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THE VERSATILITY OF SLURRY MICROTUNNELLING METHODS FOR PIPELINE CROSSINGS AND LANDFALLS

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1. INTRODUCTION

Safety is a paramount consideration in the construction and operation of utility networks, particularly in the context of occupational safety and environmental protection. This becomes even more crucial in sensitive areas such as nature reserves and coastal areas, but also when water bodies and transportation routes have to be crossed. Beneath roadways and railway lines, settlement issues must be strictly avoided to ensure the integrity of the infrastructure above. In such scenarios, slurry microtunnelling methods can assure this high level of safety as excavation of the borehole and installation of the jacking or product pipes takes place at the same time, avoiding settlement risk by continuous mechanical borehole support. Successfully executed projects, with low risk and the least possible impact on environment and surroundings help the public to gain trust and acceptance of necessary installations and to convince planning authorities of the opportunities and the benefits of trenchless technologies

2. SLURRY MICROTUNNELLING METHODS

Since the early 1980s, slurry microtunnelling has established itself, initially in trenchless construction as pipe jacking using reinforced concrete pipes. Numerous projects worldwide and the broad range of applications in pipe jacking, along with the achieved records in large-diameter and long-distance drives, attest to its success. Predominantly, microtunnel boring machines (MTBMs) with slurry conveyance are used in these applications. The explanation of the AVN technology (AVN = "Automatischer Vortrieb Nass") with its extensive geological application spectrum, tailored cutterhead designs and hard rock concepts, further underscores its significance. Thus, slurry microtunnelling methods boast the widest range of applications, in terms of pipe material, ground conditions, diameter, installation length and depth.

	PIPE JACKING	DIRECT PIPE®	E-POWER PIPE®
MTBM	**AVN or AVNS** with jet pump		
BOREHOLE SUPPORT	**Mechanical borehole support** over the entire installation process		
PIPE MATERIAL	**Pressure resistant** typically reinforced concrete pipes	**Pressure resistant** typically prefabricated steel pipeline	**All** Pullin of product pipe in second step
PIPE DIAMETER	**250 – 4,000 mm** Ø Tunnel (ID)	**600 – 1,500 mm**	**250 – 700 mm** > 400 mm with backreaming MTBM
MAX. INSTALLATION LENGTH	**~ 2,000 m** *Depending on project-specific conditions*		

Figure 1. Overview of slurry microtunnelling methods with application range

MTBMs with slurry conveyance are nowadays employed in various microtunnelling processes, not only in the classic pipe jacking of concrete pipes but also in the installation of steel pipes, pipelines, and non-pressure-resistant HDPE protective pipes. In response to the requirements of pipeline construction and underground cable installations, Direct Pipe and E-Power Pipe have been developed based on microtunnelling techniques. These methods, by definition, create the borehole in a single step and utilize a MTBM with slurry conveyance, providing continuous mechanical support of the borehole.

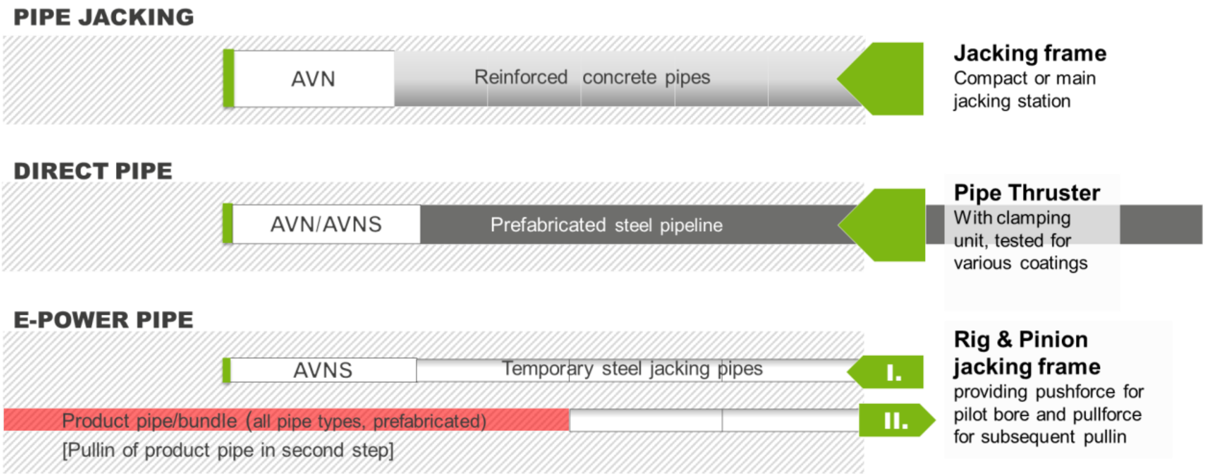

Figure 2. Working principle of slurry microtunnelling methods with continuous borehole support

