GSTT

Information

No. 24

Initiative for alternative installation methods in pipeline construction
Trenchless – cost saving - safe

November 2010

AK 12 Safe construction methods and pipeline systems

NO DIG – why dig up trenches when there are better solutions!!

Initiative for alternative installation methods in pipeline construction – trenchless – cost saving - safe

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C O N T E N T S

1. Introduction

When building an underground infrastructure, terrain and soil are penetrated, i.e. the grown ground structure is disturbed by pits and trenches. Such inner city construction measures are usually carried out in grounds where an infrastructure is already available in form of existing pipes, cables and sewers.

Time and again existing pipes are damaged when doing so, going along with dangers to the executing staff, third parties, operating safety of the network as well as with additional costs.

Damages to existing pipes caused by excavators are part of everyday construction life. Just like road accidents, they are hardly taken notice of. These damages happen frequently but are barely recognized due to the amount of daily information. Although experience shows that definitely more damages are caused by open trenching than by trenchless pipe installation methods, the public perception is completely different.

By describing and comparing the alternative construction methods to the common open trenching method, a realistic picture of the current actual construction situation can be shown in detail. This document summarizes numerous facts, pieces of information and figures which clearly speak for an initiative for alternative installation methods in pipeline construction, as these trenchless methods prove to be cost saving, economic and safe.

2. History, development and classification of trenchless systems

Trenchless systems have been developed and applied for the installation, renovation or replacement of supply and drainage pipes as well as for the exchange of cables.
In disposal engineering all systems for discharging wastewater were regularly cleaned respectively flushed to ensure proper drainage. Initially the simplest of means, such as flood rinsing were applied to achieve this. Later an all-purpose system using mobile pressure boilers and flushing nozzles was developed - with the improved jet function it was even possible to clear sewers. To be able to survey the cleaning results, self-propelling cameras were designed which could drive through the sewer and detect and document any damages to the pipe.
Based on a simple undercarriage the first three-dimensional milling robots, milling and scraper robots, as well as swaging units were introduced to the market. With these devices most types of punctual damages were to be repaired.

Then systems were called for which could repair complete pipe strings without trenches. At the start of the 70's the first needle filter liners soaked with resin were installed in the London underground and cured with warm water. Only 15 years later in 1985 the first GFK liner followed which was installed with in Sweden using the UV-light technology.

In the early 80's Pipe bursting (Berstlining) Pipe Eating were introduced as technologies and methods to renew pipes which could no longer be repaired. The range of long pipe versions was completed with new longitudinally tight short pipe segments in the 1990's.

