The steel pipe in trenchless technology

By H.-J. Kocks

Despite all the economic benefits to be derived from trenchless construction methods, the decision for or against their use is still largely governed by the trust placed in this technology and the suitability of the materials used. However, little can be gained from considering individual elements in isolation, whether field coating, equipment, or the pipe material. Only a systematic approach based on the detailed coordination of all the components involved – such as material-specific bending radii and pulling forces or the pipe end preparation described here for improved adhesion of the field coating – can yield a result that best exploits the benefits of each individual component. For welded steel pipes these results can be verified by measurements via methods of cathodic corrosion protection. So in this case there is hardly any difference from a safety point of view between conventional open-trench installations and trenchless pipe-laying.

Introduction

Trenchless pipe-laying methods have gained acceptance in all areas of the public utility industry. The use of shield tunnelling, or ram and thrust drilling processes for special construction measures such as pipe crossings beneath buildings, rivers, roads or highways, is now state-of-the-art, and conventional trenching methods would be completely uneconomical in such projects.

The most important advantages of trenchless technology can be summarized as follows:

- road damage is minimised
- fast laying as no reinstatement of the surface is necessary
- no impact on residents and traffic in the construction area
- no disruption of highway traffic thanks to little or no excavation
- no construction noise because there are no construction vehicles and construction activities as known with conventional open trench pipe-laying.

More and more, trenchless pipe-laying methods are used not only in the construction of new pipelines but also for the rehabilitation of existing service pipes and networks. Trenchless technology now encompasses a wide range of techniques which can be distinguished by the equipment or by the method used. There can be no generally valid answer to the question which type of steel pipe is best suited for which method, because this is not only determined by the method itself but, to a large extent, also by the different kinds of project constraints. Besides introducing the various steel pipe designs suitable for trenchless projects, this article will therefore also present a number of examples taken from practice, to aid the selection of the best fit solution for a given project.

Table 1: Delivery conditions for steel pipes

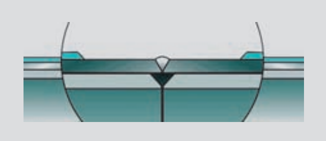
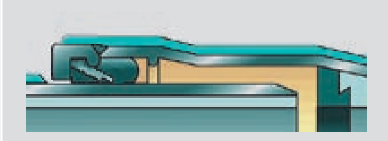
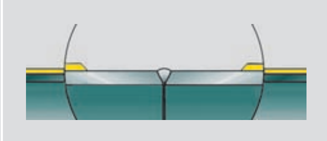
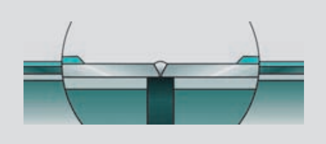
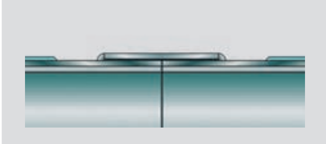
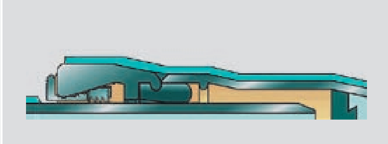
	Function standards	Title	Referenced standards	Title
Gas pipes 16 bar				
National	DIN 2470- 1	Steel gas pipelines for permissible working pressures up to 16 bar; pipes and fittings	DIN 1626	Welded circular unalloyed steel tubes subject to special requirements
International	DIN EN 12007-1+3	Gas supply systems – Pipelines for maximum operating pressure up to and including 16 bar	DIN EN 10208-1	Steel pipes for pipelines for combustible fluids – Technical delivery conditions – Part 1: Pipes of requirement class A
Gas pipes > 16 bar				
National	DVGW-Worksheet G 463	Gas supply systems – Pipelines for maximum operating pressure over 16 bar	DIN EN 10208-2	Steel pipes for pipelines for combustible fluids – Technical delivery conditions – Part 2: Pipes of requirements class B
International	DIN EN 1594	Gas supply systems		
Water and sewer pipes				
National/int.	DIN 2460	Steel water pipe and fittings	DIN EN 10224	Non-alloy steel tubes and fittings for the conveyance of water and other aqueous liquids
International				

Standards, rules and regulations

In Germany, the requirements on non-conventional pipe-laying practice are set out in the DVGW (German gas and water association) Worksheets. Non-conventional pipe-laying is not limited to trenchless methods but also comprises techniques that dispense with the normally required sand bedding. Currently the following Worksheets are applicable:

