The Second Edition of European NO DIG Conference

Segrate (Milan), Italy
25TH May 2023

Paper 25

UV-CIPP in large diameter pipes

Firmino Pires Barbosa[1]

[1] RELINEEUROPE GmbH/ D-76865 Rohrbach, Germany

ABSTRACT: As the world's leading company in the field of trenchless pipeline rehabilitation, RELINE not only offer innovative technologies for a wide range of requirements, but also valuable know-how for the planning and environmentally friendly implementation of individual rehabilitation measures: A perfect combination that helps to effectively save resources, time and costs, while at the same time delivering high-quality solutions that convince through quality, flexibility and sustainability.

Nowadays, trenchless rehabilitation of pipes with a diameter of up to 1200 mm is standard.
Trenchless rehabilitation of larger diameters (≥ 1300 mm) is always a challenging project. The prerequisite for a successful result is careful and detailed site preparation. The liner is generally designed considering all dead and live loads and manufactured ready for installation with the required thickness.

Already in the first year of production, RELINE manufactured a remarkable 180,000 metres of the Alphaliner GRP pipe liner. In the following years, the Alphaliner technology established itself due to its unique design and precisely coordinated components. To date, more than 6,000,000 meters of Alphaliner have been produced by RELINE and successfully installed by pipe rehabilitation companies.

Within this paper it will be shown the state-of-the-art design methods, the necessary equipment, and the installation procedure in detail. The theoretically part will follow some case studies of UV-CIPP liner installations with different diameter and cross-sections.

1. INTRODUCTION

RELINE is offering a variety of GRP hose liners for many different applications and a variety of powerful UV systems.

With GRP technology, RELINE offers an optimal GRP hose liner for trenchless pipeline rehabilitation that is tailored to the static requirements of the sewer, the quality of the wastewater or other media and the given safety requirements.

Glass fibre reinforced plastic (GRP) is one of the most versatile materials that can be designed and used successfully in numerous industries such as the aircraft, automotive, shipbuilding or wind turbine industries.

As a high-quality fibre-reinforced composite (FRP), GRP is produced by combining several materials - the moulding matrix such as polyester, vinyl ester or epoxy resin and reinforced high-strength fibres (usually glass, aramid, or carbon).

Materials of the highest quality - special ECR glass fibre and a resin adapted to UV light curing - form the basis for this successful GRP technology. This enables optimal curing with innovative UV light curing and long-lasting quality of the product.

Depending on the diameter and the required wall thickness of the liner, the weight of such a large diameter, among other things, requires suitable equipment for pulling in, inflating with compressed air and curing.

Within this paper it will be shown the state-of-the-art design methods, the necessary equipment, and the installation procedure in detail. The theoretically part will follow some case studies of UV-CIPP liner installations with different diameter and cross-sections.

2. Alphaliner built-up

The innovative design of the Alphaliner stands for endless areas of application and stands out with properties that set high standards.