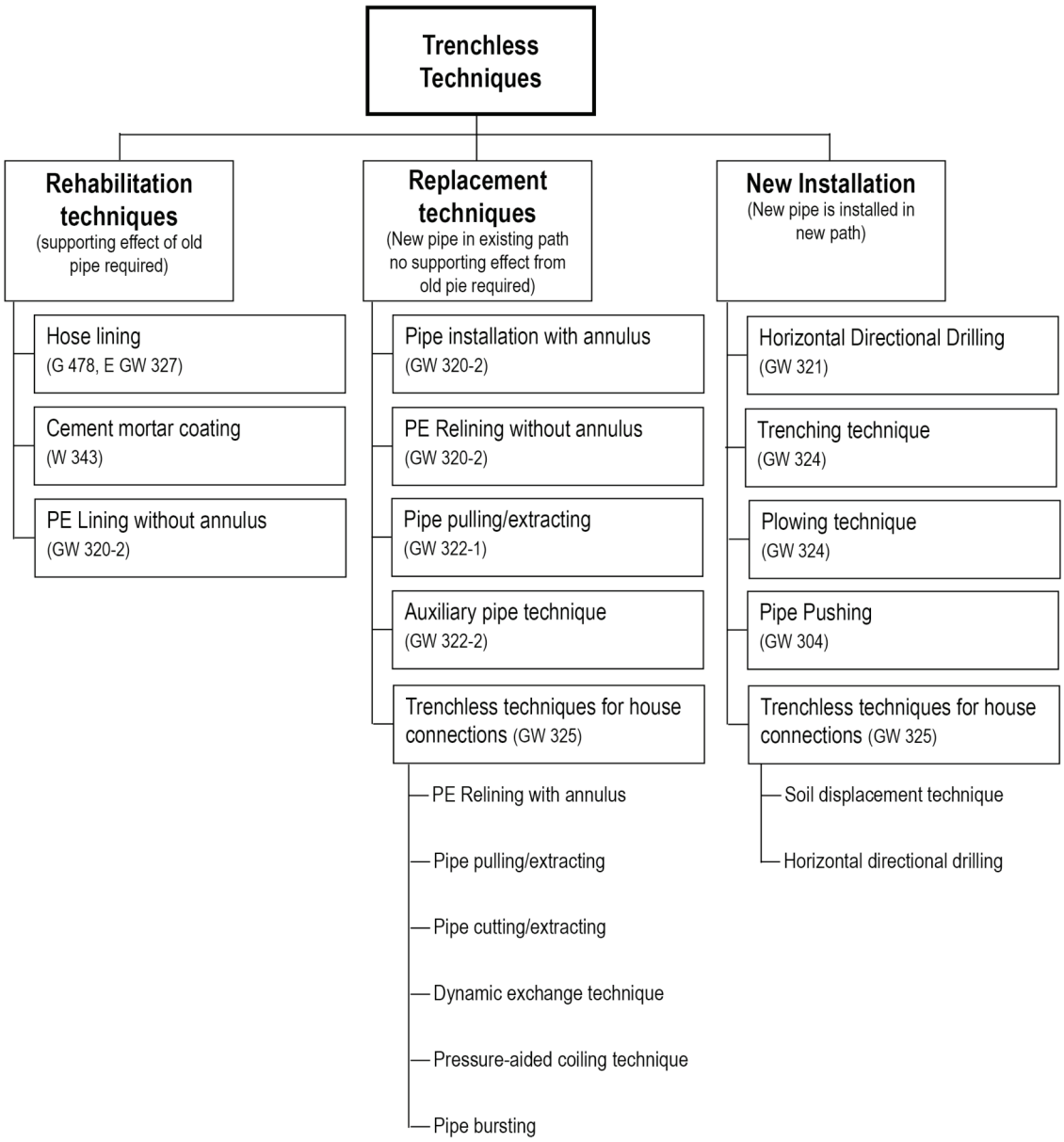
Parallel to the methods for repairing pipeline systems, soil displacement hammers were developed and introduced to the Eastern European market already in 1960. These were improved immensely in Germany and enabled trenchless installations of pipes over short distances. In the 80's bore systems for longer bore paths were created.
For the installation of new pipes mainly soil displacement hammers (for short distances and smaller diameters) are applied and steerable HDD bore rigs (HDD method for all types of soil and stones, for all lengths and diameters) and also hydraulic augering and pulling units (for house connections).

According to this the alternative trenchless bore methods are classified into **Installation and Rehabilitation** systems. These two generic terms summarize various methods to re-establish the operating safety of pipe systems which are described in the following paragraph, divided into supply and drainage.