- DVGW Worksheet GW 320-1: Rehabilitation of gas and water pipes by PE relining with an annular space between pipe and liner (2000-06)
- DVGW Worksheet GW 320-2: Rehabilitation of gas and water pipes by PE relining without an annular space between pipe and liner (2000-06)
- DVGW Worksheet GW 321: Horizontal directional slurry rotary drilling methods for gas and water pipes (2003-10)
- DVGW Worksheet GW 322-1: Trenchless replacement of gas and water pipes – Part 1: Extraction-replacement method (2003-10)
- DVGW Worksheet GW 322-2: Trenchless replacement of gas and water pipes – Part 2: The auxiliary pipe method

Table 2: Joint types for pipe pulling

Water			Gas
Welded joints		Socket joints	Welded joints
			
Butt weld, pipe end design C2 acc. to DIN EN 10298	Slip welding joint	Tyton®-Sit	Butt weld
			
Butt weld, pipe end design C1/C3 acc. to DIN EN 10298	Weld-on collar	DKM®	Slip welding joint

- DVGW Code of Practice GW 323: Trenchless replacement of gas and water pipes by burst lining (2004-07)
- DVGW Worksheet GW 324: The moling and ploughing method for gas and water pipes

PE relining in accordance with DVGW Worksheet GW 320 has been included in the above overview because this method – especially the variant described in Part 1 – has already been used in several steel pipeline projects. In this context, the GELSENWASSER method should be mentioned which will be referred to in greater detail later. The DVGW Worksheet is currently being revised, and a draft version entitled "Replacement of gas and water pipes with an annular space between pipe and liner" (Erneuerung von Gas- und Wasserleitungen durch Rohreinzug mit Ringraum) has been published in January 2008. This revised version also includes steel and ductile iron pipes, in addition to polyethylene pipes.

The DVGW Worksheets specify the pipe designs suitable for the various methods. The appendices of the Worksheets also list the permissible tensile or pulling forces and bending radii. Given the vast number of material grades and wall thicknesses available, only the most common steel pipe designs are mentioned in the tables. However, methods for calculating the limits for all the other types of pipe are also described.

Table 3: Permissible pulling forces (kN) and bending radii for Tyton®-Sit and DKM® sockets* (pipe length 6 m)

Pipe dimensions			Tyton®-Sit	DKM®	Bending radius
Nominal size	Da (mm)	Wall thickness (mm)	Pulling force (kN)	Pulling force (kN)	(m)
DN 80	97.0	3.6	20	30	115
DN 100	117.5	3.6	29	50	115
DN 125	143.0	4.0	43	70	115
DN 150	168.3	4.0	60	100	115
DN 200	219.1	4.5	102	170	115
DN 250	273.0	5.0	107	260	115
DN 300	323.9	6.3	152	370	115

* Pipes with friction joints can only be used on relatively straight routes and/or with constant bending radii, because permanent movements inside the sockets are not permissible during the pull-in.

Steel pipe designs

Steel pipe

Perhaps the most distinguishing feature of steel pipe for the public utility sector is their specific combination of strength and wall thickness, which is defined as a function of the intended application. In addition, a variety of joints, coatings and linings enable solutions to be customized to all types of application requirements and construction techniques. The application profile also determines which delivery conditions apply to steel pipe orders (**Table 1**).

Gas line pipe for operating pressures up to and including 16 bar is mainly ordered in accordance with the technical delivery conditions of DIN EN 12007-3 and/or DIN 2470-1 (currently still valid), DIN EN 10208-1 or DIN 1626. For gas pipelines operated at pressures exceeding 16 bar, DIN EN 1594 and DVGW Worksheet G 463 specify pipes according to DIN EN 10208-2. Orders for steel water pipes in accordance with DIN 2460 now usually specify the technical delivery conditions of DIN EN 10224.

Pipe joints

A major advantage of steel pipe is the wide variety of joint types available for it. State-of-the-art for the trenchless installation of gas, water and sewer pipelines are welded joints. For water supply lines, longitudinally force locking joints are also used. Welded steel pipe strings provide both longitudinal force locking and the capability of transmitting tensile forces, i.e. pulling forces, with the permissible level being limited only by the mechanical strength of the steel. Given that the longer the pipe string, the higher the pulling forces required, it becomes obvious that steel with its high strength is best suited to utilize the economic edge of trenchless installation to the full. Targeted combinations of steel quality and strength on the one hand, and the optimum pipe wall thickness on the other, open up a great variety of cost-effective product designs. **Table 2** provides an overview of the joints most commonly used for pipe pulling operations.

