points.

Rehabilitation / Structural Lining

The selection of the system in depending on the host pipe condition and operational demands is the key in ensuring a long lasting rehabilitation success. The primary interaction between a flexible liner and its relatively rigid host when subject to internal pressure is classified in “independent” vs “interactive” adopted in current European renovation product standards and illustrated in Figure 1.

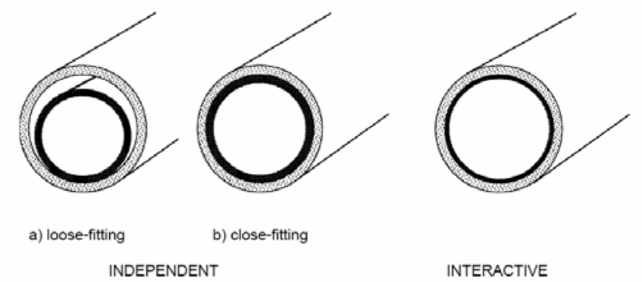

Figure 1. Structural classification of pressure pipe liners according to EN 13689:2002

It is important to note that in EN 13689 these adjectives are not defined in isolation but incorporated in the following compound terms:

<u>Independent pressure pipe Liner</u>: Fully capable of bearing all internal and external loads

<u>Interactive pressure pipe Liner</u>: Reliance on the existing pipeline for some measure of radial support in order to resist without failure all applicable internal loads throughout its design life, no external load bearing capacity

Key elements in the selection of a rehabilitation method are:

a. Exact nature of the problem(s) to be solved, particularly the host pipe condition and its mode of failure.
b. Hydraulic and operating pressure requirements including forecasted parameter
c. Materials, dimensions, age and geometry of the water main.
d. Types and locations of valves, fittings, and service connections.
e. Maximum time period in which the main can be taken out of service.
f. Site-specific factors, instant environment, soil conditions
g. Location and type of adjacent underground infrastructure

The selection of renewal technologies depends on pipe and site characteristics as well as on the inherent parameter of the techniques available. The aim of the selection process is to consider all these factors to arrive at the most cost-effective, technically viable solution. Ideally, the cost estimate should include not only direct contracting and related costs, but also indirect costs associated with public disruption and long-term maintenance. The ubiquity of scarce budgets defines the aim of selecting the most cost-effective technology.

The evaluation of the pipe conditions and the mode of failure and/or the status of deterioration are vital when selecting renewal technologies:

Mode of failure	Available solutions	Applied solution will also address:
Loss of structural	- Replacement with same size or lager - Structural Liner	- Joint imperfections - Water quality improvement - Increases hydraulic capacity

integrity		
Lack of hydraulic capacity	- Replacement with same size or larger - Structural, sem-structural or non-structural Liner in case diameter of host pipe is adequate	- Joint imperfections - Water quality
Joint failure	- Replacement with same size or larger - Structural or semi-structural Liner	- Water quality improvement - Increases hydraulic capacity
Water quality	- Replacement with same size or larger - Structural, semi-structural or non-structural Liner	- Increased hydraulic capacity

“INLINER” AND “CLOSE FIT”-SYSTEM

Lining with CLOSE FIT LINERS

Introduction close fit liner

In this procedure a thermo-mechanically deformed polyethylene tube coming straight from the factory is pulled in through a pre-existent access shaft. The high-strength polyethylene tube is re-shaped into a U-form shortly after it has been extruded. Its cross-section is thereby reduced by 30% in comparison with its original state. Because of the enhanced flexibility and smaller cross-section of the Inliner, which result from its U-shape, it can be pulled into the existent reach of the underground pipeline with the help of a winch. After reaching the final entry position the original tube shape is restored under pressure and of the addition of hot steam. The tube thereby presses itself firmly against the existent cross-section and assumes a continuous, smooth tubular form without any annular gaps.