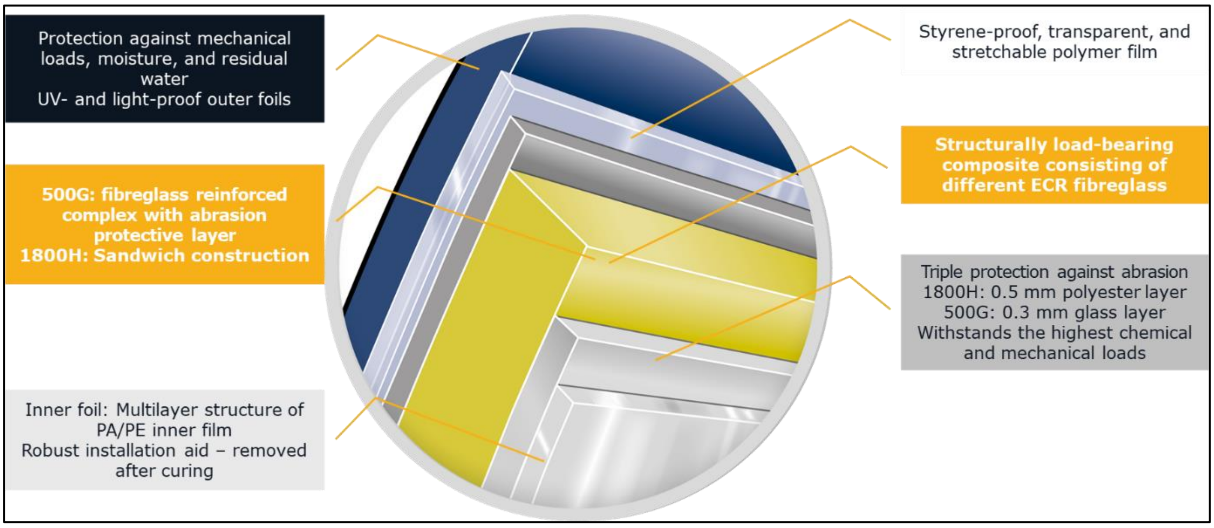

Figure 1: The Alphaliner: Properties that set new standards

The RELINE GRP hose liner types Alphaliner500G-UP and Alphaliner1800H-UP offer very high mechanical properties. They can be used in all common pipe profiles (circular, egg, box and special profiles). Individual lengths of up to more than 350 meters are possible in order to minimize the impact on road traffic during the installations works. All Alphaliner are also available with incorporated protective gliding foil or incorporated Preliner to reduce installation times to a minimum.

RELINEEUROPE offers the Alphaliner500 G for small and medium pipe cross sections. This liner type is the most favourable system for application in damaged host pipes with dimension from 150mm up to 500mm.

Since a couple of years, the demand for no-dig rehabilitation of culverts has increased significantly. Meanwhile, diameters up to 2000mm are also being rehabilitated using UV-light-curing GRP lining systems. The choice for rehabilitation of large profiles is therefore the Alphaliner1800H, which is designed for maximum static load capacity.
The Alphaliner1800H is the UV light-curing GRP hose liner with the highest mechanical characteristics worldwide. It offers a Young's modulus of 19,062 MPa (short-term value according to EN ISO 11296-4) or 15,947 MPa (long-term, 50 years, value according to DIN EN 1228).

Due to this continuous development and improvement of the mechanical characteristics, it is possible to reduce the liner wall thicknesses requested by the host pipe condition as well as from the liner design requirements. The reduction of the liner wall thickness leads to various advantages: it allows a faster and secure curing; the weight of the liner drops and allows for easier installation as well as the pulling with lower tensile forces, combined with reduction of any liner damages during the installation works.

Since 2021, for instance, all Alphaliners have been manufactured and shipped complete with an innovative concept for the outer film. This product innovation is made up of an "integrated sliding foil" (IGS) and an "integrated preliner" (IPL). Among other things, the optimization to the product maximizes the robustness of the exterior protection for all Alphaliners.

3. Structural design of lining systems

The actual German design standard DWA-A 143-2:2015 differentiates between *four* Host Pipe Conditions:

- Condition I (sewer untight; no cracks),
- Condition II (sewers with longitudinal cracks; soil pipe system stable),
- Condition III (cracked sewer with large deformations; considerable risk to failure in the near future) and
- Condition IIIa (sewer no longer existent as it is totally corroded or cracked to pieces).