Two types of welded joints are used: the butt weld and the socket weld. The longitudinal conductivity of these pipes allows the use

Table 4: Comparison of product-specific bending radii for gas pipe (DIN EN 12007-3) and process-specific bending radii according to DCA Technical Guideline

Size			DCA*	Gas Pipe L235 GA	Gas Pipe L360 GA
Nominal	Da (mm)	Wall thickness (mm)	Bending radius (m)	Bending radius (m)	Bending radius (m)
DN 80	88.9	3.2	89	117	76
DN 100	114.3	3.2	114	150	98
DN 150	168.3	4.0	168	221	144
DN 200	219.1	4.5	219	288	188
DN 250	273.0	5.0	273	359	234
DN 300	323.9	5.6	323	426	278
DN 350	355.6	5.6	356	468	305
DN 400	406.4	6.3	363	534	349
DN 500	508.0	6.3	507	668	436
DN 600	610.0	6.3	667	802	424

*Drilling Contractors' Association

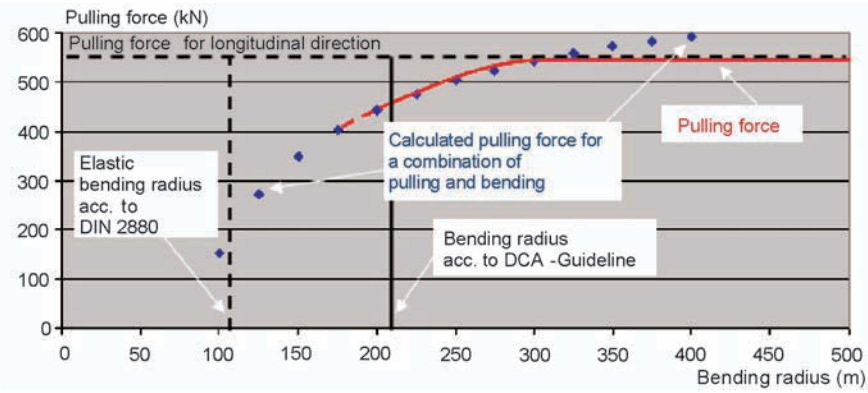


Fig. 1: pulling forces depending on the bending radius (Cond.: water pipe DN 200, butt welded v_{NFeld} = 0.9; wall thickness 4.5 mm, base material L 235)

of cathodic corrosion protection, either for the complete pipeline or just for the trenchless section. One element of uncertainty in trenchless pipelines is possible damage to the pulled-in pipe section. However, unlike all other pipe materials, welded steel pipelines fitted with cathodic corrosion protection will preserve the functional integrity of the pulled-in pipeline even in the case of a single damage in the pipe coating.

With welded pipes, the free space required to assemble the pipe for the pull-in must be considered. Usually rollers are used to support the pipe.

If there is not enough space for stringing, the pipes must be individually joined by welding in the launch bore, which is quite cost-intensive; alternatively, axially force-locking socket pipes of the type commonly used for water supply systems must be used. Depending on the tensile strength of the pipe steel and the pulling forces to be expected, two different socket pipe designs are available for the size range of DN 80 to DN 300: the Tyton®-Sit and the DKM® joint. **Table 3** provides an overview of the maximum permissible pulling forces for these socket types.

Contrary to welded joints, sockets may require a wider opening of the bore tunnel as well as higher pulling forces due to the socket design. Incoming material can block the sockets in the bore tunnel. Also contrary to welded joints, the axially force-locking property of sockets may fail under the effect of excessive pulling forces. Usually, the first joint behind the pull head collapses due to extremely tight steel pipe tolerances, as this is where the friction and weight forces acting on each pipe length are greatest. Especially in flush drilling operations it is therefore recommended to install a sealed unit behind the first socket joint, particularly in the case of drinking water pipelines. In this way, pollution of the cement mortar lining with drilling mud can be avoided. In the event of failure, the already installed pipe section can possibly be uncovered and the resulting pit can be used as a new starting point for further installation.

