Trenchless renovantion of water pipelines using the Primus Line® system

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ABSTRACT
The paper presents a flexible Kevlar® reinforced lining solution for the trenchless rehabilitation of critical water main infrastructure. The paper will show the composition of the lining material as well as the functionality of the specifically developed termination fittings. The lining material is characterized by high material strength, accommodating the operating pressures independently from the host pipe material. At the same time, the lining material has a low wall thickness of 6 – 8 mm for PN 16, reducing the cross-sectional losses significantly comparision to sliplining with HDPE SDR 11 PN 16. Due to the flexibility of the Kevlar® reinforced lining material, bends of up to 90 degree can be traversed and thus, long installation lengths of several hundred meters in one step a feasible. The paper will address needed cleaning and equipment requirements as well as the installation process. The paper will present a case study on the rehabilitation of a DN 350 water main with a single length of 400 m and eight bends of up to 45 degree.

1. Introduction

With limited financial resources at their disposal, utility operators are constantly challenged with prioritizing the rehabilitation of water mains within their network based on urgency. To ensure that the right decisions are made, the following considerations must be taken into account: what is the effect on the community in case of pipe failure and what is the likelihood that a failure will occur.

The current draft on DIN EN ISO 11295:2016-08 references the classification and information on design and applications of plastic piping systems used for renovation and replacement. The current draft of this standard includes now the renovation of pressurized assets with inserted hoses. The Kevlar® reinforced lining system "*Primus Line*®" which is manufactured by the German corporation *Raedlinger primus line GmbH* falls into this category. The liners are characterized by the following: deployed for pressurized assets including water and natural gas; the liners accommodate the complete operating pressure and are installed in U-shape; the liners maintain their round shape if not pressurized and if there is no external pressure; there is no connection between the host pipe and the liner; the liner works independently from the host pipe.

2. The Kevlar® reinforced lining system “Primus Line®”

The Primus Line® system consists of the Kevlar® reinforced liner and specifically developed termination fittings and is available from DN 150 to DN 500. The composite liner consists of three different layers. The inner layer is made of a low-density polyethylene (PE) for potable water applications that is, among others, certified according to the American NSF/ANSI 61, the German KTW W 270 and the Australian AS/NZS 4020:2005 standard. The middle layer is made of a mixture of polyester and Kevlar® for low pressure applications available from DN 150 to DN 300 with maximum operating pressures of 25 bar and 12 bar respectively. For higher pressure applications, the middle layer is made of pure Kevlar® and is available from DN 150 to DN 500 with maximum operating pressures of 56 bar and 16 bar respectively. For special high pressure applications of up to 82 bar for a DN 150 or 32 bar for a DN 400, a second layer of the Kevlar® fabric can be added. The fabric accommodates both the operating pressure as well as the insertion forces during the installation process. The outer layer is made of wear-resistant PE to protect the middle layer during the installation process (please refer to figure 1).

