ISSN 0340-3386 - K 1252 E
VULKAN VERLAG

Rohre Rohrleitungsbau Rohrleitungssysteme

3R INTERNATIONAL

Piping Systems Piping Engineering Pipes

Journal for Piping, Engineering, Practice

Special Edition 13/2002

Steel Pipelines

The Steel Pipe used for trenchless installation

Dr. rer. nat. Hans-Jürgen Kocks, Röhrenwerke Gbr. Fuchs GmbH, Siegen (G)
Dipl.-Ing. Hauke Joens, Röhrenwerke Gbr. Fuchs GmbH, Siegen (G)
Frank Föckersperger, Georg Föckersperger GmbH, Aurachtal (G)
Dipl.-Ing. Günther Walter, Universität der Bundeswehr, München (G)

erschienen in 3R international Special Edition 13/2002
Vulkan-Verlag GmbH, Essen
Ansprechpartner: Nico Hülsdau, Telefon 0201/82002-33, E-Mail: n.huelsdau@vulkan-verlag.de

The Steel Pipe used for trenchless installation

Over the last few years the trenchless pipe installation technique has become more and more important for gas and water supply as well as for sewage disposal. Depending on the installation conditions, different processes have been developed which will perfectly meet specific requirements. Steel pipe is the most appropriate solution for a trenchless line installation technique, due to its very high permissible tensile force, combined with the three-layer plastic coating as an optimum corrosion protection, and the additional fibrous cement mortar coating for special mechanical requirements. This article deals with the use of steel pipes for trenchless installation and a variety of possible applications.

Introduction

Trenchless procedures for laying pipelines have gained acceptance in all areas of the supply and disposal industry. The use of shield tunnelling, ram and thrust drilling processes for special construction measures such as under-running of buildings, river courses or traffic arteries, is state-of-the-art. In such cases the open installation is completely uneconomical. There are two different directed drilling procedures:

- ▷ water-flush drilling and
- ▷ dry drilling [1].

With water-flush drilling procedures (as opposed to dry drilling), wider pipe diameters as well as longer pipe sections can be used, since these "wet" procedures allow for a smoother towing-in of the pipes. To a great extent, the loosened ground material can be easily removed from the bore tunnel by pressing Bentonite in. The remaining material is used to fill back the annulus space between pipe and bore tunnel wall. As for the statics, the filling-back of the annulus space is a crucial advantage of trenchless laying, in that any damage of the rod surface caused by a following settlement can be avoided [2]. The necessary processing of the drilling suspension is a disadvantage of the water-flush procedures. In addition, there is the danger of "out-blowing" due to the high medium pressure, which means, for example, that Bentonite could escape from frost cracks in underbored roads. These disadvantages are irrelevant for dry-drilling procedures.

Economically, the conventional and the trenchless procedures compete directly for work within the cities, unlike special construction works. Advantages of trenchless procedures are:

- ▷ low damage of the road bed because of avoiding settlement
- ▷ bores are filled with a mixture of loosened ground material and Bentonite
- ▷ fast laying as no reinstatement of the surface is necessary
- ▷ no impact on residents and traffic in the construction area
- ▷ lack of highway obstruction because of the small excavation, and there is no construction noise because there are no construction vehicles and construction activities as known with conventional laying.

The high density of pipes in the ground under our cities is a main disadvantage of trenchless procedures, jeopardizing the success of a drill. Geo-radar and geo-electronic screenings are tried and tested for transport pipelines in the open country. However, regarding existing pipelines, the resolving of such procedures are a crucial factor if information in the net maps of the inner cities is missing [3].

In the cities, some special renovation techniques such as the Burstlining use existing pipelines for orientation, therefore reducing jeopardizing other constructions in the ground. For large numbers of residential connections, the economical benefits of trenchless new-laying and renovation procedures, gained through avoiding an expensive reinstatement of the surfaces, are soon exhausted.