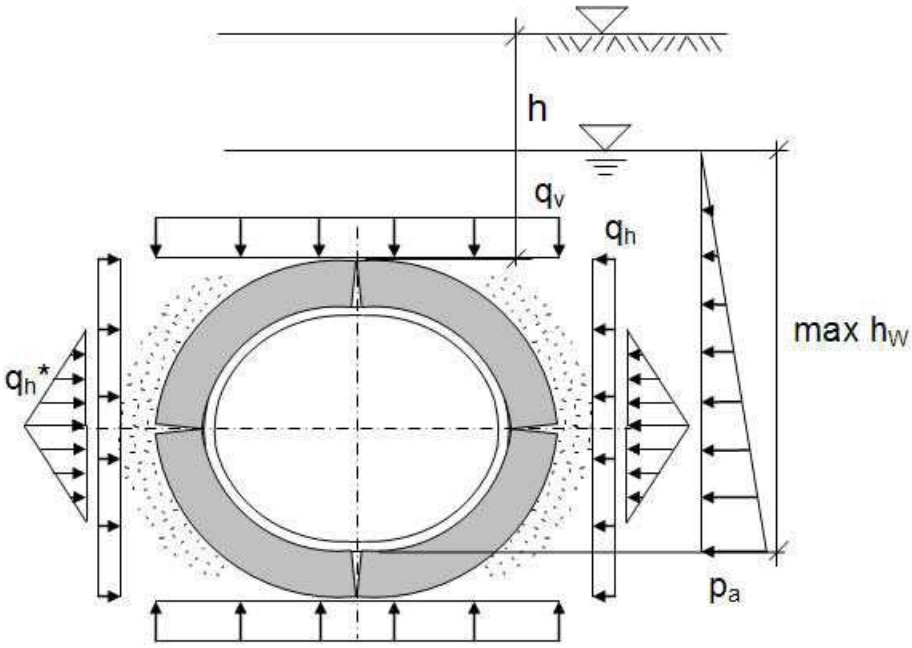

Figure 2: Structural design according to DWA-A 143 part 2 (2015)

The Host Pipe Condition I to IIIa (HPC) can be defined as shown in the following table. E.g., old pipes in both conditions II and III have four cracks and are kinematic without soil support. The difference is to be seen by regarding future movements in the near of the rehabilitated sewer: If there are no excavations, settlements, extra overburden or relevant traffic loads (e.g. enough cover height) the system remains undisturbed and Host Pipe Condition II might be assumed. The HPC IIIa is a new condition to regard pipelines behind a liner that cannot be inspected and might completely corrode in future.

Table 1: Definition of the Host Pipe Conditions I to IIIa (Table 1 in DWA-A 143-2)

	Host Pipe Condition (HPC)			
Old pipe:	HPC **I** (no cracks)	**II** (4 longitudinal cracks)	**III** (4 longitudinal cracks)	**IIIa** (fully corroded, fragments etc.)
Sufficient flexural strength σ_{Fl}	+	-	-	-
Old pipe-soil system undisturbed	+	+	-	-
Sufficient compressive strength σ_L	+	+	+	-

4. UV-CIPP Liner Rehabilitation with XXL Dimensions

The Administration for Civil Engineering of the city of Karlsruhe ordered in 2020 the no-dig rehabilitation a 220m long (722 feet) section of the main collector Landgraben with DN 1750. Due to its high mechanical properties the Alphaliner1800H produced by RELINE fulfils all requirements.

During CCTV inspections, it was detected that the concrete pipes, which were poured without reinforcement bars back at the turn of the last century, had cracks along a stretch of 220 meters (722 feet), impairing the canal's structural integrity. Since comprehensive road construction work was already planned to take place along the main traffic axis in the eastern part of the city, the Administration for Civil Engineering decided to tackle the rehabilitation of its massively dimensioned sewer canal simultaneously. The Administration for Civil Engineering independently planned, tendered, and supervised all rehabilitation measures for the *Landgraben* canal.

4.1. **Hydraulic Properties of the Main Collector Must Remain Intact**

One of the key specifications for these rehabilitation measures was that the hydraulic properties of the *Landgraben* must remain unchanged.

Several different rehabilitation approaches, such as e.g. short pipe lining (sliplining), had all been considered and then rejected, because they would have reduced down the cross section of the culvert far too much. Even open trench construction had been taken into consideration. For this option, the long construction period and the high costs ended up being the main criteria for exclusion.
This approach would have required the installation of "a bypass" to permanently reroute the flow. During heavy rains and storms, large quantities of water come through this culvert and the full flow capacity with its entire cross section of DN 1750 is needed.