2.1 Alternative to HDD

In highly permeable ground conditions, where HDD is risky or even not applicable, slurry microtunnelling methods represent a safe alternative. The choice of the best-suited method depends on diameter, installation length and depth and the final type of pipe or pipeline to be installed. Excavation of the finally required borehole diameter takes place in one single step, the borehole is continuously supported by the product pipes (Pipe Jacking or Direct Pipe) or temporary steel jacking pipes (E-Power Pipe), with almost no fracturing risk. This remains the major benefit of slurry microtunnelling methods, taking into account, that safety and environmental protection are of growing concern in the industry.
In Slurry MTBM-based trenchless technologies, the new AVNS slurry machine concept with jet pump presents a milestone pushing the boundaries towards the feasibility for longer drives in the small-diameter pipeline range.

2.2 The jet pump in slurry MTBMS

A crucial aspect is the installation of pipes in small diameters over long distances. To address this, the concept of the jet pump has been developed and integrated into the AVN concept, creating the AVNS machine range (S for Strahlpumpe, the German word for jet pump). Drive lengths have been limited in the past due to the size of powerful centrifugal slurry pumps, which are too large to fit in small diameter pipes. The jet pump concept, which had been successfully used in HDD operations before, has been transferred to slurry microtunnelling machines. As a single slurry pump, the jet pump is integrated into the MTBM and enables a high conveying capacity simultaneously requiring very little space. Due to its compact size, it can be installed in slurry machines from approximately 20 inches and larger, resulting in drive lengths of up to currently 2,000 m.

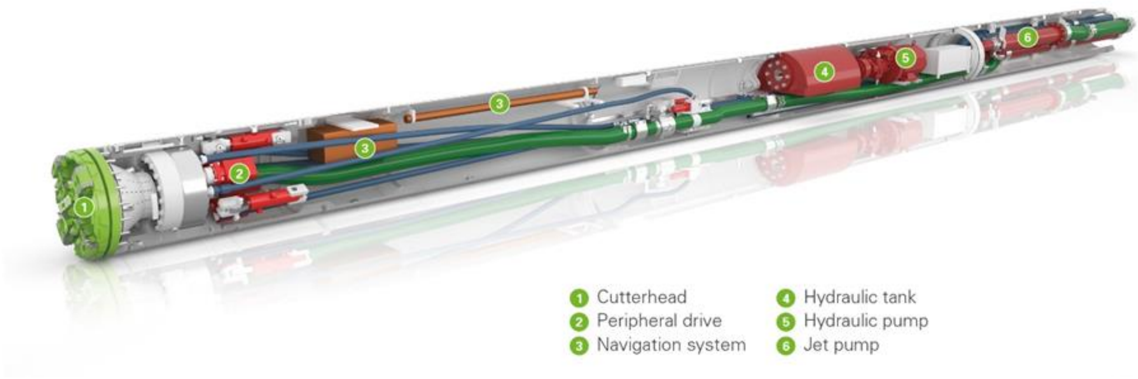

Figure 3. General jet pump principle, exemplary integration in AVNS 350 XB

3 THE E-POWER PIPE METHOD

In addition to proven trenchless installation technologies from the tunnelling and the pipeline industry, Herrenknecht has further developed slurry microtunnelling to the two-phase E-Power Pipe technology. It is used to install non-pressure-resistant HDPE pipes as cable protective pipes, or small-diameter pipelines of 10" to 28" diameter underground, wherever conventional methods, like HDD, reach their economic and technical limits. Originally, it has been designed for crossings in difficult, non-stable ground conditions or drilling with low ground cover, over long distances of up to 2,000 meters. The broad spectrum of applications ranges from the installation of cable protection pipes for underground cables and bundles to pipelines for gas supply, district heating or the transport of hydrogen.

