Renovation of old Gas, Water&Waste water systems, contributes to a more sustainable society.

Frans Alferink, Fluent Europe, The Netherlands

1. ABSTRACT

This paper discusses the optimal conditions for achieving a sustainable solution for the rehabilitation of the underground infrastructure, such as water, gas and sewer systems. During rehabilitation, or any other civil construction works, risks related to the execution of the work, as well as the risks related to the operation of the network, are important to consider. The most important risks will be discussed. The aim of any rehabilitation shall be that it leads to sustainable solutions, which means that the rehabilitation results in a system that does not create negative spin-off effects such as failures of adjacent systems. And that the final solution has a good functional performance, not only for the next month or year, but for the anticipated lifetime of the system. To this end, the issue of Quality assurance of the installed system is an important one. When rehabilitating the system, aspects like capacity of the system and tightness are the most important functional properties, reason why these will be discussed as well. Moreover, the paper will discuss the experience of using a Close-fit lining technique, Compact Pipe, for the renovation of sewer systems in Bogota and Medellin.

2. INTRODUCTION

Old water, gas and waste water networks, as well as industrial pipelines face issues with the hydraulic performance, such as the capacity and tightness. Also there may be issues with the structural integrity of the system. The declining hydraulic performance related to leakage, results in contamination of the subsoil in case of waste water pipes and industrial pipelines. And it results in losses in case of water and gas pressure pipes. For pressure pipes in general, it also increases the operational costs, because more energy is wasted by in-efficient pumping. In case of gravity waste water pipelines, infiltration of ground- surface and rainwater may occur, with the consequence that the sewer treatment plant is over-loaded and untreated waste water is by-passed to the surface water, like rivers creeks etc. All of this jeopardizes the level of sustainability.
The declining structural performance results in a potential hazard for surrounding structures, like roads and foundations and even a complete collapse of the road structure may become fact.
Now all of the above is meanwhile reasonably well recognized, although the effects of it on the environment is mostly not sufficiently considered. That is probably mainly because due to the response time, the time between the initiation of the problem and the moment the consequence becomes visible in the environment and to the public, which response time is in general rather long.
Also the related costs are not always well considered. As a matter of fact, the cost of "solving" an issue becomes very well visible when making the quotation for solving the problem by open cut, or by using a renovation technique. The costs however of not doing anything is in most cases not visualized. It seems that a below ground problem lacks visibility, is debit to this.

In choosing technologies to solve the problem, also there one tends to look at the costs of the activity, when all goes right. But the costs of the future or the cost of ownership are again many times not well evaluated. Issues like "durable solutions" and "low risk at execution" are key issues in this respect.

3. INDEX

4. HYDRAULIC ASPECTS

The most important hydraulic problem is leakage. If for instance a water pressure pipe loses 30% of the clean water by leakage then that is a big loss of precious water but also of money. A good quality potable (drinkable) water has a cost price between 0.80 to 6 Euro's per cubic meter. The high value relates to potable water produced using desalination processes , whereas the lower value represents water produced from reasonably clean aquifers or surface water. A network feeding 100.000 people using every day 150 ltrs of water per capita, means per day a delivery of 15.000 cubic meter. And to get this 15.000 cubic meter to the customer using a network with 30% leakage, means that the water company pumps every day 21.428 cubic meter into the network from which then 6428 cubic meter is lost. Depending on the price per cubic meter, the loss of money per day can then easily be calculated which loss per year for the condition mentioned above will be between 2 to 12 Million Euro's. Figure 1 shows the loss usd/year as a function of the leakage rate for a representative situation.