Due to the short installation times required for the Alphaliner, it was possible to work with a temporary, aboveground bypass for a limited period.

4.2. **Installation requirements and appropriate expertise**

Specialized expertise and the appropriate equipment to install larger dimensions can only be provided by very few professional companies.

For this reason, the rehabilitation job was tendered as "restricted according to VOB/A" and, the job were awarded to a RELINE certified installation partner, who had already completed several rehabilitation projects with sizes up to DN 1600 for the municipal water treatment authorities in Karlsruhe over the past years.

They used the Alphaliner1800H, made by RELINEEUROPE, which is DIBt certified and one of the leading liners in the world, thanks to its outstanding mechanical properties. The liner is graded in the highest material category, Group 25, according to DWA-M 144-3. Due to its excellent mechanical resilience, this liner can be used for projects with very high structural demands and large wall thicknesses.

The liner for the *Landgraben* project needed the capacity to support huge loads. The structural calculations showed that the job required an Alphaliner1800H with a composite wall thickness of 17.0 mm, specifically designed for such large profiles.

Using RELINE's REE4000 UV-curing equipment with its powerful UV-core and a total output of 24.000 watts, such a wall thickness can still be cured using only UV light.

RELINE produced the two Alphaliner, each with a length of 110 meters (361 feet), a week before they were to be installed. The two shipping crates destined for the project in Karlsruhe weighed around 25 tons each. An extra-wide heavy transport truck took the liners to Karlsruhe on the evening before installation. At the job site, a 120-ton crane was waiting and ready to maneuver the heavy boxes along a path of about 30 meters (100 feet), right to the installation pit which was located alongside the road.

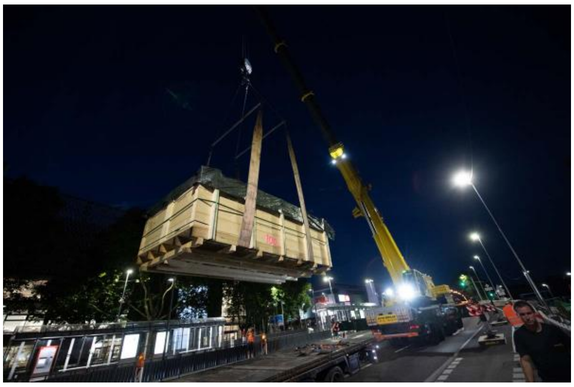

Figure 3: Alphaliner production

Figure 4: Handling of large dimension liner at the job site

Due to the size of the job, two large excavation pits need to be prepared in order to install the liner safety and without any damage. At the entry pit, the shaft dropped about 5 meters (16 feet) deep. At its exit point, the excavation pit was still almost two meters (6.6 feet) deep. At both ends, a specialized company had already cut away the approximately 30-centimeter thick (1 foot) cement culvert.

Retaining the flow played a key role. During the rehabilitation job, wastewater was bypassed via a 230-meter long (755-feet) pipe bridge with a redundant layout and DN 400 HDPE pressure pipes. The pumps with a displacement of 400 liters/sec (105 gallons/sec) were also designed redundantly.

Figure 5: By-pass system with redundant design

4.3. **Installation process of heavy weight Liner**

RELINE, the liner manufacturer had been involved in the planning of the project right from the very beginning. All components employed at the job site were specifically selected to enhance each other’s performance and make the job as efficient as possible.

To pull the liner into the pipe, the newest heavy-duty conveyor belt with an automatic folding device, specifically designed for large profiles, was used. Foldable, three-piece packers as well as the equipment to firmly fix them in place, which is necessary to secure them against blow-out due to extremely high pressures inside the liner, were also supplied by RELINE. On site, three application engineers from RELINE supported the installation crew during the whole installation process.