The appendices to the national DVGW Worksheets for trenchless construction methods define the basic data applicable in Germany for calculating the pulling forces; the examples given set out the values in tabular form as a function of the permissible bending radii. The higher the pipe material's strength and the greater the pipe wall thickness, the higher the pulling forces and the smaller the bending radii that can be realized. The first step in calculating the pulling forces is to determine the permissible bending radius. The basic data for calculating the permissible elastic bending radii for gas pipe can be found in DIN EN 12007-3 for operating pressures up to and including 16 bar and in DIN EN 1594 for operating pressures above 16 bar. For water pipes the calculation for the bending radii is given in the national DIN 2880. Bending radii determined in this way must always also be assessed technically, taking account of the intended pipe-laying method.

The process-specific bending radii can be calculated on the basis of recommendations in the Technical Guideline of the Drilling Contractors' Association (DCA) [1]. Of the two types of bending radii, the larger is valid in each case. **Table 4** gives an example of such a comparison for various gas pipe sizes intended for operating pressures up to 16 bar. Depending on the material used, the product-specific bending radius according to DIN EN 12007-3 may be either smaller or greater than the process-specific bending radius recommended in the Technical Guideline of the DCA. For gas pipe in L235 GA, the product-specific bending radii according to DIN EN 12007-3 are valid, while pipe in L360 GA shall comply with DCA Technical Guideline.

These bending radii flow into the permissible pulling force calculation according to the formula given in the national DVGW Worksheets:

$$F_{BZzul} = \left(\sigma_{BZzul} - \frac{d_a \cdot E}{2000 \cdot R_{min}}\right) \cdot \frac{A_{quer} \cdot v_{NFeld}}{1000}$$

$$A_{quer} = \frac{\pi}{4} \cdot \left(d_a^2 - d_i^2\right) = \frac{\pi}{4} \cdot \left[d_a^2 - \left(d_a - 2 \cdot s_{min}\right)^2\right]$$

$$\sigma_{BZzul} = \frac{K}{S} \cdot f_{BZ}$$

Where

F_{BZzul} = permissible pulling force during construction

σ_{BZzul} = permissible stress during construction

da = pipe outside diameter

E = Young's modulus (210 000 N/mm²)

R_{min} = minimum bending radius

A_{quer} = solid cross sectional area of pipe wall

ν_{NFeld} = coefficient of utilization for field weld

K = specified minimum yield strength of pipe material

S = safety coefficient for pulling force calculation (= 1.1)

f_{BZ} = permissible load factor during construction (This factor is 1.34 for tensile bending loads and becomes 1.0 for the load case of stretched pulling, with $R_{min} \rightarrow \infty$)

d_i = pipe inside diameter

s_{min} = minimum pipe wall thickness

It must be taken into account here that the pulling forces in the case of tensile bending loads may be raised to 1.34 times the specified minimum yield strength. The application of this factor is limited by the permissible pulling force in relation to the effective cross sectional area in the case of stretched pulling. Here the permissible pulling force is calculated using a safety coefficient of 1.1 in relation to the specified minimum yield strength of the pipe base material. **Figure 1** illustrates how the use of the factor under combined tensile bending loads influences the pulling force permissible (taking account of the applicable limit value) for a welded DN 200 water pipe with a standard wall thickness of 4.5 mm and made from L 235 steel (formerly St 37.0).

Coatings

The standard coating for steel pipes is a three-layer polyethylene system in compliance with DIN 30670. Alternatively, a polypropylene coating in compliance with DIN 30678 can be used. For particularly demanding and difficult service conditions, an fibre cement mortar (FCM)-coat according to DVGW Worksheet GW 340 can be applied on top of the plastic coating (**Figure 2**).

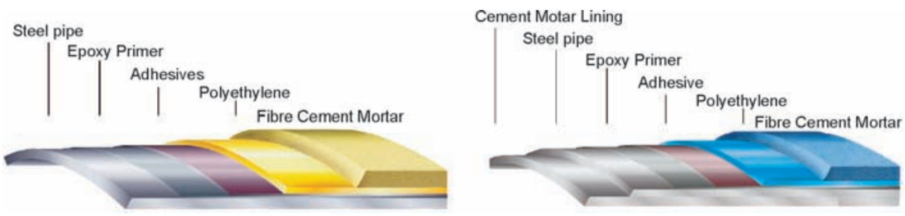


Fig. 2: Structure of coated gas and water pipe

The three-layer polyethylene coating according to DIN 30670 consists of an epoxy resin primer, an adhesive, and the actual polyethylene layer. Standard coatings (Type N) can be used for operating temperatures up to 50°C, and special coatings (Type S) for temperatures up to 70 °C. The standard layer thickness (n) depends on the pipe size and ranges from 1.8 mm to 3.0 mm (**Table 5**). The reinforced layer thickness (v) is about 0.7 mm, but if required greater thicknesses are also possible.