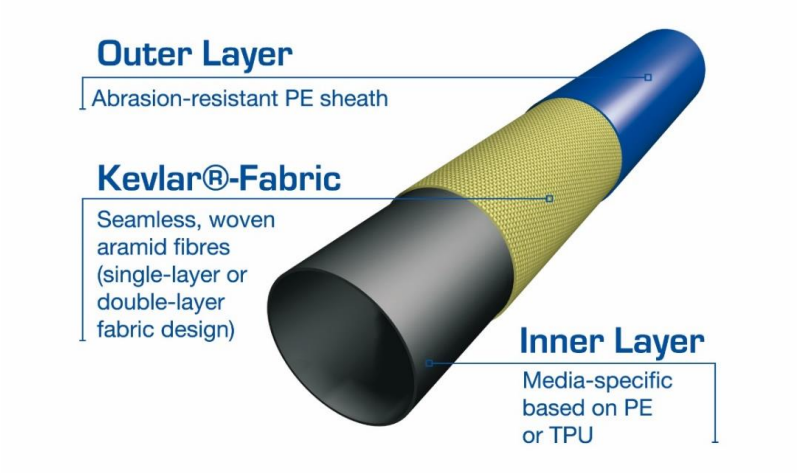

Figure 1: Schematic view of the Primus Liner

The second part of the system is the specifically developed termination fittings. There are two types of termination fittings: the low pressure fitting which is available from DN 150 to DN 300 and the installation is performed mechanically (compression style fitting). The Primus Line double-sided flange piece is installed at a corresponding flange at the host pipe. The flange at the host pipe is only needed for the assembly of the connector. A plastic contoured sleeve is installed onto the Primus Liner. The connector core with corresponding contours is inserted. With mechanical force, the connector core is inserted and a durable and pull-proof connection is achieved. Since it is a mechanical installation, a leak test can be perform right after the installation. The second flange of the double-sided flange piece can be used to integrate a hydrant, service connection, or valve (please refer to figure 2).

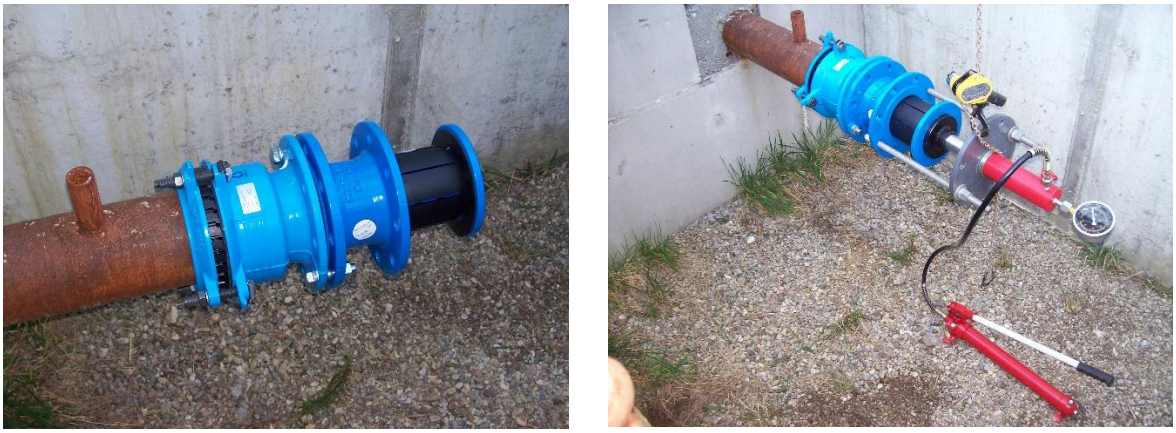

Figure 2: Installation procedure of the low pressure termination fittings

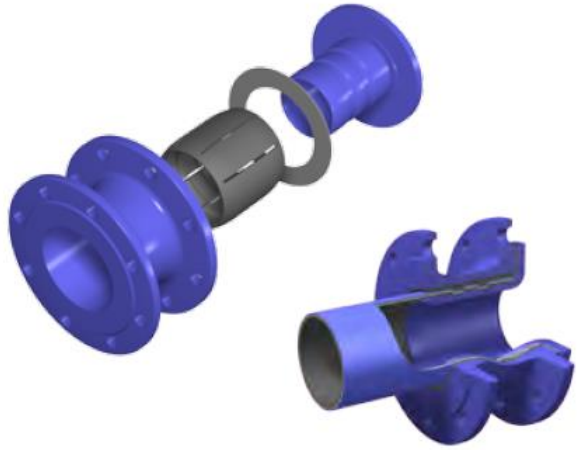

Figure 3: Exploded and general assembly drawing of the low pressure connector

The medium and high pressure fitting is available from DN 150 to DN 500 and the installation is performed with a two-component epoxy resin. The Primus Line outer sleeve with flange is mounted to a corresponding flange at the host pipe. The Primus Liner is trimmed and secured. The connector core with a contour is inserted. A two-component epoxy resin is injected with high pressure into the outer sleeve and a malleable steel jacket on the inside of the outer sleeve forces the Primus Liner into the connector core. There is a curing time of 4 hours at an ambient temperature of 20 degree Celsius before a leak test can be performed (please refer to figure 4).