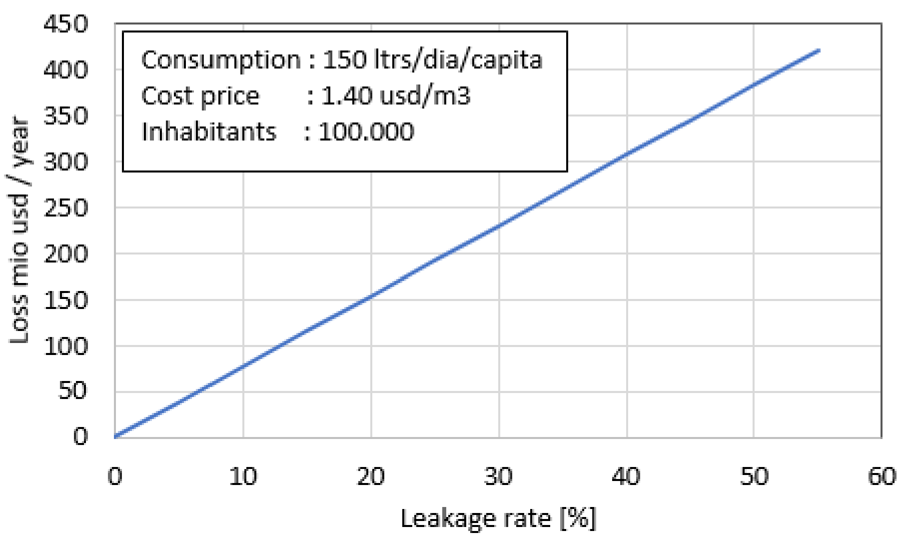


Figure 1. – Losses in USD/year depending on leakage rate.

What is clear from the figure is that it is extremely important to choose the pipeline system in a smart way to limit the risk of leakages. In Reference 1 and 2, some more information is given on experiences with sustainable water supply systems and designing systems to lower the risk for failures and leakages.
If No-Dig systems are used than it is also important to choose those that really solve the problem for now and the anticipated lifetime of the system.

The other issue is the loss of capacity and or the increase of pumping costs. When the pipe gets encrusted then two things happen at the same time. One aspect is that the hydraulic roughness increases and the other aspect is that the internal diameter decreases. This will result in a poor delivery to the customer, on capacity, water quality and pressure. Or when the delivery is kept up to level this it is resulting in higher pumping costs. Figure 2 shows the latter effect.

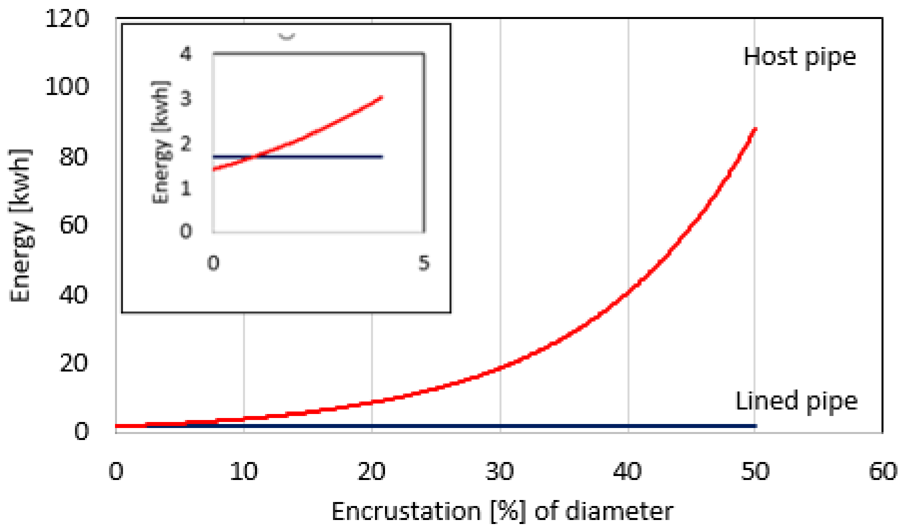


Figure 2 – Comparison of pumping costs with the old pipe versus a lined pipe (with same service degree)

With encrustations of 1.5% or more, the result of renovating the pipe already pays off. In this case a 1 kilometer long, 200 mm (internal diameter) host pipe was lined with Compact Pipe DN200, SDR 17.

In most cases it is seen that both effects occur at the same time, leakage and encrustation. Lining the old pipe by using a liner pipe solves both issues at the same time.

It shall be realized that with a lower energy consumption also the CO2 emissions are decreasing.

5. STRUCTURAL ASPECTS

Pipes that can no longer resist the pressure or can no longer resist the soil and groundwater pressures, may collapse. Such a collapse may have high consequences. Roads may collapse, traffic disturbed etc. Soil may be displaced by washing away etc. The costs related to this kind of unplanned not foreseen events, are always high and non-controllable. When choosing the rehabilitation technique it is important to consider this aspect as well. In most cases it is wise to choose an independent liner technique to be sure that also for the future, the solution will work, even when the old pipe does no longer give the required resistance against groundwater, soil and internal pressure loading.

6. RISK ASPECTS

For several of the above mentioned hydraulic and structural problems, solutions exist. Local repair methods have been and are still being used to solve a local leakage or structural problem. In most cases they are rightfully considered as a temporary solution creating time for planning and executing of a more sustainable solution. Lining techniques are providing such more sustainable solutions.