Outside the cities, directional drilling procedures are of only minor importance save for the above-mentioned special construction works, or for instance for some conditions imposed on installation works in nature reserves. The ploughing procedure could gain acceptance for installation of transport pipelines where there are favourable ground conditions, and this would be for pipe dimensions of currently up to DN 300. The main competition tool is the use of ditch mill machines as commonly used for conventional installation. There is an unavoidable increase in costs for the pipe material over pipe material costs for conventional laying, but there is a significant decrease in laying costs. Consequently - as with the economical comparison of both procedures - the costs for additional measures, (in order to ensure a sufficient longitudinal locking force or the mechanical protection of pipes for trenchless laying) are becoming more and more crucial. From this viewpoint, choosing the right design of pipes for each type of laying is of vital importance. This article shows the different steel pipe designs used for trenchless installation procedures with installation examples, and the versatility for using this technique.

Steel pipe designs for trenchless installation procedures

For conventional as well as trenchless laying, choosing the most suitable pipe design depends mainly on the laying procedure and the local conditions for each project. There are particular requirements for the installation which have to be met at the planning, laying and pipe towing-in stages, depending on the pipe design.

Connecting techniques

A main advantage of steel pipes is the versatility of possible connecting techniques. State-of-the-art for trenchless installation of gas, water and sewage pipelines use welded joints. For water supply lines, longitudinal force locking joints are also used. Welded joints have

Dr. rer. nat.
Hans-Jürgen Kocks
Röhrenwerke Gbr. Fuchs GmbH, Siegen (G)
Tel. +49(0)271/691-170
E-Mail: hans-juergen.kocks@fuchsrohr.de

Dipl.-Ing. Hauke Joens
Röhrenwerke Gbr. Fuchs GmbH, Siegen (G)
Tel. +49(0)271/691-171
E-Mail: hauke.joens@fuchsrohr.de

Frank Föckersperger
Georg Föckersperger GmbH, Aurachtal (G)
Tel. +49(0)9132/7844-0
E-Mail: info@kabelpflug.de

Dipl.-Ing. Günther Walter
Universität der Bundeswehr, München (G)
Tel. +49(0)89/6004-2698
E-Mail: guenter.walther@unibw-muenchen.de

the advantage of longitudinal force locking combined with longitudinal conductivity. With welded joints, the mechanical strength of steel can thoroughly influence the level of the permissible tensile strength. Above all, the economical advantages of trenchless installation can be shown by using the maximum towing-in lengths. Differing steel qualities and their different material strengths combined with the optimum pipe wall thickness, offer a great variety of economical product designs.

Two types of welding joints are used:

▷ butt-weld and

▷ socket weld (**Figure 1**).

The longitudinal conductivity of these pipes, allow the use of cathodic corrosion protection. For the installation work it is not important whether the whole pipeline or only the trenchless installed section, is cathodically protected by the means of local equipment. An element of uncertainty for trenchless installations is the possible damage of the towed-in pipe section. However, unlike all other pipe materials, the welded steel pipelines combined with cathodic corrosion protection, will preserve the function and service life of the towed-in pipeline even in the case of damage such as scores in the coating.

For planning, not only tensile forces but also the bending radius of steel pipes have to be taken into account. Elastic bending radii are determined in DVGW worksheets according to each kind of application. For water and sewage pipelines this is R_{min} = 500 Diam. For gas pipelines the data in the DVGW work sheets G 462 and G 463 have to be taken into account. For an overview of these data and calculation principles refer to the DVGW work sheet GW 321.

Bending radii will influence the pipeline guiding and determine the size of the pilot bore for the towing-in process. In the case of welded pipelines, the required space for assembling the used pipe sections has to be considered. For that, the single pipe sections are usually put on rollers.

A lack of space for pipe section assembling, requires either costly single pipe welding in the pilot bore, or using axially force-locking socket pipes as commonly used for water supply systems. Depending on the tensile forces of steel pipes within the dimension range from DN 80 to DN 300, there are two different designs of socket pipes: Tyton-Sit and DKM joints (**Figure 2** and **3**).

For an overview of the maximum permissible tensile forces in accordance with the socket design refer to **Table 1**.