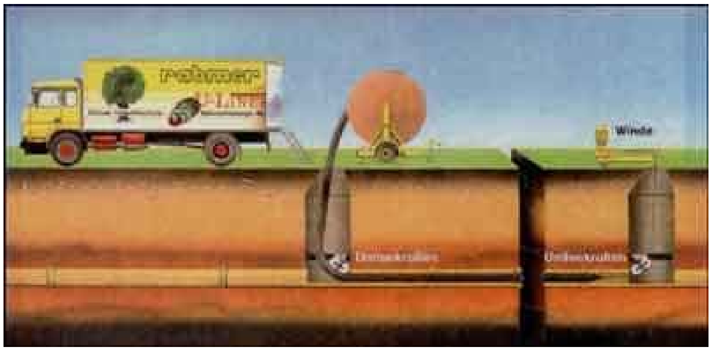

Figure 2. Technology Close Fit (Source: Rabmer)

Procedure close fit liner

A – Preliminary works

Cleaning, disconnection of the pipeline to be rehabilitated, mobile CCTV monitoring, pipe calibration and transport of the close fit liner to the site are the first steps. More details about these working steps see section 8.

The physical properties and the shape of the close fit liner enable it to be wound around drums in lengths of up to 1,600 m when it is produced. It is completely seamless. The twofold deformation involved in bending it into a U and winding it around the drum has no negative effect on the quality of the polyethylene tube.

Figure 3: Close fit liner wound on a drum (Source: Rabmer)

Division into rehabilitation sections and spatial requirements

The pipeline system is divided into sections that can be up to 950 m long in straight reaches, depending on the diameter, delivered length and strength of the close fit system. In determining the lengths of the allocated sections, the capacity of the equipment, the selected cleaning method and especially the structural properties of the pipe must be considered.

B - Installation of the close fit liner:

Pulling-in process

The close fit liner is pulled directly off the drum through the shaft into the pipe by a wire rope winch. Deflection rollers and pulling-in devices are utilised, assuring a smooth passage of the close fit liner through the shaft and pipe entrance.

This method facilitates pulling processes of Liner being several hundred meters long. Apart from the access points, no excavation is necessary.

Figure 4: Close fit liner pulled into a water pipe (Source: Rabmer)

Reforming the tube

After the close fit liner has reached its final position, both ends are cut off. Specially developed terminal pieces are then fitted onto its ends to close them off, and finally the tube is reformed to its original round shape with the help of steam (up to 125°C) and pressure (about 1.8 bars). Since the external diameter of the close fit liner corresponds to the internal diameter of the host pipe, it presses firmly against the wall of that pipe after reformation. No annular gap remains.

Figure 5-7: “Old pipe” / close fit liner before reforming / close fit liner after reforming (Source: Rabmer)

C - Final steps

Finishing processes

The finishing process consists of the attachment of fastening rings to both ends of the section. It varies according to application.

Connections

These are done in open construction by means of flanging or welding. All existing standard pipe connecting methods can be applied on close fit liners.

Processing the removed sections of the pipe in the shaft area

The removed sections of the existing pipe are either replaced by new sections or they are processed and prepared at the same time as the main pipeline and then inserted in between the ends of the close fit Liner.

Reconnection of the section

All newly installed sections are re-connected with either flanges or electrofusion couplings.

Final cleaning

A final CCTV inspection and a high-pressure jetting conclude the process..

Materials for close fit liners

Close fit liners for water pipes are made of polyethylene (PE-HD). Polyethylene is a chemically highly stabile, flexible, environmentally friendly thermo elastic plastic that is very resistant to abrasion and has a favourable roughness under operational conditions. The following table shows the lowest wall thicknesses of the different sizes. The SDR (standard dimension ratio) expresses the relationship between diameter and wall thickness.

Dimension	Water		Gas		SDR	Minimal wall thickness
[mm]	PE 80	PE 100	PE 80	PE 100	[-]	[mm]
100	6 bar	10 bar	1 bar	4 bar	17,6	6
125	6 bar	10 bar	1 bar	4 bar	17,6	7
150	6 bar	10 bar	1 bar	4 bar	17,6	8

200	6 bar	10 bar	1 bar	4 bar	17,6	11
300	6 bar	10 bar	1 bar	4 bar	17,6	17

Figure 8: Wall thickness of liners depending on dimension and pressure

Summary close fit liner

The close fit liner procedure is an economical and reliable solution for the renewal of gravity and pressure pipelines. The advantages of the close fit procedure are:

Operational performance

- Very long sections without couplings and improved hydraulics due to smooth surface
- Slight loss of diameter is compensated by the smoothness of the inner surface keeping the hydraulic capacity

Quality of the transported medium

- Suitable for potable water
- Prevention of inner and outer corrosion, no new accumulation of deposits/incrustations

Spatial requirements/ operating sequence

- Little or no work above ground
- Little space required for the construction site and excavation of access pits
- If existing, installation can be executed through pre-existent access shafts
- Close fit method can be applied independent from existing host pipe material and dimension