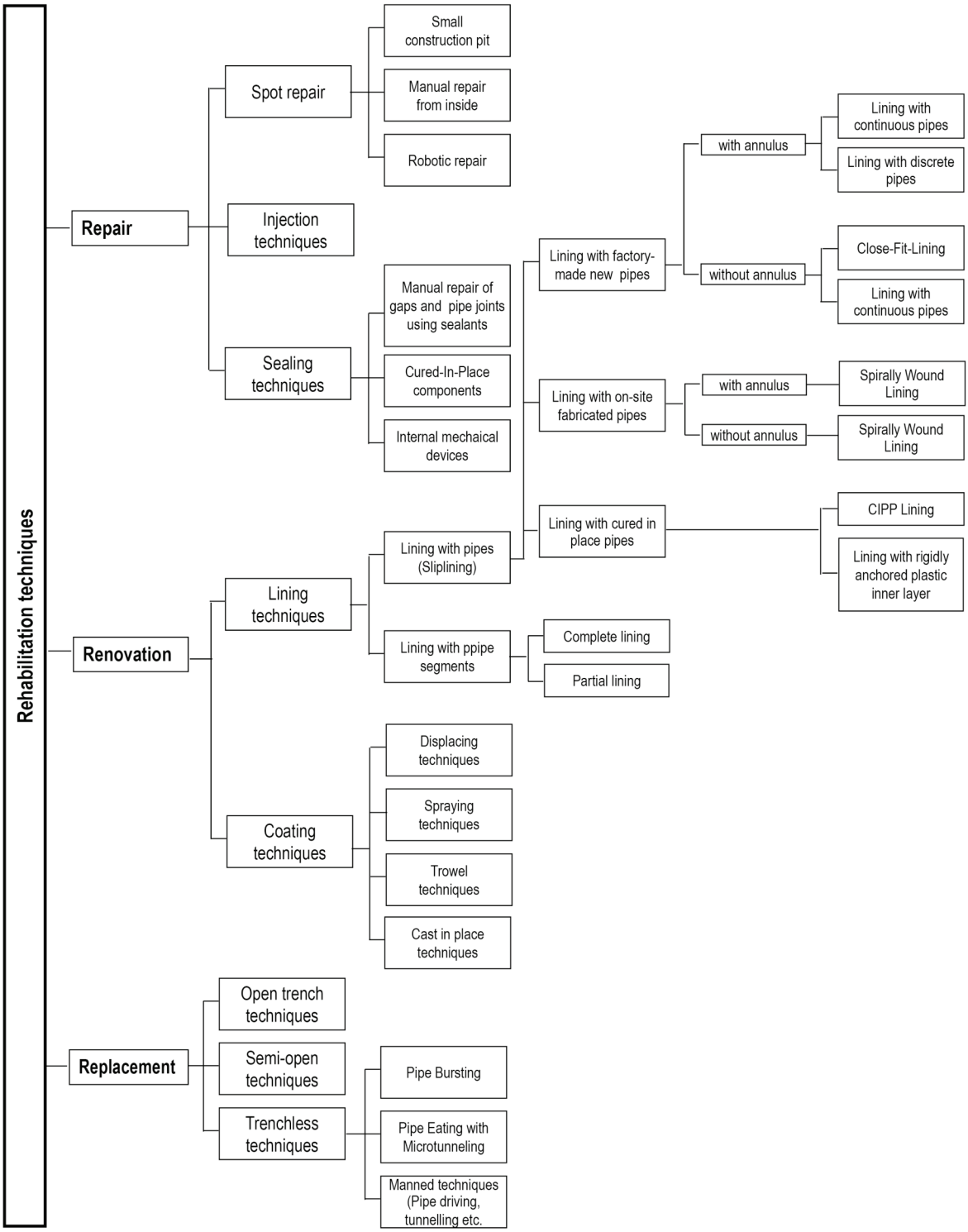
3. Overview of the trenchless methods

The technical work and data sheets for the rehabilitation and installation of supply pipe networks are covered by the DVGW (German Gas and Water Board) concerning solely pressure pipelines. Data sheets and guidelines for the trenchless installation of district heating pipes are published by the AGFW. Guidelines and technical work sheets for the rehabilitation of drainage networks are created under the patronage of the ATV (Sewage Association), which was later re-named the DWA in 2004 (German Association for water, sewage and disposals). Both associations developed their own vocabulary for partially the same technical processes. Up to today there is no standardized terminology.

In the following the comparison of the official tables from the DWA and the DVGW is to show the similarities but also the differences.



3.1 Table by DVGW, W 403



3.2 Table by DWA (from ATV-DVWK-M 143-1)

Further new trenchless methods are continuously being developed which the associations include in these overviews usually at later stages.

3.3 Definition of terms

The indicated overviews of the DVGW or the DWA show the various trenchless construction technologies to re-establish the operating safety of a pipeline networks for supply and drainage.

The various tables partially show the same methods as they can be applied for gradient pipes as well as for pressure pipelines. Naturally there are of course single methods or method groups that are only applied within their own range.
Here it must be mentioned that the different associations use different terms for the method groups.