Sockets, unlike welded joints, may require a wider opening of the bore

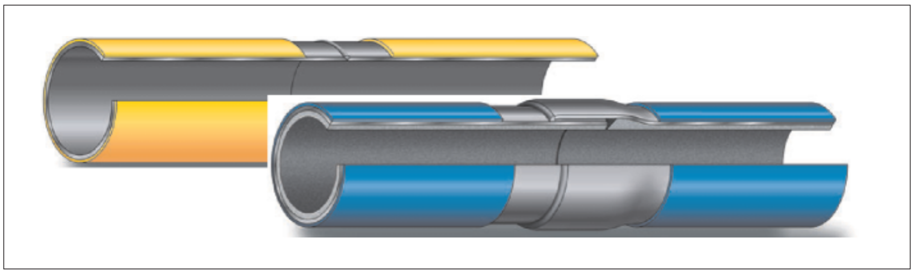

Fig. 1: Welding joints

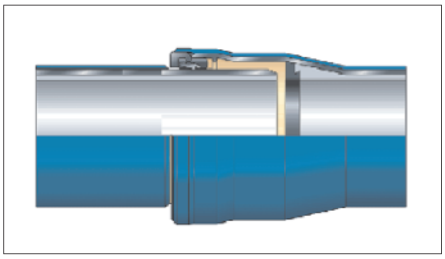

Fig. 2: Tyton-Sit socket

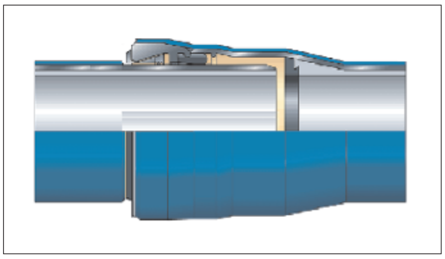

Fig. 3: DKM socket

Table 1: Permissible tensile forces (kN) and bending, dependent on socket design (pipe length 6 m)

size	Tyton-Sit		DKM	
	tensile force (KN)	bending radius (m)	tensile force (KN)	bending radius
DN 100	23	115	50	115
DN 150	48	115	100	115
DN 200			170	115
DN 250			260	115
DN 300			370	115

tunnel as well as higher tensile forces due to the socket design. Incoming material can block the sockets in the bore tunnel. Sockets, unlike welding joints, can suffer a failure of axially force-locking at excessive tensile forces. Usually, the first joint behind the tow-head collapses due to extremely tight steel pipe tolerances, as this is where the friction and weight forces, occurring on all single pipe lengths, are greatest. Therefore, especially for flush drilling procedures, it is recommended to install a sealed unit behind the first socket joint, particularly for drinking water pipelines. Thus, a pollution of the cement mortar lining by incoming drilling suspension can be avoided. In the case 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.

Coatings

Standard coating for steel pipes is made of a three-layer polyethylene system according to DIN 30670. Alternatively, a polypropylene coating in compliance with DIN 30678 can be used. For particularly demanding and difficult installations, an FCM coating according to DVWG worksheet GW 340 can be additionally applied to the plastic coating (**Figure 4**).

The three-layer polyethylene coating acc. to DIN 30670 consists of an epoxy resin primer, an adhesive and the plastic coating made of polyethylene. Standard coatings can be used for operating temperatures up to 50 °C, and a special 'S' coating for temperatures up to 70 °C. The standard layer thickness (n) depends on the pipe size, and ranges from 1.8 mm

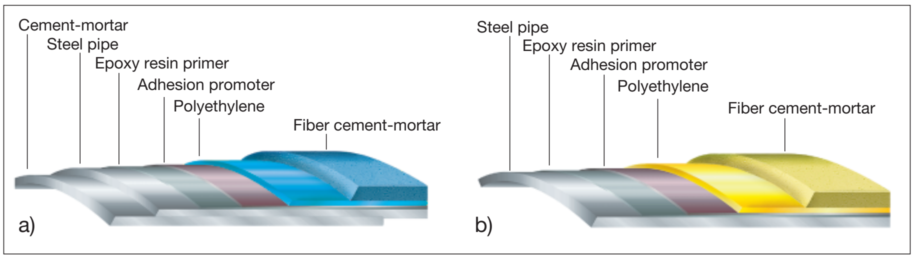

Fig. 4: Layer structure of water (a) and gas (b) pipe

Tab. 2: Standard layer thickness of polyethylene and polypropylene coating

polyethylene coating according to DIN 30670		polypropylene coating according to DIN 30678		
Size	layer thickness (n)	layer thickness (v)	size	Layer thickness
up to DN 100	1.8 mm	2.5 mm	up to DN 100	1.8 mm
over DN 100 to DN 250	2.0 mm	2.7 mm	DN 125 to DN 250	2.0 mm
over DN 250 to below DN 500	2.2 mm	2.9 mm	DN 300 to DN 500	2.2 mm
from DN 500 to below DN 800	2.5 mm	3.2 mm	from DN 600	2.5 mm
from DN 800	3.0 mm	3.7 mm		

Fig. 6: Rheinberg, DN 100 (1990)

to 3.0 mm (**Table 2**). The enforced layer thickness (v) is about 0.7 mm, and if required an increased layer thickness is possible.