Procedural advantages

- Structural integrity either restored or improved

Economic efficiency

- Lower costs compared to conventional rehabilitation methods
- No indirect costs resulting from public disruptions (traffic jams, dust, dirty roads...)
- Short construction time (about 1 to 2 days per rehabilitated section)
- No isolation of laterals is necessary, since no annular gap is formed
- Minimal disruption of the affected households

Lining with cured-in-place pipes – The INLINER - System

Introduction Inliner system

A flexible, multi-layered textile tube, impregnated with epoxy resin is inverted through the entire length of the interior of the pipeline to be renovated. . The polyaddition (=hardening) of the resin takes place under a pressurised condition and the addition of hot steam, resulting in a continuous seamless cured pipe, entirely in contact with the host pipe.

Figure 9: Inliner System (Source: Rabmer)

Operating sequence – Inliner system

A - Preliminary works

Cleaning, disconnection of the pipeline to be rehabilitated, mobile CCTV monitoring, pipe calibration and transport of the close fit liner to the site are the first steps. More details about these working steps see section 8.

Division into rehabilitation sections and spatial requirements

The pipeline system is subdivided into sections, which can be up to 350 m long for diameters over 500 mm and up to 650 m long for diameters under 300 mm. The length renovated strongly depends on other factors than the capacity of the inversion machine, e.g. bends.

Preparation of the epoxy resin and impregnation of the tube

The tube is wound on a drum. In order to fill it, a few meters are wound off and laid down on a protection foil to prevent damage.

Pulling-in process

As a result of the reversal process, the tube lining is turned inside out. The inner side impregnated with resin is pressed up against the wall of the host pipe. The rotation of the drum shaft thrusts the tube, constantly being pressurised during the inversion process.. The reversion speed of up to 2 to 5 m/ min. is controlled by a retaining belt attached to the tube end.

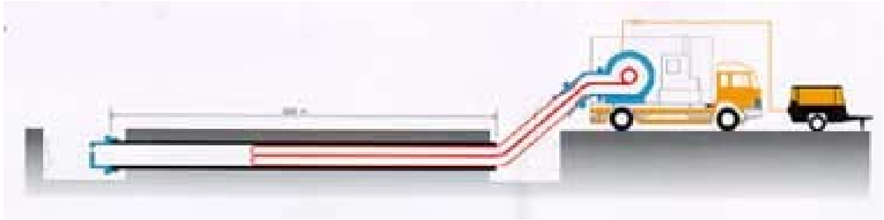

Figure 10: Schematically draft of an Inliner installation (Source: Rabmer)

Heat curing process

After the liner has passed throughout the entire length of the host pipe and arrived at the target shaft, vent tips are attached to the end of the tube to enable the circulation of hot. Hot steam is introduced through the drum into the pressurised Liner. Steam circulates throughout the curing process by keeping the internal pressure constant.

<u>C - Final working steps</u>

- Final processing
- Re-connection
- Re-establishing the connections between the sections
- Final cleaning and CCTV inspection

Range of Applications

The Inliner system can be used for all types of pipes (sewage, gas, potable water, oil, industry, etc.) from DN 100- DN 1600 mm.

Limitations of bends:

- Bends with a radius of < 3D: maximal angle 60°
- Bends with a radius of = 3D - 5D: maximal angle 90°
- Bends with a radius of > 5D: Several 90° bends
- The difference of inner to outer radius causes wrinkling at the inner side and potentially a gap at the outer radius. This is an inherent part of the system and cannot be avoided and the customer must be aware of this limitation

Material of Inliner systems for water pipes

A – Tubes for pressure pipes

Base material: The textile structure of the base material consists of high-strength, endless woven (seamless) polyester yarn, serving as the carrying layer for the polymer coating that firmly adheres to it.

<u>Coating for drinking water:</u> For potable water applications a PELD (= low density polyethylene) or LLDPE (= linear low density polyethylene) coating is used. It guarantees water tightness, provides perfectly smooth surfaces and an unusually high level of chemical resistance.

B - Two-component epoxy resin:

Only high-quality, two-component epoxy resins are utilised with good properties for adhesion and curing in humid environments. The curing process of epoxy resins doesn’t require volatile components and therefore don’t show shrinkage. Unlike polyesters, the volumes of epoxy resins remain constant when they harden, which is an important advantage. When they solidify, they maintain a relaxed polymer structure without residual tension. The reach high flexural E-modulus of up to 3,700 Mpa, high resistance to mechanical impact and abrasion and exceptional adhesive strength. When completed cured, all of the materials are insoluble in water and environmentally neutral.

