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New trenchless technology for small diameters and long drives and its use in underground cable installation

By Dr. Marc Peters and Tobias Engel, Herrenknecht AG, Schwanau-Allmannsweier, Germany

Abstract

With the new legislation for Grid Expansion in Germany passed at the end of 2015, the trenchless installation of underground cables presents a challenge for grid operators and engineers. To ensure the required connection from North to South until the year 2025, a total of 2,250km of new lines have to be installed underground, where a minimum of 10% are expected to be using trenchless technology.

With minimum disruption of surface and environment, trenchless technology complies with residents and landowners and can considerably speed up approval procedures.
Besides the proven tunnelling and pipeline methods, which are mainly used for sensitive crossings, a new technology for separate cable installation was required. The aim was to develop a highly efficient solution to compete with open-trench methods. By the help of an automated system, cables have to be installed quickly over long distances, with low investment in equipment and manpower.

Herrenknecht AG has now developed a technology which meets these requirements. It installs close parallel underground cables with minimal overburden of 1.5m over long distances. The tunnelling machine AVNS type with powerpack and slurry pump in the machine has a boring diameter of 505mm and is designed for 1,000m drive length.

These features also make the machine concept interesting for other trenchless technologies. With the use of the AVNS, longer drive lengths can be realized even in small diameter pipe jacking of 250mm upwards, depending on geology. Furthermore, this machine can also be used for Direct Pipe® and opens up the lower diameter range from 18” to 30” pipelines.

This paper presents the new technology for the trenchless installation of underground cables as well as the AVNS machine type with its use in Microtunnelling and pipeline construction.

1. Introduction

The essential aspects for large, upcoming expansion projects to be a success in Germany's extra high voltage transmission grid are: security of the power supply, giving due regard to people and the environment during construction and operation, planning the realisation time of the projects and costs of the infrastructure as effectively as possible, and making these consistent with one another.

In order to ensure this, the number of pilot plans for underground cables was increased again as of another law adopted by the Bundesrat in December, 2015. The objective of the accelerated underground installation is for higher acceptance by the population of the planned lines and expedited implementation. This change to the priority status of underground cables creates the chance to accommodate the concerns of the population and of nature protection, by completely revising line design.

Picture 1. Conventional installation of cables in open-trench, Raesfeld, Germany

Conventional installation of cables in open trenches, as in the first German pilot project by grid operator Amprion in the Raesfeld project in 2014 (see Image 1), no longer represents a comprehensive solution. However, since the cable is laid underground, the environment is extensively utilised during open installation; especially due to alignment preparation, large ground movements, lasting soil compactions, and the consequences of recultivation measures.

Only trenchless tunnelling technology can guarantee protection of the surface in such a way that the environment is taken into consideration, residents and property owners are not burdened, and the approval process can be expedited.

2. Existing technologies and their applications fields

In general, there are different trenchless installation methods which can be used to install cables or casings underground. Originally coming from pipeline construction, HDD, Direct Pipe® and Pipe Express® have to be considered. Of course, Pipe Jacking and Segment Lining, as the well-established tunnelling methods to be used according to the needed cross section and length of the installation.
Each of the existing trenchless technologies has its own areas of application. Underground conditions, as well as excavation diameter and drive length, play a role during method selection. A rough overview of the areas of use for the previously described methods is provided below (Table 1).

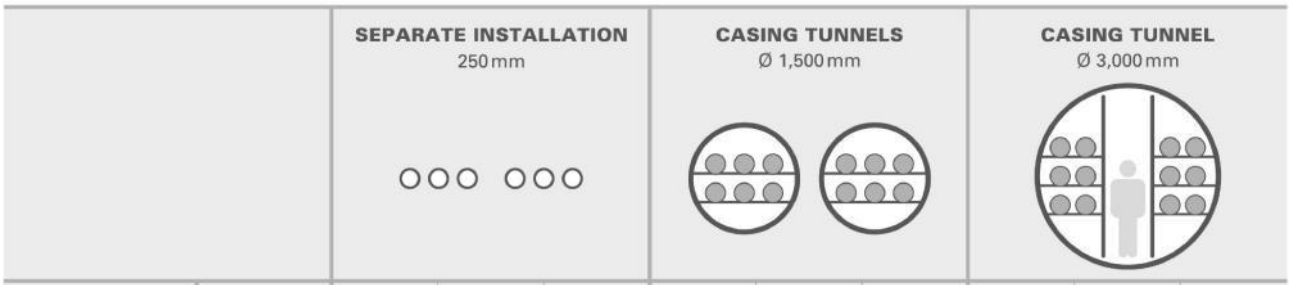
	Pipe Express® Semi-trenchless	**HDD** trenchless	**Direct Pipe®** trenchless	**Pipe Jacking** trenchless	**Segment Lining** trenchless
Diameter [mm]	ID 900-1500	ID 250-1500	ID 711-1500	ID 250-4000	ID 2300-4000
Pipe material	Steel Concrete Plastic (HDPE)	Steel Plastic (HDPE) Cast iron	Steel (Plastic)	Steel Concrete GRP/Hobas Clay pipe	Concrete segments Combisegments (incl. Inliner) Rib & Lagging
Max. drive length *dep. On Ø	40“ – 60“: 1000m	Ø bis 20“: 4km Ø bis 60“: 1,7km	Ø bis 38“: 300m Ø bis 60“: 1,4km	Ø 250mm: 100 m Ø3000mm: 1.5 km	Ø 2000mm: 2 km Ø 3000mm: 8 km
Geology	all Rock up to 100MPa	stable	all Rock up to 150MPa	all	all
Shaft building	Pit	Pit	Pit with bottom plate and sealing	Shaft with bottom plate and sealing	Shaft with bottom plate and sealing
Access	No	No	No	yes > Ø 3000 mm	yes > Ø 3000 mm