Under the generic term „Trenchless Construction Method“ the DVGW describes “Renovation” as support effect of an old pipe, “Renewal method” as pulling in a pipe into an old path and the “New Installation method” as a truly new installation. The definitions are printed in the tables.
Yet no standardized terminology has been agreed on but this should not hinder the ever growing popularity of trenchless technologies in all areas.

In addition renewal and installation methods for pipes in accessible and non-accessible supply pipelines are to be mentioned. They are not indicated here but also hold the advantages of trenchless technologies.

4 Conditions for safe working

Innercity construction measures are usually carried out in grounds where an infrastructure is already available in form of existing pipelines (cables, pipes, sewers etc.) Again and again existing pipes are damaged when doing so, going along with dangers to the executing staff, third parties, operating safety of the network as well as with additional costs.

To guarantee the safety of such construction measures by means of and inter-divisional knowledge and thoughtful action, only staff who are qualified in accordance to the DVGW instructions GW 129 should be allowed to carry out construction works close to existing pipelines.

BG Bau (German building cooperative) plays a fundamental part in ensuring the operating safety with their safety regulations and requirements.

The BALSibau initiative (German consortium of network operators for limiting damages in construction) have established an inter-divisional qualification concept on the basis of the DVGW instructions no. GW 129, which provides practical knowledge based on damage analysis. People working in the civil engineering field will receive an identity pass after successfully participating in a GW 129 training session.

Qualified staff and safe construction methods play a major role in preventing accidents.

Further conditions for safe work are:

- Knowledge of the machine technology
- The correct application of technical devices
- The assignment of „trained“ staff
- Fundamental, technical knowledge of the applied construction methods regarding their application possibilities and limits.
- Knowledge regarding soil type, groundwater conditions and specialities in the surroundings of the construction section.
- Knowledge of the bore path area and any crossing adjacent pipes and cables
- Compliance with working and health protection laws, control and documentation
- Adherence to working, safety and construction technical specifications and their regular examination and adherence during planning and execution taking all necessary measures into consideration within the area of the construction section
- Precise knowledge of type and characteristics of the construction section
- Adherence to directives and regulations
- Knowledge of measures to be taken in case of damages

4.1 Labour protection law regulations (excerpt)

§ 5 Evaluation of the working conditions
(1) The employer has to asses the risks the employees are exposed to and to take the appropriate labour protection measures.
(2) The employer has to asses the risks depending on the type job. In case of similar working conditions assessment of one job is sufficient.
(3) Dangers can especially be caused by:
arrangement of the place of work
physical, chemical and biological influences,
arrangement, choice and application of working means, especially working materials, machines, units and rigs and the application thereof,
the set up of the working and production methods, work sequences and working times and their interrelation,
insufficient qualification and instruction of the employees.

§ 6 Documentation
(1) According to the type of work and the number of employees the employer has to provide the required documentation which states the result of the risk assessment, the labour protection measures taken and the result of their examination.

4.2. Other regulations as well as further government and organisation regulations (e.g. BGB, VOB /C or safety and health protection)

Work in the sewer system always has hidden risks when investigating, building, rehabilitating and servicing.

It is definitely not sufficient to consider safety issues during construction. Safety matters must be considered in all phases from planning to development. (see section 8 of EN 752-3;1996). These safety and health protection matters should especially be attended to during preliminary investigation construction and servicing.

The obligatory safety and health measures refer to the respective regulations by the local trade organisations and accident insurance companies, e. g.:

- Accident prevention regulation “Basics of prevention” (BGV A 1),
- Preventive occupational health regulations (BGV A 4)
- Accident prevention regulation “Construction work” (BGV C 22),
- Accident prevention regulation “Sewer systems” (BGV C 5),
- BGR “Pipeline construction works” (BGR 236),
- BGR “Working in closed areas of sewage systems” (BGR 126)
- Explosion protection laws (BGR 104).
- Regulation for the protection against dangerous materials (GefStoffV)
- Regulation for safety and health protection for work with biological materials – Bio-material regulation (BioStoffV)
- Regulation for medical supply during work (ArbMedVV)
- Regulation for safety and health protection on jobsites – Jobsite regulation
- “Safety and health for work processes with biological working materials in sewage systems” TRBA 220

4.3. Obligation for inspection, obtaining of plans and for the detection of adjacent pipes

4.3.1 Work preparation, application, network information

Prior to start of work the civil engineering contractor must get information about the location of pipes and units in the construction area.