In the first step, the AVNS Slurry MTBM and the reusable, temporary steel jacking pipes are pushed through the ground along the specified alignment by a Rack & Pinion jacking frame installed in the launch shaft.

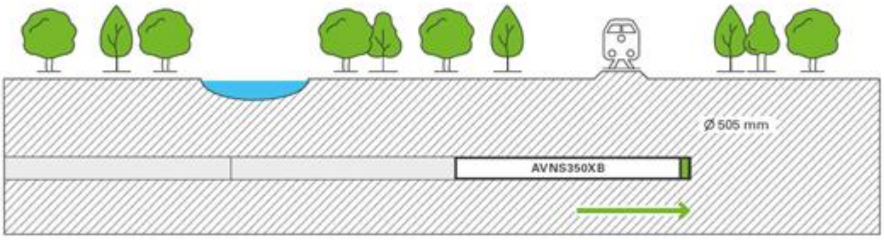

Figure 4. E-Power Pipe Step 1: Pilot bore with temporary steel jacking pipes

After breakthrough at the target point, the MTBM is separated from the pipe string and a pullhead is then attached instead. The prefabricated product pipe lying ready for installation is then connected. Whilst the temporary jacking pipes are pulled back by the jacking frame, the product pipe is also successively pulled in. The borehole thus remains mechanically supported the entire time. During insertion, the product pipe can be embedded into the ground with the addition of backfill material. The overcut can be grouted at the same time with a self-hardening grout (e.g. cement-based) if required.

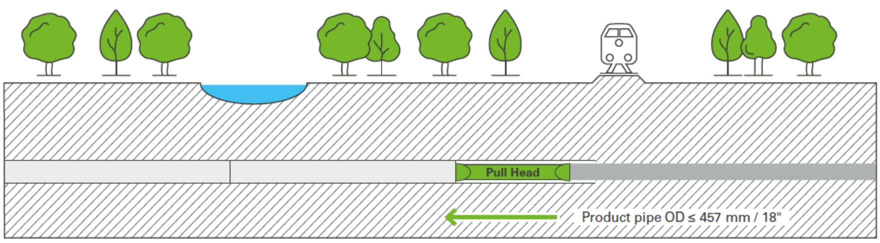

Figure 5. E-Power Pipe Step 2: Pullin of the (prefabricated) product pipe

Minimal earthmoving, no heavy equipment between launch and target pits, thus less noise and exhaust emissions, with less impact on the surface are the main benefits of the E-Power Pipe method – in comparison to open cut installation of the pipes or cables. These are of special interest when concerns of landowners and environmental protection play a key role for the project to be realized. Compared to HDD, E-Power Pipe can work in shallow depths, with high precision and in a wide range of ground conditions.

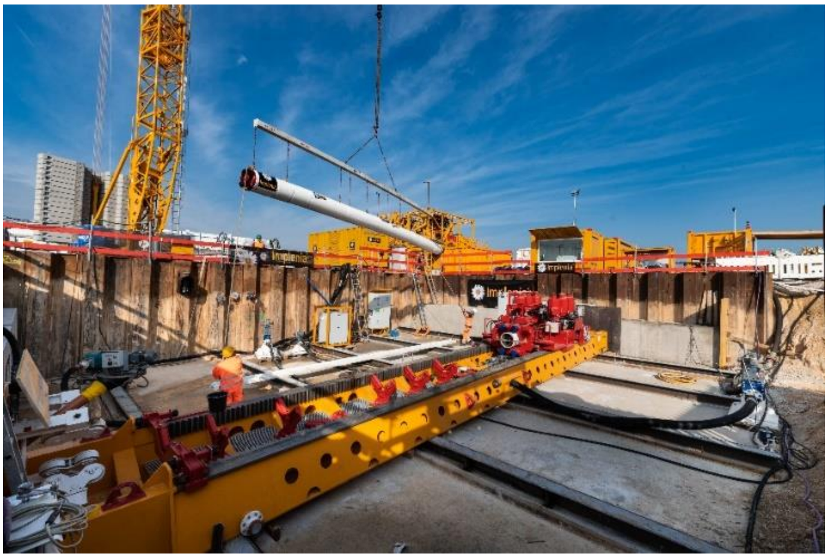

Figure 6. AVNS350XB Slurry MTBM in operation on E-Power Pipe Project in Germany

To date, several projects have been executed with E-Power Pipe with an overall total length of 12.7 km. The world record length has been achieved in the Netherlands in January 2022, where a bundle of cable casings has been installed with E-Power Pipe on an outstanding length of 2 km.
By mid of 2025, a complete set of E-Power Pipe equipment will be in operation for Heitkamp Construction Swiss to install cable protection pipes in various construction lots of the SuedLink project in Germany.