Table 1. Overview of existing tunnelling technologies

3. The New E-Power Pipe Technology

Initial Situation

While the aforementioned, established pipeline and tunnel installation methods are intended to be used predominantly in cases involving sensitive crossing, it was necessary to develop a new technology for individual installation of underground cables. The main challenge: inserting the cables into the ground at low depth and at a defined distance to extend across the longest drifts possible. The table below shows which methods can be used for which types of cable installation. This makes it clear that so far, no process has been able to meet all the requirements in the non-accessible area of individual installation.



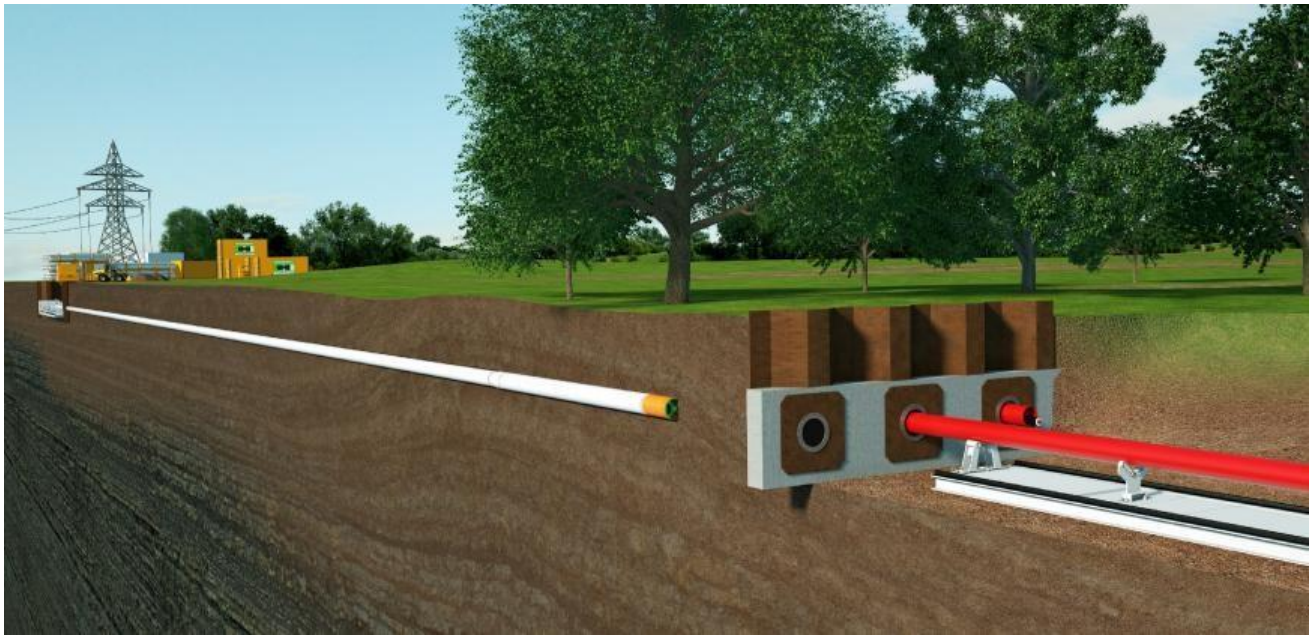
Technology:	Ø in mm	SEPARATE INSTALLATION 250 mm			CASING TUNNELS Ø 1,500 mm			CASING TUNNEL Ø 3,000 mm		
		Shallow	Accuracy	Length > 1,000 m	Shallow	Accuracy	Length > 1,000 m	Shallow	Accuracy	Length > 1,000 m
› Pipe Jacking	250-4,000	■	■		■	■	■	■	■	■
› Segmental Lining	2,300-4,000							■	■	■
› HDD	250-1,500			■			■			
› Direct Pipe®	700-1,500				■	■	■			
› Pipe Express®	900-1,500				■	■	■			
› Power Pipe	250-700	■	■	■						