Table 5: Standard layer thickness of polyethylene and polypropylene coating

Polyethylene coating in accordance with DIN 30670			Polypropylene coating in accordance with DIN 30678	
Nominal size	Layer thickness (n)	Layer thickness (v)	Nominal size	Layer thickness
≤ DN 100	1.8 mm	2.5 mm	≤ DN 100	1.8 mm
DN 100 – DN 250	2.0 mm	2.7 mm	DN 125 – DN 250	2.0 mm
> DN 250 < DN 500	2.2 mm	2.9 mm	DN 300 – DN 500	2.2 mm
DN 500 < DN 800	2.5 mm	3.2 mm	≥ DN 600	2.5 mm
DN 800	3.0 mm	3.7 mm		

Polypropylene coating is produced in accordance with DIN 30678. Its design is similar to that of the polyethylene coating but offers higher mechanical resistance. The current raw material will allow the use of the coating for operating temperatures of up to 100 °C while the layer thickness, as with the polyethylene coating, depends on the pipe size (Table 5).

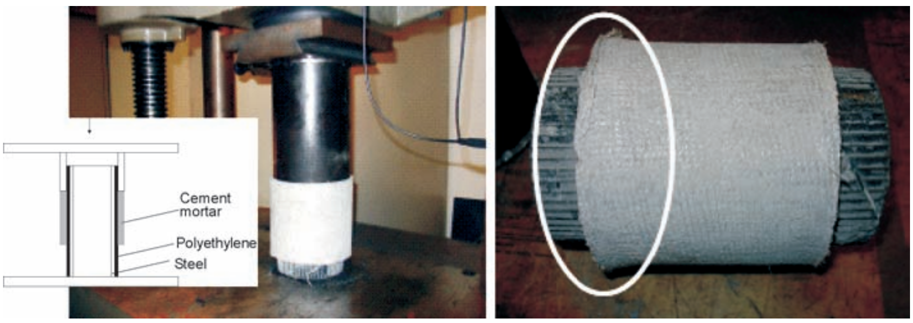


Fig. 3: Shear test of cement mortar coating (FCM-S)

One of the advantages of plastic coatings is that they can be fitted with ribbing for increased ruggedness. For the pulling method, inclined ribbing is applied as mechanical protection of the pipe coating surface.

FCM coating according to DVGW Worksheet GW 340 was originally developed to eliminate the need for the sand cushioning usually required with conventional pipe-laying in stony and rocky ground. The compressive strength and, especially, the impact resistance of FCM are many times the values of plastic coatings. In addition, special coating types have been developed for use in trenchless projects. Pipe pulling can cause high shear stresses due to jacket friction, which are transmitted from the coating to the pipe.

The special FCM coating (FCM-S) for trenchless applications differs from the standard variant (FCM-N) in that there is an adhesive layer between the plastic coating and the FCM top coat. Today, it is possible to produce a coating which will only separate from the underlying polyethylene coating if the mortar layer has been destroyed, independent of the direction of the forces acting on it. **Figure 3** shows the test set-up and the result of a shear test conducted on an FCM coating.

For the manufacture of FCM-S coating, the polyethylene coating is extruded with an axial T-profile. While the coating is still hot, coarse polyethylene particles are fused onto the surface to give the ribbed coating a rougher structure. In this way, mortar movement is completely ruled out both in the circumferential and the longitudinal direction. A length of 2-3 cm at either pipe end is left uncoated with cement mortar so that the casting mortar or resins used for field coating can also hook up

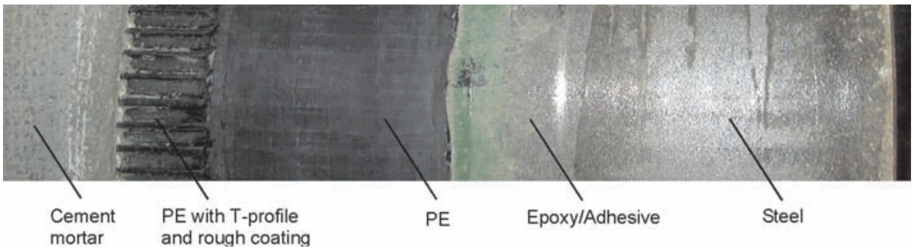


Fig. 4: Pipe end design of FCM-S coating according to DVGW Worksheet GW 340

mechanically with the pipe's cement mortar coating (**Figure 4**).