Polypropylene coating is produced acc. to DIN 30678 and is of a similar design to the polyethylene coating, but offers a higher mechanical resistance. Curent raw material will allow the use of the coating for operating temperatures of up to 100 °C while the layer thickness depends, (like the polyethylene coating) on the pipe size (Table 2).

FCM coating according to DVGW worksheet GW 340 was originally developed in order to dispense with the sand-cushioning usually used with conventional pipe installation in stony and rocky ground. The compressive strength and impact resistance especially, are many times over the values for plastic coatings. Special coating types were developed later, allowing the use for trenchless laying. Pipe towing can cause high shear loads due to jacket friction, which have to be transmitted from the coating to the pipe.

On-site treatment of joint areas

All pipe joints need corrosion protection and, if required, a mechanical protection in the joint areas before pipes are towed into the ground. Generally, field coating with corrosion protection tapes or thermo-shrinking materials according to DIN 30672 can be used for all polyethylene coatings. Alternatively or rather additionally, there are products such as Canusa TBK (Thrust Bore Kits) GRP or Duroplast filler, which are specially designed for trenchless pipe laying with its higher mechanical stress during the pulling of the pipes.

Fig. 5: Field coating of FZM coating with casting mortar

Polypropylene requires GRP or filler because of their higher adherence which is better than that of common field coating materials according to DIN 30672. Completion of the pipe joint area is done by using the FCM coating along with the common corrosion protection systems according to DIN 30672. As the cast mortar coating (FCM) should have a minimum thickness of 7 mm, the difference can be completed by an easy-to-use casting mortar (**Figure 5**). GRP or Duromer systems can also be used, these systems are much more expensive and not so easy-to-use but reach their full hardness after much shorter curing times.

Trenchless installation of steel line pipes

Starting with shrouder pipe thrusting as used for example for railroad-crossings, the controlled horizontal drilling procedures became more and more important at the end of the 80s, especially for special construction projects such as river-crossing. Development started with pipes of wide diameters and continued with smaller pipe sizes used for gas and water supply. Scholz, at a seminar on controlled horizontal drilling at the Institute for Sewerage Systems at the Bochum Ruhr University on 24 September 1996, reported on a river crossing implemented by using controlled horizontal drilling [4]. This overview started with the river crossing of the Danube in 1990 over a length of 550 m and with a pipe diameter DN 800. Further examples followed in the period up to 1996 with dimensions of up to DN 1200 and installation lengths of up to 1160 m (**Table 3**)

Development in the area of smaller pipe sizes went much slower. The first installation with a polyethylene coated steel line pipe with cement mortar coat was documented at the NGW Rheinberg in 1990 (**Figure 6**).

It is a gas line DN 100, which was towed in under a parking lot and a Federal road, over a length of 130 m. This installation was the state-of-the-art for this size range at that time. Referring to this project, Bayer reported in an article about the principles of the controlled horizontal drilling procedures in the 3R international 1991 on installation possibilities for the utility service [5]: "By means of the controlled horizontal drilling procedure, the following products can be installed underground: ... 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 starting

Tab. 3: River crossing with Ruhrgas involved from 1990 to 1996 [4]

Year of construction	river / channel	length (m)	Diameter DN	nominal pressure (bar)
1990/91	Danube Lech	550 380	800 800	80 80
1993	Elbe Havel 2 channels	680 480 400	1100 1100 1100	84 84 84
1994	Ems	550	1200	84
1995	Isar	1160	900	80
1996	North-Baltic Sea Channel	550	700	84

Fig. 7: Wesenberg, DN 300 (1996)

pits. (Steel pipelines with a diameter of up to DN 100 are much easier to install.)"

In 1996, on behalf of the Saarferngas, a 368 m DN 200 high pressure gas pipleine was drilled under the Moselle. Ground conditions were completely different to the soft ground required only a few years ago. Under the Moselle, 80 m of very hard quartzit had to be drilled through [6].