Table 2. Overview of the methods that can be used for trenchless underground cable installation

Herrenknecht AG has developed a new method which fills this gap with E-Power Pipe. This allows underground cables to be installed close to the surface at a minimum overburden of only 2m across long drifts. The AVNS350XB tunnelling machine is used, which has an excavation diameter of 505mm, is dimensioned for drive lengths above 1.000m. AVNS machine technology is a new development by Herrenknecht AG. The machine can achieve considerably greater advance lengths in a small diameter range due to its use of a new power supply and the introduction of jet pump conveyance technology.

The E-Power Pipe method

The jacking frame is installed from the starting point and connected with the tunnelling machine via several thrust pipes. The tunnelling machine is pushed with thrust force in the direction of the destination point along the specified alignment. This is disassembled following the tunnelling machine's cutting action. Subsequently, the plastic guard tube is connected with the thrust pipe in the borehole and withdrawn by retracting the thrust pipes. The guard tube is mechanically and thermally connected to the floor during the insertion process while adding backfill material. This creates a connection between the cable guard tube and the ground that is free of cavities. The underground cable is inserted after the guard tubes are completely in place, and this is not a part of the process.



Picture 2. The E-Power Pipe method for trenchless installation of underground cables

The procedural components

The requirements for a new type of installation process for underground cables with a closed construction method have led to the development of several separate elements, which combine to provide an innovative and environmentally-friendly method for carefully installing underground cables.
The quantity of pipe exchanges and consequent time needed must be kept a low as possible for high tunnelling performance to be achieved. Furthermore, the thrust pipes must be joined with high tensile strength in order to safeguard insertion of the cable guard tube. These characteristics have led to the development of a new thrust pipe, which facilitates almost continuous tunnelling due to its length and significantly expedites the coupling of the water circuit with a sleeve system integrated into the pipe.

A jacking frame with 10m stroke and 350tonne thrust force has been developed specifically for this thrust pipe. The jacking force is transferred with a pressure ring which enters the thrust pipe via a locking mechanism and creates a positive connection. This connection also safeguards retraction of the thrust pipe.

The AVNS 350XB tunnelling machine is a new development that satisfies the requirements related to mandatory installation depth, drive length, and precision of the procedure. Essentially, three of the tunnelling machine's components have been newly developed from scratch for this purpose. The most important innovation is the integration of a jet pump as a slurry pump. This proprietary development from Herrenknecht AG facilitates a conveying capacity of 1000l/min while simultaneously requiring very little space. The hydraulic unit integrated in the tunnelling machine is a further unique selling point. This eliminates the coupling of hydraulic lines otherwise typical at this construction size, along with the associated losses of performance.

A measurement system ensures that the bore alignment is precisely maintained. This continually determines the position, direction, and tilt of the tunnelling machine. The measurement system aims towards a magnetic field generated on the surface level, and is thus also suitable for very long drives. The machine can be used on a spectrum of up to 30MPa during excavation of loose soils and soft rock.

4. Benefit for existing technologies

The demands and requests long existing on the market for increasingly long drives, with simultaneously smaller diameters, have now been met with the development of AVNS technology. The unique combination of power supply and conveyance technology at an excavation diameter of 505mm also increases the scope of application in pipeline construction and pipe jacking.

5. Outlook

After manufacturing is completed, the machine components are tested for operational capability on a specially setup test stand by Herrenknecht AG. The test stand allows three parallel boreholes to be launched over a length of 30 m. The arrangement of the bores corresponds exactly with the specifications for an installation under real conditions. After the test has been completed, it can be used on the jobsite for the first time in a section designated for installation of underground cables. Protection pipes for three 380 kV lines over a length of 300 m must be installed in the construction section designated for that purpose. Each boring axis has a distance of 1 m when there is an overburden of 2.5 m.

6. Literatur

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Autoren:

Dr.-Ing. Marc Peters
Herrenknecht AG, Schwanau

Tel.: +49 151 16346356
E-Mail:
peters.marc@herrenknecht.de
Internet: www. herrenknecht.com

Tobias Engel
Herrenknecht AG, Schwanau

Tel.: +49 151 14654806
E-Mail:
engel.tobias@herrenknecht.de
Internet: www.herrenknecht.com