4 THE DIRECT PIPE METHOD

For nearly 20 years, the Direct Pipe method developed by Herrenknecht has been used globally for the trenchless installation of prefabricated steel pipelines, in more than 250 pipeline crossings and landfall projects. It combines the advantages of slurry microtunnelling with the Pipe Thruster technology to enable trenchless installation of pipelines or casings in difficult ground conditions while reducing the risks typically associated with HDD. Direct Pipe allows excavating the borehole while simultaneously installing a prefabricated and already tested pipeline in one single continuous step. Typically, Direct Pipe is used to safely cross rivers or waterways, infrastructure objects, and other man-made or natural obstacles, but also to cross shorelines and beaches on landfalls, outfalls, and shore approaches.

Figure 7. Functional principle of Direct Pipe for one-step pipeline installation

Thanks to further technical development and growing popularity among clients and contractors, the range of applications for Direct Pipe has steadily been expanded over the years. Today, Direct Pipe is also increasingly used for marine landfalls and/or outfalls, for pipeline or export cable landfalls of offshore wind farms. For these shore approaches, the Direct Pipe MTBM can (at least partly) be disconnected remotely from the pipe string at its target point on the seabed and then be recovered.

Figure 8. 3x Direct Pipe 42 inch equipment with jet pump in operation on Coastal Virginia Offshore Wind Project, for 9 export cable landfall drives (Michels Trenchless Inc., USA)

New developments in technology, such as the jet pump and the respective machine design, now make it possible to use Direct Pipe even for small diameters starting at 24". Thus, the AVNS machine concept has recently been integrated in the Direct Pipe technology to enable one-pass installation for longer crossings, in particular in diameters smaller than 36 inches. At the same time, the method has also evolved in terms of installation length and diameter. In New Zealand, in 2020 the world record was set with the installation of a 2,021 m long 48" treated-water pipeline into the open sea, after successfully completing a 1,930m long outfall two years earlier.

5 THE CONVENTIONAL PIPE JACKING METHOD

Conventional pipe jacking, mainly using reinforced concrete pipes, has a long tradition. In the 1980s, it was primarily used for constructing sewer and water tunnels to improve the supply and infrastructure of growing cities. Today, the technology is employed whenever obstacles along the route need to be safely underpassed. Its applications now range from small-diameter sewer pipes to larger, accessible tunnels that can accommodate cables, pipelines, or district heating pipes.
The majority of pipe jacking projects use Slurry MTBMs, which have the widest range of geological applications. A jacking frame is installed in the launch shaft. Its hydraulic cylinders are used to push the MTBM and the jacking pipes through the ground to a target shaft. The remote-controlled MTBM excavates the soil at the tunnel face. No staff has to work in the tunnel during construction. The position of the MTBM is supervised by a guidance system. With smart lubrication of the pipe string (e.g. by a volume-controlled bentonite lubrication system), and the use of interjacking stations, friction forces along the tunnel and respective jacking loads of the jacking frame in the launch shaft can be considerably reduced. Thus, large-diameter and long-distance drives of more than 1.5 km can be realized, depending on diameter and specific project and ground conditions.

Figure 9. Pipe Jacking key equipment components with AVN MTBM.