Figure 4: Installation procedure of the medium and high pressure termination fittings

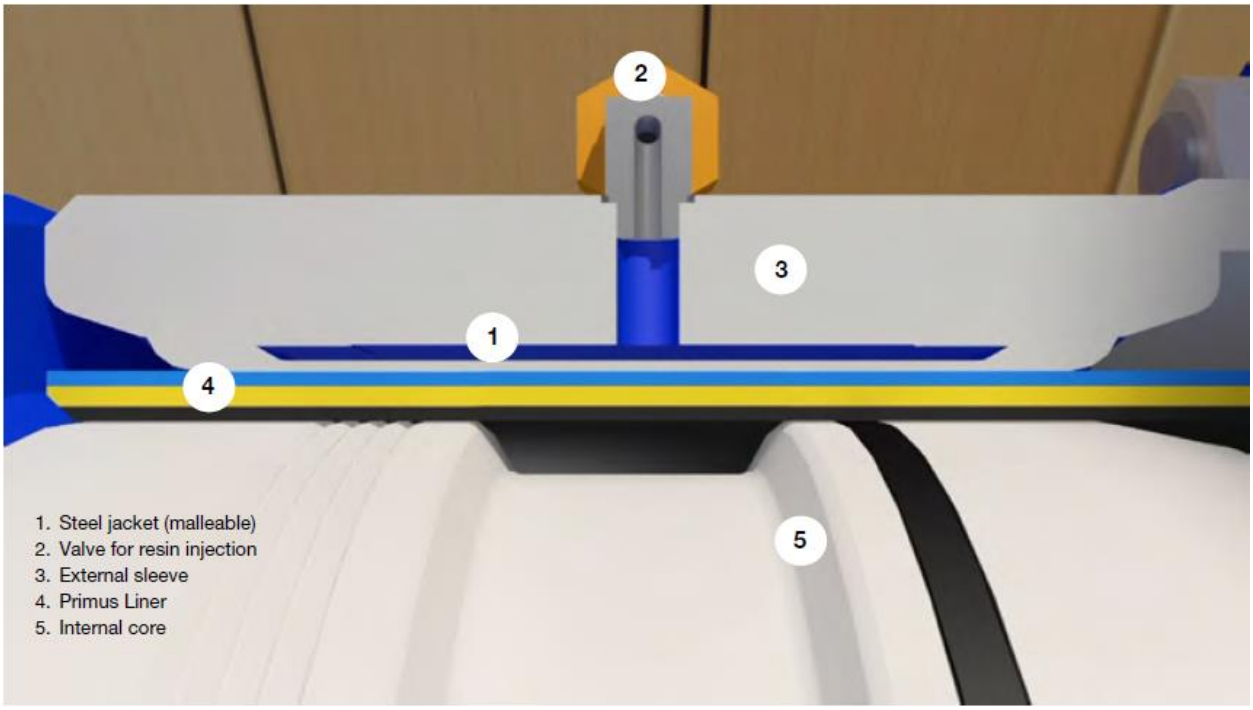

Figure 5: Medium and high pressure connector before the injection of the two-component resin