On-site treatment of joint areas

All pipe joints need corrosion protection and, if required, mechanical protection in the joint areas before the pull-in. For field coating, corrosion protection tapes or thermo-shrinking materials according to DIN 30672 or DIN EN 12068 can be used for all polyethylene coatings. Alternatively or additionally, there are products such as Canusa TBK (Thrust Bore Kits) FRP or thermosetting filler, which are specially designed to accommodate the high tensile stresses of pipe pulling in trenchless projects (**Figure 5**).

Fig. 5: Field joint coating of polypropylene coated pipes with an additional FRP system

Field coating of the pipe joint area is done using the FCM coating along with the common corrosion protection systems according to DIN 30672. As the fibre cement mortar coating (FCM) should have a minimum thickness of 7 mm, the difference can be evened out with an easy-to-use casting mortar (**Figure 6**). FRP or duromer systems are also available. These systems are either glass fibre reinforced or sand-filled casting systems on a polyurethane basis and have largely the same processing characteristics as casting mortar. Here too, suitable corrosion protection is applied beforehand such as heat shrinking tubes or anti-corrosion wraps.

Application examples

The steel pipe as an inliner: Relining

The relining with steel pipe is a rehabilitation method wich has often been used in the last years. The contrary to plastic pipes the relining with steel pipe at time is not covered by DVGW Worksheet GW 320-1. This will be changed in the near future within the next edition of this worksheet. Steel line pipe counts among the systems with static stability and is frequently used where the old pipe no longer meets the specified requirements. Pulling in a new pipe string through an existing pipe necessarily means that the pipeline diameter is reduced.

Contrary to widespread earlier expectations, water consumption has gone down in recent years both in private households and in the industry as a whole. Since this trend is largely attributable to the increased use of water circulation systems, it is reasonable to consider downsizing the pipe cross section as part of the rehabilitation, especially with older pipelines. In such cases, pulling in the new pipe through the existing pipe seems a very obvious solution. An excellent example is the sliplining method patented by GELSENWASSER, which has been in use since the early 1990s [2]. This inliner technique is suitable for both welded and axially force-locking socket joints. However, the pipe size is also an important parameter when it comes to selecting the best suited joint. Making up mechanical connections necessarily requires much more annular space between the new installed pipe and the old one. The pit requirements are dictated by the route conditions. It is impossible, for example, to pull a steel inliner through a bend. Originally straight pipelines in mining subsidence areas must therefore be checked for bends that could have developed due to soil

Fig. 7: Slip lining with a steel socket pipe

Fig. 6: Field joint coating of FCM-coated pipes with an additional casting mortar

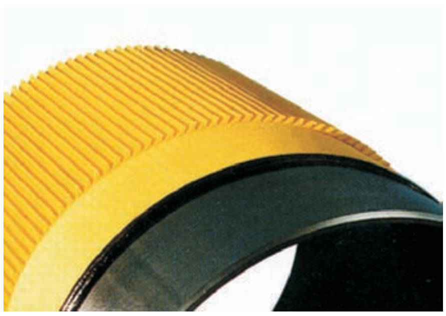


Fig. 8: Ribbed coating on steel pipe with welded joints

movement over the years. Unexpected pipeline internals which might obstruct the sliplining can be detected with the aid of a camera pig. Before pulling in the inliner pipe, the existing pipeline must be cleaned using circular metal or rubber scrapers or similar devices.

The sliplining process must be coordinated with the assembly work in the launch pit. The joint areas in socket pipe strings are protected by special metal sleeves (**Figure 7**), which assist the sliding process so that no further protection is required for the pipe coating. In the case of welded joints, a ribbed profile extruded on top of the plastic coating serves as the sliding surface during sliplining (**Figure 8**). Depending on the joint used; pipe string lengths of up to 400 m can be pulled in using this technique. The annular space between the old pipe and the inliner is usually filled with insulating material.

Horizontal directional drilling (HDD)

Horizontal directional drilling methods have increasingly been used roughly since the late 1980s, particularly for special construction measures such as river crossings in pipelines.

The development started with large-diameter pipes and continued with the smaller pipe sizes used for water and gas supply. At a seminar on controlled horizontal drilling at the Bochum Ruhr University's Institute for Sewer Systems, on 24 September 1996, H. Scholz [3] reported on a river crossing implemented by controlled horizontal drilling. This overview started with the 550-metre Danube crossing in DN 800 pipe installed in 1990. Further examples followed in the period up to 1996 with pipe sizes up to DN 1200 and installation lengths of up to 1160 m (**Table 6**).