It is advised that the solution to be chosen is based on the Sustainability of the solution, and not only on the costs. Sustainable means here a solution that re-instates the function of the system with a long anticipated lifetime, 50 yrs or longer, against reasonable costs. In that respect it is important to mention the controllability of the costs during execution of the work and therefore it is also important to be aware of the risk of execution and the consequences of these risk. Both moneywise as well as performance wise. In this chapter a discussion about the risks are given.

First considering the risk in a qualitative way.

Important parameters for the risk assessment are the following:

a. Third party damage.
Staying inside the old pipe does not give any risk for third party damage. If however, the old pipe is broken by cutting or cracking, and a bigger diameter pipe is pulled in place, then there is a risk that neighboring services like other pipes and cables and even foundations may get damaged. This can be either in an indirect way because of the ground pressure and movement that is caused by the installation, or by parts of the broken pipe that may be pushed through the soil and hit a cable or pipe. During the installation also the pipe may get damaged. The risk of disastrous pipe damage however, can to some extend be limited by using so -called crack resistant materials like PE-RC or PVCO. These pipe types do not suffer from scratches and point loading to the extent that standard pipes do.
Next to damage of neighboring cables and pipes, also damage to the street may occur. Especially when the host pipe is located at shallow depths. If this happens than the costs are non-planned and high, something that should be prevented.
b. Factory produced versus in-situ produced.
Liners that are fully produced inside a production environment and for which quality control regimes on the final pipe can be applied, will have a lower risk in not achieving the requested quality of the liner than those that are produced in-situ. (Reference 3)
c. Chemical curing process in-situ needed or no curing involved.
An important aspect is the curing that may be needed in-situ. Most curing processes depend to some extend on the environmental conditions, which may vary from day to day and not easy to predict. When using a any curing process , then the quality of the liner can only then be proven after installation.
d. Limited free space between host pipe and liner during insertion.
First generation close-fit lining techniques, where a round pipe, slightly reduced in diameter, is pulled into the host pipe, may suffer from the minimal space between host pipe and liner and use high axial forces to pull the liner into the host pipe. And when there is an offset in a pipe connection than there is a risk of a complete blockage / interruption of the insertion, as well. The consequence is then to dig up the pipe locally. Again a situation where the costs are not planned and high.
e. Risk of interruption of the installation. Not only the first generation close-fit technologies, but also pipe bursting is somewhat sensitive for this. Host pipes may be embraced by tree roots or passing a foundation, which may cause the bursting process to stop. Digging is then almost always the only way to solve the (local) problem.
f. Risk of damage of the liner when installing. In combination with the earlier aspect of limited space during insertion, in such cases pipelines may get damaged. This situation is even more severe when considering pipe bursting and directional drilling techniques.

Several of the above risks can, at least to some extent, be mitigated. If not fully mitigated a Plan B should exist. Therefore always a risk analysis should be applied. For instance, there where damages of a PE liner can be expected during insertion of the liner, it is recommended to use a PE RC material to limit the effects of a damage on the lifetime of the pipe. (Reference 4)

7. EXAMPLE PROJECTS IN COLOMBIA

Both in Bogota and Medellin renovation projects have been executed using a close-fit pipe renovation technique with factory folded PE pipes. All projects were carried out in the gravity sewer application. The diameter of the pipes are varying in diameter from 200 to 450 mm. The section lengths varied from 80 to 200 meter.

Project Bogota

The project in Bogota was carried out to solve structural as well as hydraulic problems. Table 1 gives a summary of the Bogota pilot project.

Table 1 - Pilot projects in Bogota

Aspect	Project 1	Project 2
Customer	Acueducto de Bogota	Acueducto de Bogota
Application	Sewer	Sewer
Diameter Host pipe	200 mm	300 mm
Length of section	82 meter	60 meter
Technology applied	ZinZanja Compact Pipe DN200 SDR 26	ZinZanja Compact Pipe DN300 SDR 26

Some impressions of the installations are given in figure 3:

Figure 3 - Impressions from the projects in Bogota.

In the figure the preparatory work and the insertion of the pipe is shown. There is no need to break away the street or the manhole. The pipe is inserted via an existing manhole. At the very right the result of the installation is shown. A smooth independent pipe inside the old host pipe has become reality. Despite the slightly smaller inside diameter of the new pipe, the pipe has now a better hydraulic performance then before the renovation. This due to a significantly improvement of the pipe-system roughness.

The time needed to line the host pipe was around 10 hrs. With an improved planning this could be shortened to about 6-8 hrs.