6 COMPLEMENT TO HDD – RETRACTABLE SLURRY MTBMS

A detailed geotechnical investigation of the soil along the drilling route is crucial in planning HDD (Horizontal Directional Drilling) projects. While soil types like clay, silt, sand, or rock are not an obstacle for the method, precautions must be taken in unstable ground such as gravel. Crossing natural watercourses typically presents the greatest geotechnical challenges for HDD. Unlike structures like roads, which usually involve obstacles in relatively homogeneous ground, the soil beneath and around a larger watercourse is often very heterogeneous and difficult to model. Various grain sizes (blocks, gravel, sand, silt, clay, and their mixtures) can alternate over short distances, making the ground beneath a river subject to significant changes.
To minimize construction difficulties as much as possible, it is necessary to thoroughly understand the locations of all difficult soils. Surprisingly, the most challenging are not usually the hardest formations, but rather the highly unstable rock layers that make creating a stable borehole difficult. These typically include uniformly graded, coarser sands and gravels with very few fine particles and loose packing density. Particularly challenging are so-called "rolling gravel layers," which have large pore volumes and very low internal friction. Additionally, very soft to slurry-like silts or clays can lead to unstable boreholes.

6.1 Construction of a steel casing for HDD

To drill through difficult layers, temporary protective casings can be installed for subsequent HDD drilling, ending in the stable layer below. Temporary protective casings have long been a standard in HDD installation techniques. Low cover in the starting area, ground permeability, and lack of stability can necessitate this special solution. A protective casing is installed in the sensitive area, typically designed to accommodate both the product pipe and all drilling tools. Such a steel casing can be installed using a retractable Slurry MTBM. Since the drilling ends in the deeper stable layer where retrieval of the jacking machine is not possible, the machine is designed to be retracted through the installed steel casing back to the launch shaft.

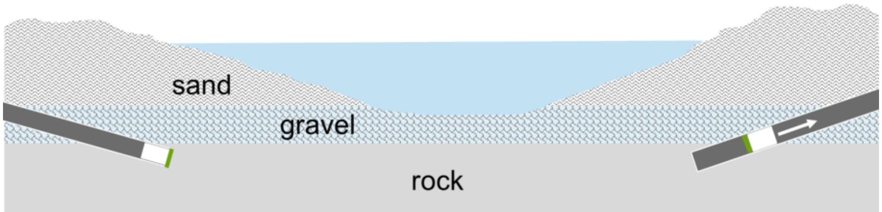

Figure 10. Principle of retractable MTBM used for HDD casing installation

In addition to a foldable cutting wheel, the retractable MTBM is equipped with an additional extension shield, which can remain in the ground as part of the protective casing after the machine is retracted. A major advantage is the controlled jacking process, which allows the protective casing to be laid either in a curve or securely straight. With this retractable technique, protective casings longer than 200 meters can be installed.

Figure 11. Retractable Direct Pipe MTBM used for New Jersey Expansion Project, USA, for 48“ HDD casing of 85m length

7 CONCLUSION

For more than 40 years, slurry microtunnelling has been in worldwide operation to install utility lines and networks underground. In recent years, slurry microtunnelling has witnessed significant advancements, driven by the increasing recognition that in many locations open-cut installation frequently is not reasonable or even not feasible, and widespread HDD is not applicable in any condition.

In urban settings, for river crossings or coastal landfall projects, slurry microtunnelling often becomes the only viable option. The constant escalation of project requirements has led to continuous advancements in trenchless techniques, drawing from experiences in tunnel and pipeline construction. Today, a wide range of technical solutions and combined approaches make construction planning more flexible and execution more effective, catering to almost every conceivable requirement – whether it comes to diameter, installation depth, ground conditions, groundwater considerations, or long-distance installations.

To enhance the feasibility of pipeline and underground cable projects, planners must incorporate all relevant conditions during the planning phase, possessing a comprehensive understanding of the diverse technical implementation possibilities. This approach ensures the identification of methods or solutions that best align with technical, economic and environmental parameters.

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Erick Strauss was born in 1978 in Caracas, Venezuela. After his degree in Mechanical Engineering in 2003 at the University Simon Bolivar in Venezuela, he started working for Inversiones JPK as a Field Engineer for drilling and maintenance of deep-water wells until 2012. In 2014, he graduated with a master's degree in Energy Conversion and Management at the University of Applied Sciences in Offenburg, Germany, and joined Herrenknecht as a sales support engineer in the Business Unit Utility Tunnelling. After several years as Product Manager for segment lining machines. Since 2023, he is responsible for the sales in Italy and Mexico for the Utility Tunnelling portfolio, ranging from tunnelling and pipeline equipment to shaft drilling machines.