Development in the area of smaller pipe sizes went much slower. The first installation with a polyethylene coated steel line pipe with a cement mortar top coat was documented at the NGW Rheinberg gas and waterworks in 1990 (**Figure 9**). It is a gas line in DN 100, which was pulled in beneath a parking lot and a Federal road, over a length of 130 m. This installation was the state-of-the-art of its type at the time. Referring to this project, Bayer reported in an article about the principles of controlled horizontal drilling in a 1991 issue of 3R international on installation possibilities for utilities [4]:

"The following products can be installed underground by means of controlled horizontal drilling:

... thin-walled steel line pipes up to a maximum diameter of 150 mm, but the latter ones only in case of especially soft ground and with sufficient space for longer launch pits. (Steel pipelines with a diameter of up to DN 100 are much easier to install.)"

In 1996, on behalf of Saarferngas AG, a 368-metre DN 200 high pressure gas pipeline was

Table 6: River crossings (Ruhrgas) 1990   1996 [2]

Year of construction	River / canal	Length (m)	Diameter DN	Nominal pressure (bar)
1990/91	Danube Lech	550 380	800 800	80 80
1993	Elbe Havel 2 canals	680 480 400	1100 1100 1100	84 84 84
1994	Ems	550	1200	84
1995	Isar	1160	900	80
1996	North Baltic Sea Canal	550	700	84

Fig. 9: Rheinberg, DN 100, 1990

Fig. 10: River crossing at the Moselle, DN 200, 1996

Fig. 11: Wesenberg, DN 300, 1996

Fig. 12: Hamburg, DN 200, 2000

pulled in beneath the Moselle (**Figure 10**). The soil conditions were completely different to the soft ground critically required only a few years ago. Under the Moselle, 80 m of very hard quartzite had to be drilled through [5]. In the same year, a 576 m DN 300 polypropylene coated steel pipeline was drilled for the first time, commissioned by VNG Leipzig in Wesenberg (**Figure 11**).

Further milestones in the development included the first trenchless installation of socket pipes in Offenbach in 1997 using the Tyton Sit connection, and the jacking of DN 200 socket pipes with DKM joints in a project commissioned by the Hamburg Waterworks in 2000 (**Figure 12**).

Horizontal directional drilling has successfully established itself in special construction projects such as crossings beneath natural and man-made obstacles in nature reserves and urban or residential areas, or on roads and highways.

The extraction & replacement method

Extraction & replacement is a trenchless method for replacing service lines in the range of DN 100 to DN 400 without altering the existing route. Especially in Berlin, extraction & replacement methods such as hydros® or hydros® PLUS have been used from the early 1990s. The trade name hydros® stands for Hydraulisches Rohrzugspalt-Verfahren, which is the German term for hydraulic method for pipe pulling and splitting. The method was developed for the trenchless replacement of old – in most cases ductile iron – service lines.

In this process the pulling unit is installed in the exit pit to simultaneously extract the old pipe, pull in the new pipe and destroy the old pipe with a mandrel. The new pipe string is made up in the launch pit. Pulling and assembly phases must therefore be carefully coordinated. Usually the old pipe is extracted in short lengths, depending on the strength of the old pipe material. Given a pulling length of 60 to 80 m there are usually several small pits in which the sections of the old pipe are demolished.

Extraction and replacement by the "auxiliary pipe method" takes place in two stages. Once again, a launch pit is required for the new pipe and an exit pit for the old pipe, as well as a pit for the equipment. In addition, intermediate pits must be provided every 20 to 50 meters in the area of pipe branches, service connections, and valves and fittings. An auxiliary pipe is jacked in from the launch pit, pushing a length of the old pipe towards the exit pit. This procedure is repeated until the last old pipe length has been retrieved and replaced by an auxiliary pipe. The pipe duct is now supported by the auxiliary pipes which carry the load of the soil cover and the traffic load. In the second stage, the new pipe is taken into the launch pit and attached to the auxiliary pipe via a pulling head. Length by length, the auxiliary pipe is pulled back and the new pipe is pulled into the pipe duct. Steel and ductile iron pipes are usually assembled in the pit.