Project Medellin
In Medellin projects were carried out in the city center as well as close to metro station "Ninguía" The pipe passes below a roundabout that is located below a viaduct and also passes one of the main road

Table 2 - Pilot projects in Medellin

Aspect	Project 1	Project 2	Project 3	Project 4
Customer	EPM	EPM	EPM	EPM
Application	Sewer	Sewer	sewer	sewer
Diameter Host pipe	400 mm	300 mm	400 mm	450 mm
Length of section	80 meter	90 meter	105 meter	78 meter
Technology applied	ZinZanja Compact Pipe DN200 SDR 26	ZinZanja Compact Pipe DN300 SDR 26	ZinZanja Compact Pipe DN400 SDR 26	ZinZanja Compact Pipe DN450 SDR 26

Where the first two projects were in the middle of the street, but inside the city, the most challenging project however was the one located at the metro station Ninguía. The pipe crosses a very busy Autopista and exactly in the autopista a manhole with a change of direction of about 40 degrees is located. It was decided to split the total section in 2. One is shown as the green line in Figure 4. It passes the 40 degree manhole as well as some other 4 intermediate manholes which have a more or less straight flow direction. After inspection and cleaning, Compact Pipe was pulled in passing the manhole with the 40 degrees directional change, without any problems. Here the advantage of a folded pipe becomes very well clear. Due to the space available between folded pipe and host pipe, there is no risk of the pipe getting stuck during pulling in. Especially when the host pipe is passing busy roads or other critical parts, then one should not accept any risk of getting stuck, road upheaval (like possible when using pipe bursting). The total length of this section is 105 meter. The other section (section 1) also passes under a road but that road is less busy. The length of the second section is 78 meter. Figure 5 gives some general impressions of the first project.