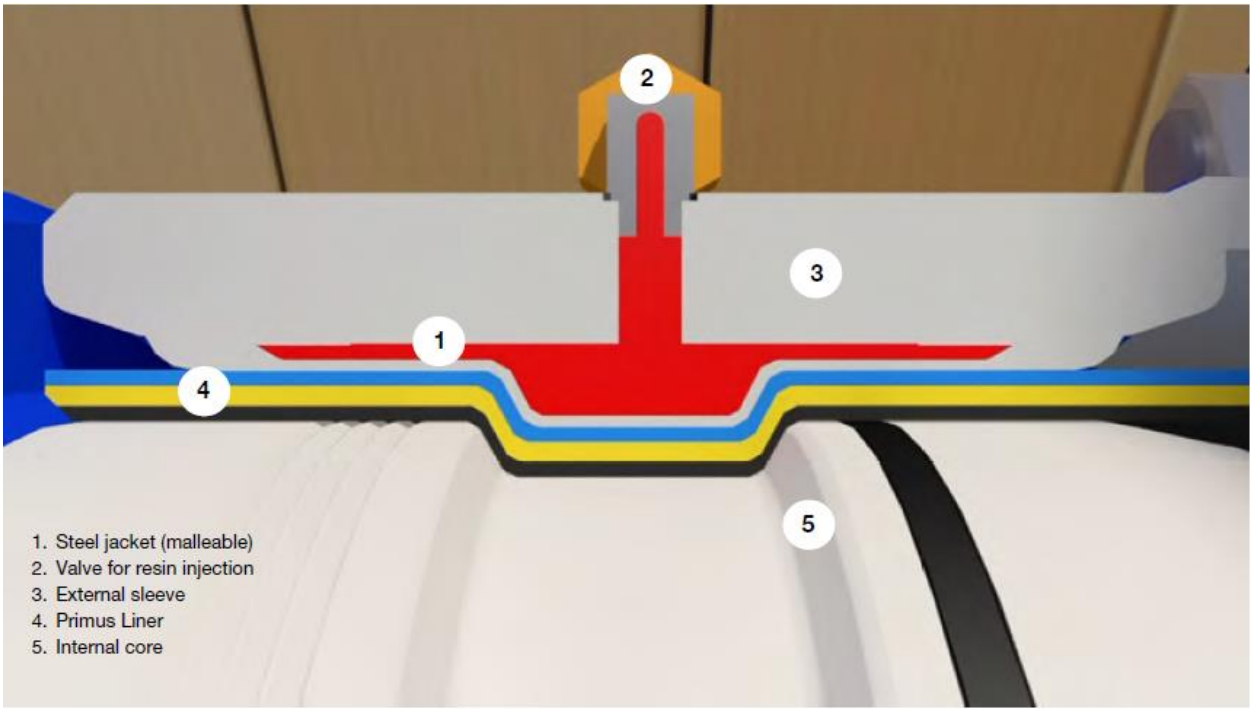

Figure 6: Medium and high pressure connector after injection of two-component resin

3. Installation procedure of the "Primus Line®" system

The semi-structural lining system that is capable of accommodating the operating pressure independently from the host pipe requires the host pipe for ground and traffic loads only. The system can be installed regardless of the host pipe material and is suitable for asbestos cement, PVC, HDPE, steel, cast iron, ductile iron a.s.o. As a prerequisite for the longevity of the installation, a CCTV camera inspection is performed to assess the condition of the host pipe. Usually, a rope connection is created between the start and destination pit by means of a CCTV camera. The goal of the inspection process is to detect any obstacles that are protruding into the cross-section of the pipe which could damage the liner during the installation process. In a second step, a mechanical coarse cleaning process with metal scrapers and pull through rubber discs is performed. With HDPE, PVC, AC and cemented lined pipes, usally only lose debris is found in the host pipe. Hence, cleaning with pull through rubber discs will be sufficient. In case of cast and ductile iron pipes as well as steel pipes, severe incrustation may be expected. These can be loosened using scraper pigs and removed using rubber discs. With steel mains, protruding welding seams may be expected which can be removed with cutters. After a subsequent CCTV inspection and once a free inner diameter is available, the installation can commence. The pre-folded liner is sent to the construction site on specific transport reels depending on the required sectional lengths. The liner is folded into U-shape at the factory to reduce the associated pulling forces during the insertion process. Thus, long installation sections can be realized and the stress on the material is minimized. A pulling head is mounted to the start of the liner and connected to a pulling winch. The liner can be installed with installation speeds of up to 400 m per hour. The liner is inserted lose-fit with a pulling winch and does not adhere to the host pipe. Once the liner is in place, compressed air of 0.5 bar is applied to turn the liner into round shape (please refer to figure 7). The liner does not adhere to the host pipe and a small annular space[1] will remain between the liner and the host pipe which does not have to be grouted. Once the liner has been turned into round shape the corresponding termination fittings are installed. After a leak test similar to local standards for HDPE pipes, disinfection, flushing and subsequent connection of the renovated section to the existing water main network, the rehabilitation is completed.

