TRENCHLESS SOLUTIONS FOR SEWER NETWORKS AND SEA OUTFALLS.

Author: Frank B. Stevens  Pr. Eng, BSc (Civil), HonFIMESA, FSAICE
Technical Representative for Herrenknecht AG (Utility Tunnelling).

stevens.frank@herrenknecht.de

ABSTRACT:

Services laid underground are indispensable for the supply of water and sanitation services especially for a growing urban population. A major challenge for many cities in South Africa is to build functioning sewage systems which serve individual households and industry as well as ensuring that final effluents are discharged to rivers and the ocean in a sustainable manner and which, at the same time, preserves the environment as required by the Water Act.

Trenchless technology offers various economical and ecological benefits when such systems are installed underground. This paper shows different trenchless installation methods and highlights how trenchless methods are used for state-of-the-art projects such as sewers, sea outfalls and sea intakes. Due to the looming water shortage facing Southern Africa desalination plants are set to become more relevant. Selected case studies both locally and internationally will give insight into the challenges and successes factors in such projects. Whilst the use of trenchless technology is still in it’s infancy in South Africa (compared to Europe say) there are a number of projects being planned where its use could be advantageous and prove to give the optimal solution.

INTRODUCTION:

Whilst it is intended, throughout this paper, to emphasize the benefits and methods used for trenchless technology it is also important to point out the importance of making the correct decisions and choices before the commencement of the project. It will also be of value to give a brief description of the different types of machine available together with its method of operation. The body of the paper will be as per the following headings:

1) The benefits of using Trenchless Technology.
2) Issues that have to be considered prior to commencing the trenchless option.
3) A brief description of three Machine types.
4) Some commonly asked questions.
5) Examples, both national and international, of the use of Trenchless Technology.

1) The benefits of using Trenchless Technology:

Minimal impact to the environment: no harm to marine wildlife, sea or river water quality is untouched, emissions and vibrations are considerably reduced.

Minimal impact to the existing infrastructure: Trenchless Technology can be applied to in densely populated areas, a small job-site is needed, there is less impact to existing services.

Reduction in construction time: the project is not affected by inclement weather and storms.
Damage by tides and currents: not a problem as outfall usually well below the sea-bed.

2) Issues: that have to be considered prior to choosing Trenchless:

The Following issues have an essential influence on the type of machine chosen and the technology to be adopted:

- Soil conditions
- Accuracy of geotechnical report
- Ground water conditions
- Machine Selection
- Drive length
- Diameter of the pipes which has to be installed
- Client / engineer efficiency and responsiveness
- Contractors experience and efficiency
- Site organization / logistic
- Experience of the MT crew
- Quality of shafts
- Quality of jacking pipes

(More background on the importance of soil conditions and the importance of accurate geotechnical information follows).

**Soil and Rock Conditions:**

Recommended measurable properties / tests in **LOOSE SOIL** (e.g. gravel, sand, silt, clay and mixtures thereof)

- **Grain size** distribution can be identified by sieving (coarse) and settling (fine)
- **Compactness** of the packing (granular soil) can be determined by SPT (standard penetration test)
- **Consistency** (in cohesive soils) can be determined by SPT (standard penetration test)
- “**Atterberg Limits**” - accurate measurement of the consistency in the laboratory
Recommended measurable properties / tests in **HARD ROCK** (e.g. sandstone, granite, mudstone, limestone, basalt, gneiss, …)

- **Compressive strength** can be determined in laboratory tests as much samples as possible.
- **Tensile strength** can be determined in laboratory tests (as much samples as possible)
- **R.Q.D.** index is obtained by visual examination of cored rock samples.

**3) A brief description of tunneling machine types available:**

Generally tunnels having a diameter of less than 4.2 m are considered to be “**Utility Tunnels**” (most municipal service delivery tunnels fall into this category) and tunnels with a diameter greater than 4.2 m are known as “**Traffic Tunnels**”. Diagram 1 below shows the diameters which can be handled by various machine types.

![Diagram 1. Various Tunnelling Machines available.](image)

A brief description of four of the above machines will illustrate how each has been developed for specific and unique situations.
3.1) **AVN or Slurry Machine.**

Diagram 2. AVN Machine.

An AVN Machine

- Can handle all types of geology (soft ground, heterogeneous ground and rock).
- Diameters range from 0,4m to 4,2m.
- Tunnel face support using slurry suspension.
- Thrust achieved by hydraulic cylinders.
- Tunnel lining pipe jacking or segmental lining.
- A cone-shaped crusher handles stones and rocks.

Advantages: usable in most ground conditions with high ground water pressures. High safety record and can handle vertical and horizontal curves. Long pipe jacking stretches more than 1 000m.

Uses a universal navigation system which allows for exact positioning.

More than 950 AVN machines have been used successfully world-wide and an AVN machine was used in Durban recently for the Point Road micro-tunnel.