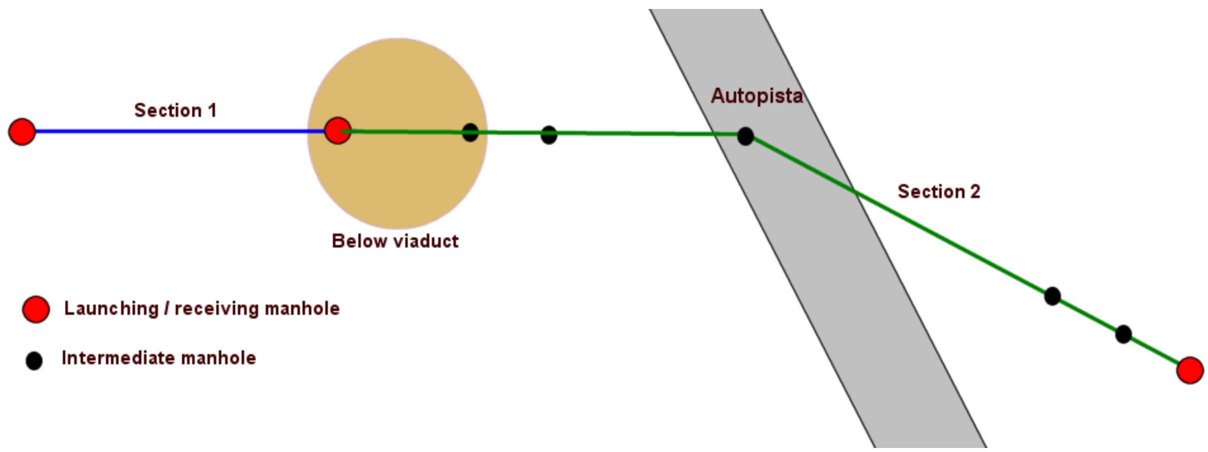


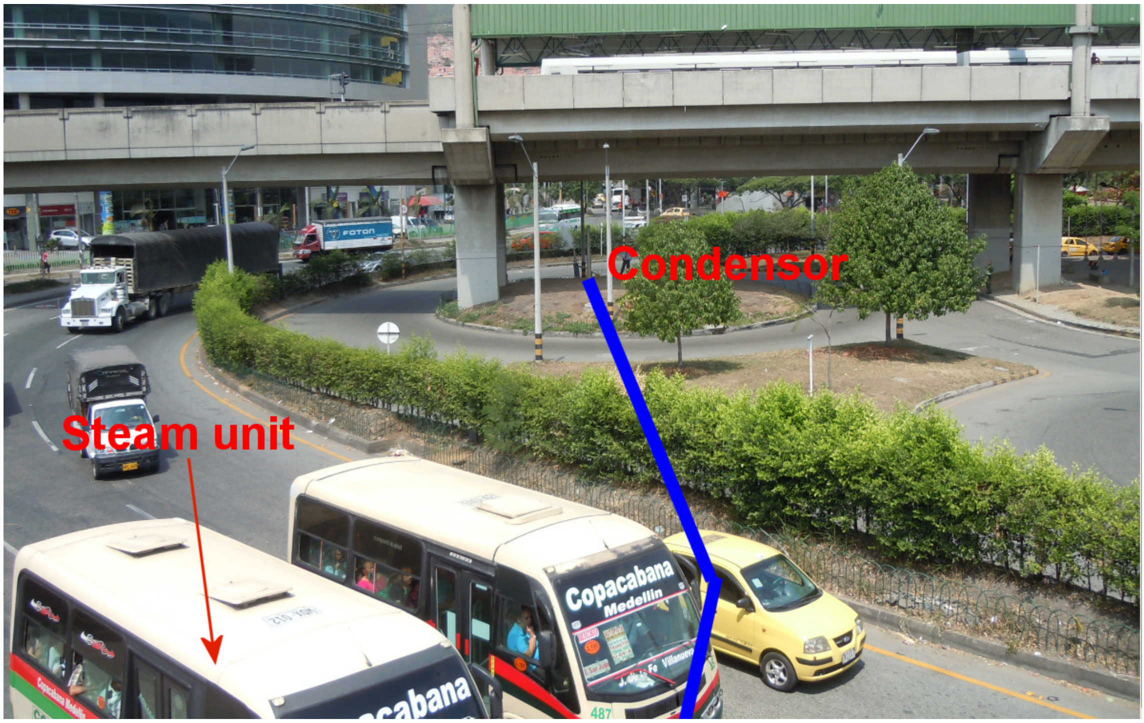
Figure 4 - Scheme of the project Metro (station Ninguía) in Medellin

Figure 5 - Some impressions of the installation of Compact Pipe in the first project.

At the left the drum with Compact Pipe is shown. At the right the insertion via the manhole is shown of a 300 mm Compact Pipe.

Figure 6 shows some more detail about the metro 'Niguía' project.

Insertion in the early morning.



Impression of the layout and traffic situation. The blue line indicates the routing of the pipe and the red arrow points to the direction where the steam unit is located.

Reverting the pipe by using steam. The parameters, pressures and tempertatures are monitored during the reverion process. (This is a non-curing process. It just wakes up the materials memory)


View in an intermediate manhole after reversion.

Figure 6 – impressions of the installations at the project “Niguía”

After the pipes have been pulled into the host pipe, the pipes were reverted by using steam to initiate the memory of the pipe and air-pressure to cool down the pipe. All sections took around 8-10 hrs. The traffic could flow freely and was not disturbed. The result of the lining is a smooth (higher capacity) and leak-tight pipe system.

8. Conclusions

An important driver in the design of new infrastructure is the focus on obtaining a sustainable solution. Not only meaning that the infrastructure will last for many years, but also it’s functional performance does not change in the course of time.

Many old below ground infrastructure like gas, water and sewer pipes however, do suffer from a declining functional performance. This results on one hand in a declining service to the client, but it also has a negative effect on the environment. Higher pumping costs yielding higher energy consumption and hence higher emissions and / or contamination of the ground and groundwater.

The level of risk when executing a rehabilitation work is an important and decisive parameter for the choice of the approach. Digging up the pipe has a disturbing effect on traffic and it’s related business, but also digging up an old pipe creates the risk of third party damage. Damage to other below ground service like cables and pipes.

No-Dig technologies can be used to avoid digging. But when the activity does not stay inside the old pipe but moves outside, like in case of pipe bursting, then again the risk of third party damages increases.

Therefore using technologies that stay inside the cavity provided by the host pipe are the preferred solutions when other cables and pipes are close to the host pipe. Also technologies that have a lot of space available between host and liner pipe are preferred over the ones that only have a narrow free space available. Especially with host pipe systems that suffer from misalignment in the connections and or do have some directional changes, there is a risk of getting stuck during insertion. Although sewer pipes are well aligned in maintaining a reliable gradient, it is well known that many old sewer mains do suffer from directional changes, especially in the vertical plane. This is due to the fact that the more rigid pipes transfer the load on the crown of the pipe to the pipe sole area. The natural variation of the stiffness of the soil in the sole is considerable and hence vertical settlement differences occur. (Reference 1) .

9. References

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