Figure 7: Delivery of the DN 250 PN 15 pre-folded Primus Liner to a construction site

[1] The Primus Liner is manufactured in nominal diameters from DN 150 to DN 500. For example, the Primus Liner DN 250 has an outer diameter of 237 mm and a corresponding inner diameter of 225 mm. The void between the host pipe and the liner will depend on the host pipe material and its respective inner available diameter. A minimum annulus space of 1 mm is required for the installation

4. Areas of application

The Kevlar® reinforced lining system is suitable for the trenchless rehabilitation of difficult to access and critical water mains from DN 150 to DN 500. The system allows to increase the pressure rating on existing network independently from the host pipe since the lining system has its own pressure rating. This means that the existing host pipe is only used as a conduit. Thus, the lining material can also be installed in larger host pipe diameters, if a reduction in hydraulic capacity is feasible. For example, a DN 500 liner can be installed into an existing DN 700 host pipe. Furthermore, the system is very economical in case of rehabilitating asbestos cement water mains since the cost for the disposal of the host pipe material in a traditional dig-and-replace scenario is very high. In addition, the lining material has only a small wall thickness of 6 mm – 8 mm for PN 10. Thus, the hydraulic capacity is only reduced minimally in comparision to HDPE-100 SDR 17 PN 10 (please refer to figure 8).

Host pipe	HDPE-100 SDR 17 PN 10	ID HDPE-100 SDR 17 PN 10	Primus Line PN 10	ID Primus Line PN 10	Gain in capacity
DN 150	DN 125	110.2 mm	DN 150	122 mm	+ 22.56 %
DN 200	DN 180	158.6 mm	DN 200	170 mm	+ 14.89 %
DN 250	DN 225	198.2 mm	DN 250	225 mm	+ 28.87 %
DN 300	DN 280	246.8 mm	DN 300	272 mm	+ 21.46 %
DN 350	DN 315	277.6 mm	DN 350	302 mm	+ 18.35 %
DN 400	DN 355	312.8 mm	DN 400	342 mm	+ 19.54 %
DN 450	DN 400	352.6 mm	DN 450	396 mm	+ 26.13 %
DN 500	DN 450	396.6 mm	DN 500	442 mm	+ 24.45 %

Figure 8: Capacity gains using Primus Line versus sliplining with HDPE-100 SDR 17 PN 10

In addition, the flexibility of the Kevlar reinforcement allows to traverse around bends of up to 90 degree. Thus, long installation lengths are feasible and the amount of excavation pits can be reduced. Furthermore, in case of needed land easements, needed excavation pits can be planned on public property or existing maintenance chambers can be used for the installation. Since the product is completely manufactured and quality controlled at a factory environment, the installation is fast with up to 400 m per hour. The system is extremely economical for critical crossings, such as river, street, and railway crossings. In addition, significant savings can be realized in city environments due to small excavation pits and a fast installation. The system has a minimum life span of 50 years.