3.2) **HDD (Horizontal Directional Drilling Rig):**

Diagram 3. HDD Rig.
• Excavation method: a drill bit excavates the soil in a pilot hole, subsequently a reamer widens the borehole.
• Can handle soft ground and rock.
• Diameters range from 0.2 m to 2.0 m.
• Bentonite suspension used for hydraulic support.
• The carriage thrusts the rotating drill rods forward and pulls them back during reaming.
• Tunnel lining is the pipeline.
• Advantages: economic and environmentally-friendly method for installing pipelines. By using a Pipe Thruster the thrust and pull forces can be increased by up to an additional 750 t.
• The excavated material is mixed with the bentonite and is transported via an annular gap between drill rods and the borehole wall.
• The final borehole diameter is achieved by reaming.
• The world record for an HDD borehole is 1,705 m in length with a diameter of 1.8 m.

General HDD Function Principle:

In the HDD method, pipelines are laid in three stages. First, a pilot drill is carried out from the launch point, using rotating drilling rods. The excavated material is transported to the surface by the drilling fluid which also gives the chisel extra drive.

In the second phase, the retraction of the drilling pipeline, the excavating diameter is gradually enlarged with a reamer. In most cases, the borehole is supported by a bentonite suspension which at the same time serves as the transport medium for the excavated material.

Finally, the pipeline is installed by pullback of the pipeline. This method is suitable for diameters of up to 1.5 m and for lengths of up to around 3,000 meters, depending on the diameter. Drilling in less stable geologies, such as gravel, is not always possible because, unlike in the pipe jacking or segmental lining methods, the drill hole is not immediately stabilized.

HDD application for landfall - shore approach

Horizontal Directional Drilling method is applied for seawater intakes, outfall lines and landfalls for oil, gas or telecommunication pipelines. There are several options regarding construction method and drilling direction depending on diameter and length of pipeline and geological conditions.

Horizontal Directional Drilling can be considered as a very flexible construction method for connection lines between land and the sea bed. The HDD-Rig can be positioned on the onshore jobsite or offshore on a barge, a jack-up platform or cofferdam. To increase flexibility, a Pipe Thruster can be used to generate additional thrust force to push longer or larger pipes. According to the circumstances onsite, the pipeline can be prepared onshore or floating on the water. The final design of a landfall installed by HDD depends on the project requirements and conditions.
3.3) **Direct Pipe.**

Diagram 4. Typical Sea-Outfall HDD process.

• Handles all types of geology.
• Diameters range from 0.8m to 1.5m.
• Excavation by AVN machine and pipeline installation carried out in one step.
• Hydraulic support by using slurry suspension.
• A pipe thruster advances the machine through the pipeline with thrust forces of up to 750 tonnes.
• Advantages: the borehole is created and the pipeline inserted in one continuous step. Very high installation speeds. Precise steering possible on upward and downward slopes and in curves.
• Longest drive to date 1,400m.

4) Some commonly asked questions.

4.1) How is the machine recovered after completing a sea outfall project?

After exposing the machine below the sea-bed lifting equipment is attached to the machine (Diagram 6). Once the equipment has been removed from the tunnel the bulkhead is closed and hydraulic cylinders are used to release the machine from the pipe-string. Final lifting of the machine to the surface is carried out by a barge (Diagram 7) or by using airbags (Diagram 8).

4.2) Which factors are important at tendering stage?

• Allow sufficient preparation time.
• Tender according to current standards and legislation.
• Every project is unique – adjust machine technology according to the geological and hydrological conditions.
• Clearly define internal diameter and drive lengths.
• Accurately document existing lines.
• Ensure that the work is undertaken by experienced contractors.

5) Examples of where trenchless technology has been used successfully.

A small sample of typical tunnelling projects which employed trenchless technology includes:

• The Durban’s Mahatma Gandhi Road Micro Tunnel – sewer 1.35m diam; 225m long using an AVN machine.
• Main Reef Road Johannesburg – sewer using an auger boring machine.
• Rysumen Nachen, Emden, Germany – sewer 1.2m diam; 238 m long using an AVN machine.
• Durban Harbour Sub-Aqueous tunnel – sewer 5.15m diam; 492m long using a TBM.

Conclusion:

From the above trenchless technology clearly offers many advantages over conventional open trench installation of services. By using the correct tunnelling methods and machines will ensure a safe, timeous and cost effective end result. The choice of the correct technology depends on the geological and operational requirements together with time-frames and cost targets.

Recommendations:

The benefits of using of Trenchless Technology in South Africa is not yet fully understood and appreciated and consultants and contractors are encouraged to consider this technology as a viable option for sewer and sea outfall projects.

References:

1. “Mahatma Gandhi Road sewer micro tunnel” Authors: Frank Stevens and Montso Lebitsa.
2. “Installation of shore approaches and sea lines with trenchless method technologies and case studies” Author: Lutz zur Linde.
3. “Pipeline equipment- Mexico PEMEX” Author: Swen Weiner.