Summary Inliner System

Figure 11 – 13: Pipe before rehabilitation / pipe with impregnated textile tube before heating / rehabilitated pipe
(Source: Rabmer)

The Inliner-procedure is a reliable and an economical solution for the renovation of open channel- and pressure pipes. The advantages of the Inliner system are:

Operational performance

- Long sections without couplings and improved hydraulics due to smooth surface
- Slight loss of diameter is compensated by the smoothness of the inner surface keeping the hydraulic capacity
- Guaranteed impermeability

Quality of the transported medium

- Coating applicable for the transportation of potable water
- Complete protection against inner corrosion

Spatial requirements / work process

- Minimised civil engineering work
- Construction site above ground reduced to access pit and one truck with installation unit
- If available, installation can be executed from pre-existent access shafts
- Flexible dimensioning to any shape and size required

Process-technological advantages

- Bends, deflections and deformations in the pipeline do not represent crucial process-technological difficulties.
- Lateral connections can be incorporated into the rehabilitation process.
- Applying a well designed Inliner with the required structural load-bearing capacity can restore the section implying conditions comparable to a newly installed pipeline.
- The elongation at break and the flexural and tensile properties of the Epoxy resins can be modified to specific customer requirements.

Economic efficiency

- Lower costs compared to conventional rehabilitation methods.
- No indirect costs resulting from public disruptions (traffic jams, dust, dirty roads...)
- Short construction time (about 1 to 2 days per rehabilitated section)
- Minimal disruption of the affected households No risk and/or disruption of the adjacent underground infrastructure as a result of excavation. Subsequently, damage to the road surface as a result of settling down soils is avoided.

Project Case Studies

Water supply system Budapest: Main lines with a length of 40 km were rehabilitated using different Lining systems interactive compound systems, interactive load bearing systems or full structural solutions. The used Liner systems were chosen for each line by the degree of deterioration, operational experience and quantitative risk assessment. A good example for a thorough investigation and evaluation process are cast iron mains with 70+ years of age being in excellent condition. These mains had only to be sealed water-tight by an interactive compound Liner system, as the former sealants were biodegradable and already absent.

Water supply system Vienna: A necessary pressure increase at a 2.3 km pipeline required a structural CIPP-Liner to minimise the water losses to an acceptable level and to achieve a sustainable status of its structural integrity.

Gas supply system Vienna: Main lines were rehabilitated using different Liner systems either interactive compound systems or fully structural solutions. The applied Liner systems were chosen for each line, following specific criteria for the degree of deterioration, operational experience and quantitative risk assessment.

Preliminary Work

Cleaning

The cleaning process and its parameter depend on the Liner system chosen, degree of incrustations, pipe material, pipe integrity and discharge method of the loosened deposits. As an example, a CIPP-Liner technology requires high pressure water jetting with up to 1200 bars.

Retention of Water supply

For the duration of the rehabilitation the line has to be put out of service. Temporary bypass is provided to retain the water supply.

CCTV-Inspection

TV-Inspections have to be made in different stages of the rehabilitation sequence:

- Prior rehabilitation or renewal of the lines: to inspect, allocate and document the existing conditions
- Immediately after the cleaning and before installation of the CIPP-System to control the efficacy of the cleaning and the required status for the rehabilitation process applied

- After rehabilitation of the pipe-section: for documentation of the finished product

Pipe calibration

A calibration of the pipeline becomes necessary when the required free cross-section of the host cannot be guaranteed. Additionally, intruding welding seams, protruding tapping etc... can easily be removed by a robot cutter. Incrustations and deposits can be loosened by rotating jets, high pressure water cleaning or rotating chains.

Approvals/Authorisations

The chosen materials and combinations thereof have to be authorized by public institutions and continuously approved for the use with the transported medium. This includes aptitude testing as well as the quality control of the final product.

Critical issues for rehabilitation - rehabilitation strategies

The rate of deterioration of an underground supply system is not only a function of material ageing but rather the cumulative effect of numerous external forces acting on it. During a recent water main evaluation, a 70+-year-old unlined cast iron pipe was found to be in excellent condition with negligible internal or external corrosion. Based on the field observations, there is no reason to believe that these mains will not provide another 70+ years of satisfactory service. Conversely, in another system, cast iron mains less than 50 years old are experiencing excessive and rapidly increasing burst rates and severely progressing corrosion. Rehabilitation of these mains is needed in the near future.