5. Case study

5.1. Renovation of a DN 350 water main with a single length of 400 m and eight bends of up to 45 degree

The DN 350 drinking water pipeline to be renovated is located in one of the most densely populated neighborhoods of Haifa, the third-largest city in the State of Israel. The pipe runs along and below a two-lane main road. An open trench repair would have caused major traffic disruption. Thus, the customer decided for trenchless rehabilitation, using Primus Line DN 350 PN 21.
During the CCTV inspection eight bends of up to 45 degree were discovered – instead of the expected and projected four bends. Due to the flexibility of the Primus Liner, the four additional bends could be traversed without opening any extra excavation pits. In addition, the client did not face any additional cost resulting from this variation. The installation of the Primus Line® system could be performed in less than 7 hours.

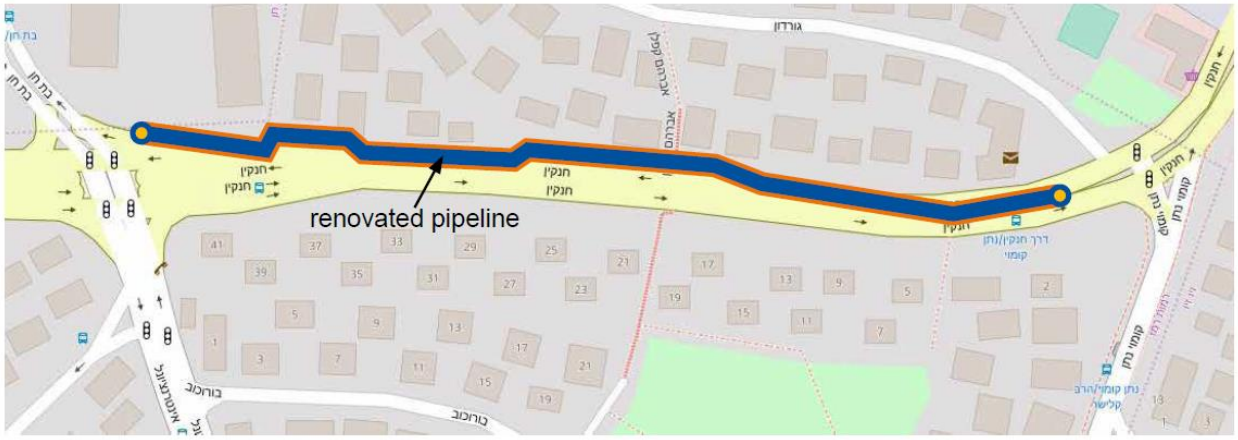

Figure 9: Run of renovated pipeline

6. Benefits and limitations

Although the Kevlar® reinforced composite lining system can be used for an array of applications, it does not intend to cover the complete range of rehabilitation jobs. Instead, it can be considered a sophisticated solution for water mains that are located in difficult to access areas such as river crossings, water mains running through congested cities, or through areas where it is difficult to get land permits. The system is exceptionally cost-effective when long installation lengths are feasible or multiple bends need to be traversed. Furthermore, if the hydraulic capacity needs to be maintained, the Primus Line® system offers a wall thickness of only 6 mm compared to corresponding HDPE pipes. Moreover, the system can be used to upgrade existing water mains to accommodate higher pressures by installing a higher pressure liner.

On the other hand, the system is not necessarily cost-effective for water mains in residential areas where numerous service connections need to be maintained. Generally, service connections can be integrated, however excavation is required in these areas. Furthermore, the lining system is currently only available from DN 150 to DN 500. Thus, larger trunk mains cannot be relined without significantly reducing the hydraulic capacity.

7. Concluion

Trenchless technologies can provide cost-effective solutions compared to traditional open trench methods, however no single solution can cover all areas of application so far. Numerous factors need to be taken into account, such as the structural integrity of the host pipe, existing service connections, accessibility of the host pipe and many more. Therefore, network operators need to understand the advantages and limitations of each single technology available to get the best quality and most economical solution for a specific project.