Fig. 13: Device for bursting the old pipe

Fig. 14: Pulling unit for burstlining

Burstlining

Replacement by the burstlining method leaves the remnants of the old pipe in the soil. An expansion head bursts the old pipe and rips it up with a suitable tool (**Figure 13 and 14**), before it starts replacing the soil to enable the new pipe to be pulled in, which can have either the same or a larger diameter than the old pipe.

In a recent project, GASO Dresden used the burstlining method to replace a 405 m section of a DN 100 steel gas pipe with a new steel pipe protected with a polyethylene-coating and an additional cement mortar top coat (**Figure 15**). The section to be replaced was divided into two sub-lengths of roughly 200 m, each of which was welded and coated in the field. The old steel pipe was cut open and expanded, before the new steel pipe string was pulled in. The installation took place in four operating steps. First the old pipe was cut and subjected to two expanding steps. The new steel pipe was pulled in concurrently with the third expanding step. The need for repeated expansion was mainly due to elastic recovery (spring-back) of the cut old pipe.

Plough technology

Trenchless plough methods were developed especially for pipe laying and replacement in open expanses of ground where earthmoving work should be reduced to a minimum. In addition to saving work, time and resources, the plough technology offers significant advantages from an ecological viewpoint because it leaves the structure of the soil largely unaffected.

Using the rocket plough (developed and patented by the Föckersperger company based in Münchaurach, Nuremberg), the pipe is attached directly to the displacement head (rocket) on the ploughshare and pulled into the cavity made by the rocket (**Figure 16**). The expanding head can cut cavities up to 500 mm in diameter and pull in pipes up to DN 250 (even larger diameters are possible, depending on the ground and route conditions). At the same time, an installing shaft mounted onto the rocket can be used to install additional protection pipes, cables and tracing bands. The positioning accuracy can be checked and adjusted with the aid of a combined laser scanner and panoramic digital imaging unit. With the rocket plough, the pre-assembled pipe string is fitted to the installing shaft towed by the traction unit. In the case of uncertain ground conditions it might be sensible to use a pipe with an additional fibrous cement mortar coating (FCM). It is possible to check and monitor the tensile forces acting on the pipe string. Injecting a bentonite suspension can reduce friction and consequently the pulling force required.

The Föckersperger company based in Pauluszell, near Munich, has meantime developed an alternative ploughing method which dispenses with the need for assembling and pulling the pipe string outside the launch pit. In contrast to the rocket plough method, string assembly is done directly on the route. The plough is towed toward the pipe string by powerful winches.

Making use of the allowable deflection (elastic bending radius) of the pipe joints, the ploughshare feeds the string to the desired laying depth. The complete absence of tensile stresses acting on the pipe means there is no limit to the string length that can be laid by this method (**Figure 17**). It is currently used for pipe sizes up to DN 100.

Fig. 15: Steel pipe with pulling head

Fig. 16: Münchaurach, DN 200, 2001

Fig. 17: Pauluszell, DN 100, 2008

Conclusion

Trenchless pipe laying technology has achieved a degree of importance that can hardly be overestimated. Practically all the major pipe-laying projects today include trenchless crossings beneath railway tracks, waterways or roads, not only, but also because this technology has proved to be the most cost-effective. However, the advantages of trenchless pipe-laying are not limited to new pipeline projects: they also play a major role in the rehabilitation of pipelines and pipe networks. Pipelines represent between 60 and 80 % of a public utility's fixed assets. Based on recent analyses, a pipe replacement rate of 1.5 % must be expected if the current level of supply reliability is to be maintained. The fact that some areas in the public utility industry have reported replacement rates of between 0.1 and 0.5 % only serves to indicate the growing need for maintenance and rehabilitation of pipe networks. Here, the use of trenchless technology has experienced a continuous upward trend with a view to avoiding costly reinstatement of the surrounding landscape and roads and generally keeping investment outlays within reasonable limits.

The suitability of pipe systems mainly depends on the mechanical load-carrying capacity of the pipes and their coating. Steel pipe strings with welded joints have high mechanical strength and can take very high pulling forces. So they can be used for all types of trenchless installation. The pipe wall thickness and steel grade can be adapted from case to case to the load conditions of the application profile in hand. In this context, the protective efficiency of the coating is no less important than the mechanical strength of the pipe. Summing up, steel pipe offers flexibility in the design of joints, a wide choice of coatings and field coating systems that readily accommodate trenchless methods, plus the option of cathodic corrosion protection. All this combines to make the steel pipe an integrated system perfectly matched to the requirements of trenchless pipe-laying technology.

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