Figure 6: Preparation of liner for pulling process

Figure 7: Pulling head

Once started the process of installing the liner, it is important to keep it moving because of its weight. A winch with a tractive power of 10 tons, of which about 4 tons were effectively needed, was used.

After the liner pulling head was shaped appropriately, the liner was lowered into the pit with the help of an excavator. At both ends of the pipe, the gang installed large dimension packers (chromated aluminum made end cans) and secured them firmly in place using special equipment. It goes without mentioning that the packers were secured using special ratchet straps specifically designed to withstand such immense forces.

The compressor used during calibration had the size of a minibus van. Combining two radial compressors, the liner was inflated from both ends until it reached an interior pressure of 200 millibar (2.9 psi) and lay close-fit against the walls of the host pipe.

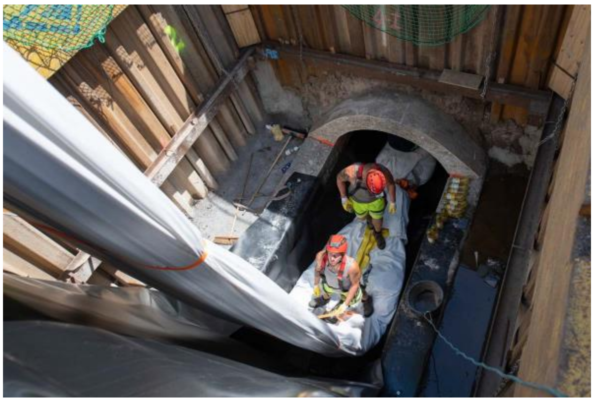

Figure 8: Pulling process of liner

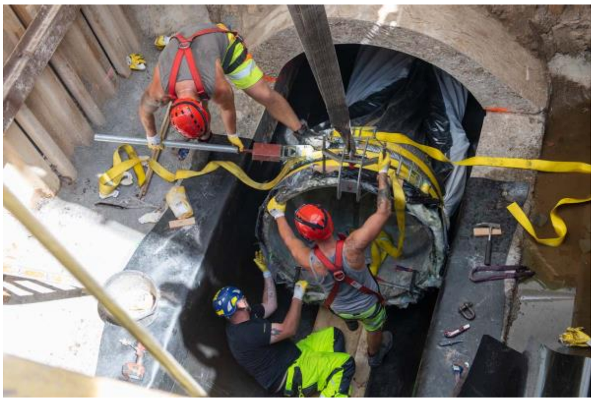

Figure 9: Installation of packer (end can)

4.4. UV-curing process of 17mm thick Alphaliner

The REE4000 UV-curing system with its stepless extendable, electricity-powered UV core and a power output of 6 x 4,000W, was specifically designed to cure even the largest liner dimensions.

The curing process, with all its relevant parameters such as pressure, temperature, curing speed, and the actual power output of each UV-lamp, is permanent monitored during the curing process and, precisely recorded and documented in the curing protocol. In the case of this 110-meter long (361 feet) Alphaliner1800H with 17.0 millimeters wall thickness, the curing table specified a curing speed of 0.27 meters (0.89 feet) per minute. So, the crew could now take a five-hour break to relax after a long, hard day of work, since UV-curing is basically a fully automated process.

Figure 10: Curing process with permanent monitoring

Figure 11: Protocolling of all curing data

Figure 12: Members of the crew inside of the cured Alphaliner DN 1750

This success story demonstrates just how important it is to coordinate processes between individual parts of the company RELINE (e.g. engineering, application technicians and production) and with the installation partners.

5. References

(1) RELINE website: https://www.relineeurope.com/en

(2) Worksheet DWA-A 143-2
Rehabilitation of drainage systems outside buildings - Part 2: Structural calculation for the rehabilitation of wastewater pipes and sewers with lining and installation methods

(3) RELINE / JESCHKE – Job Site Report Landgraben Karlsruhe DN1750 – 07-2020