In the same year, a 576 m DN 300 polypropylene coated steel pipeline was drilled for the first time for VNG Leipzig in Wesenberg (**Figure 7**).

Further stages of development were the first trenchless installation of socket pipes in Offenbach in 1997 using the Tyton-Sit-connection and the pulling of socket pipes with DKM-connection with the dimension DN 200 on behalf of Hamburg Waterworks in 2000.

Controlled horizontal drilling procedure could gain acceptance in the field of special construction projects such as river-crossings, running under buildings, traffic routes and nature reserves, as well as in local service areas. However, installing pipes in the open field is currently uneconomical. In such cases, the ploughing procedure has been established according to ground conditions especially in the dimension range up to DN 300.

Using the rocket plough (developed and patented by Föckersberger Company), the pipe is directly mounted onto the extending piece (rocket) and pulled in the cavity made by the rocket (**Figure 8**).

The extending piece is able to make cavities up to 500 mm diameter and to pull in pipes up to DN 250 (even wider 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. Exactness of the position can be adjusted and checked by means of a panoramic laser device.

With the rocket plough, the pre-extended pipe string is arranged behind the entering shaft towed by the traction unit. In the case of uncertain ground conditions it might be sensible to use an additional pipe with fibrous cement mortar coating (FCM). It is possible to check the arising tensile forces on the pipe string. Inserting a Bentonite-suspension can reduce friction forces and consequently the required tractive power. Within the framework of a pilot scheme, the maximum arising tractive powers for pulling in a steel pipe were determined. It was a cement-mortar coated design with the dimension DN 200 which was pulled in without Bentonite-suspension. The measuring and evaluating of the results was carried out by the Institute for Water Nature at the Army University Munich (Institut für Wasserwesen der Universität der Bundeswehr München).

In Münchaurach there was mainly a silty, slightly-clay like soft sand, stiff in some places with a semi-solid consistency. Due to the semi firm sandstone, the soil could be displaced only with medium to large difficulties. In order to determine the tensile force, the pre-assembled steel pipe string was mounted on a tension/pressure cylinder. A transducer transformed the transferred hydraulic pressure in an electric signal which was recorded and saved by a data logger with a sampling interval of one second. Simultaneously with the tensile force recording, the distance was recorded by means of a contact, measuring at the front wheel of the plough.

At the pulling of the pipe string a tensile force of 80 kN was reached. Considering that for example with steel grade St 52.0, a permissible tensile force of approx. 570 kN is possible, it shows that it is not the pipe length, but the towing capacity of the winch, which limits the possible pipe length for the pulling-in installation.

Fig. 8: Münchaurach, DN 200 (2001)

Concluding remark

Suitability of pipe systems mainly depend on the mechanical load-carrying capacity of the pipes and their coating respectively. Due to their suitability for welding and their mechanical strength, steel pipes allow very high tensile forces. So they can be used for all types of trenchless installation. In every individual case, wall thickness and steel quality can be adjusted to the relevant pipe load. The protection effect of the coating is as important as the mechanical strength of the pipe. After the pulling-in procedure, the corrosion protection coating has to be in a proper condition without any defects. This can only be guaranteed if the outer pipe protection is also adjusted to the existing ground conditions. Worksheet GW 321 "Controlled, horizontal drilling procedures for gas and water pipelines" gives information about the steel pipe designs, the permissible tensile forces and bending radii.

References

[1] DVGW-information: Controlled, trenchless pipe installation procedures, gas/water information no 7, 11/94 publ. DVGW, Eschborn, Nov. 1994

[2] Kiesselbach, G.: Trenchless pipeline installation compared to conventional installation under the geo-mechanical and pipe-technological aspect

[3] Busch, C; Kathage, A.F.: The technology of georadar: state of development and usage, gwf gas - natural gas, 137 (1996) 584-590

[4] Scholz, H: River-crossing, lecture on the seminar "horizontal flash drilling procedure", Institute for sewer technology at the Ruhr University Bochum

[5] Bayer, H.J.: The principle of controlled, horizontal flush drilling, 3R international, 30 (1991) 511-517

[6] Kocks, H.J.; Joens, H.; Reekers, C.: Fibrous cement mortar coating - a mechanical protection for plastic coated steel line pipes, bbr, 48 (1997) H. 8 S. 32–38