These strategies to handle deviations of the actual pipe condition from the desired status can be divided into:

- **Fire-brigade strategy**: a corrective action takes place only when the deviation becomes obvious
- **Preventive (interval-based) strategy**: a corrective action takes place in fixed intervals
- **Condition-oriented (demand based) strategy**: corrective action takes place when output reaches an optimum

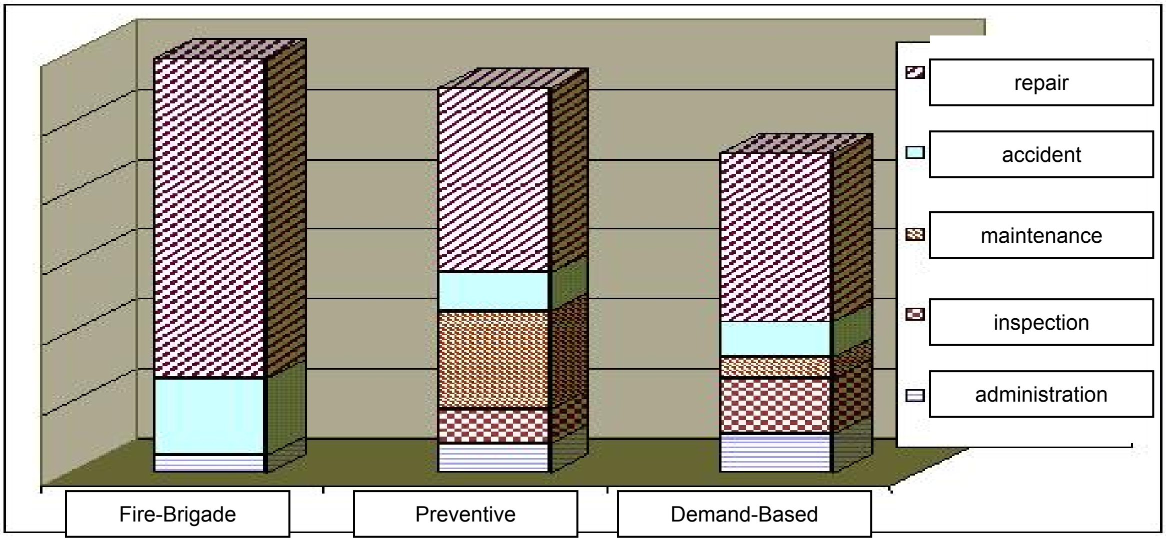

Figure 14. Pipe rehabilitation strategies and costs

If the costs between these strategies are compared, one can see that the overall costs of a fire-brigade-strategy are the highest. When deviations from a planned state occur during this strategy immediate action is necessary and planned actions with a call for tenders is often impossible and the missing planning phase will cause collateral damages.
Therefore, broad based decision factors regarding infrastructure replacement, whether based on age, pipe size, pipe material, linings, etc. will not result in an effective use of limited capital resources. A more holistic approach prior to the decision making is needed to achieve the optimum exploitation of the asset owner's limited resources.

This question can only be answered through actual knowledge of the conditions and service characteristics of the existing main, comparing repair, replacement, and rehabilitation costs, and a clear understanding of the anticipated results of the various rehabilitation techniques available.

Conclusion

The population worldwide is steadily growing, resulting in a steadily increasing demand for potable water. Although a lot of new water pipelines were built in recent decades, it is a fact that in many places clean and reliable water supply is not the status quo. Defective underground pipelines, being corrosive, structural unreliable, contaminated, are not only waste our scarce resources but also are responsible for spreading diseases. None revenue water levels of up to 50% is a reality in various regions of the world.

The conventional replacement of pipelines by excavation is very expensive, time-consuming and extremely disruptive to the public. The steadily increasing demand for excavation free technologies worldwide is a good sign that the potential of this innovative methodology will be more and more appreciated. Numerous No-Dig projects, especially the Close Fit – and the Inliner system, applied in major cities in Europe and all over the world have proven its applicability and efficiency. The relative short construction time and ”new pipe” quality, by limiting the disruption of the immediate environment to a minimum are indisputable advantages.