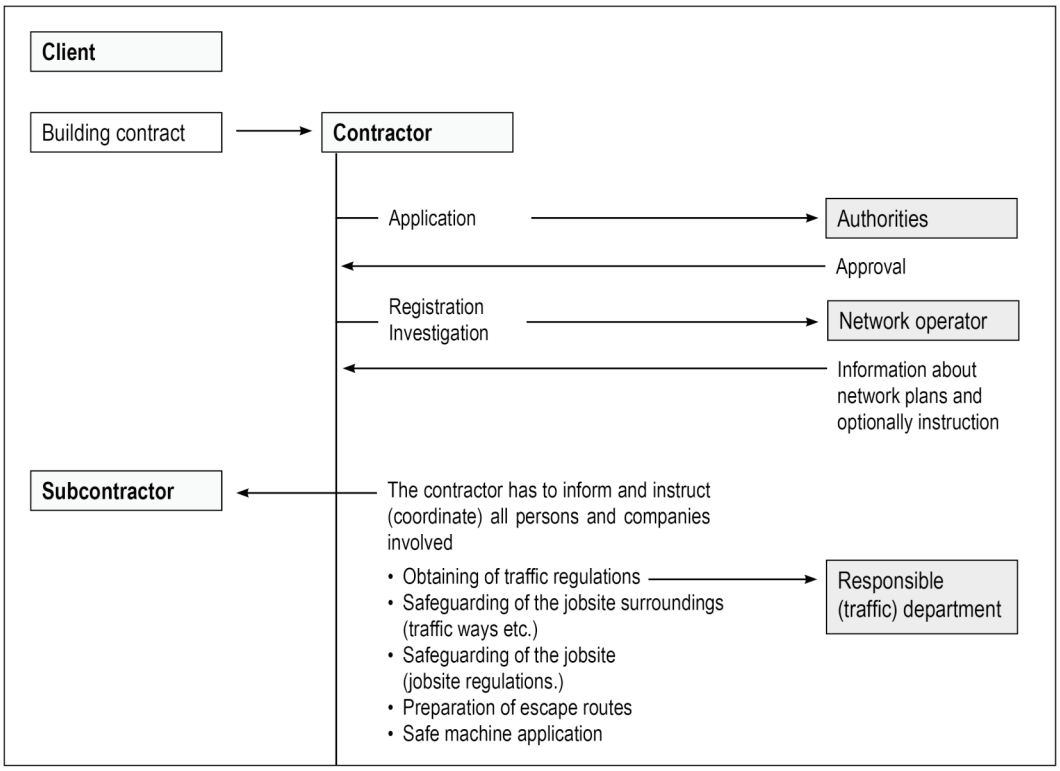
Violation of this investigation obligation can have severe consequences - especially with regards to liability. The violation of this investigation obligation is adequate with the violation of due diligence.

When starting the construction, up to date planning documents must be made available to the contractor, too.

If construction plans are altered or extended, the company must carry out new investigations and then apply for the approval from the relevant service or disposal company.

The civil engineering company is obliged to apply for the construction process at the relevant offices.

When several companies are involved there is the liability to co-ordinate in order to prevent any colliding dangers. (BGV A1 § 6, SiGe Co-ordinator)



The constructor has liabilities towards the contractor (see BGB). They refer to e.g. ground investigation and information about alternating soil conditions or, e.g. the safety relevant information on underground facilities and structures in the planned construction area, which the constructor has set up so far.

4.3.2 Working in the area of ground service lines

Before carrying out any work using machine technology the contractor must determine whether there are any ground service lines within the construction area which may endanger people working in the area.
Ground service lines are e.g. cables, gas, water and sewer pipes.
There is the risk of danger especially by:

- Damages to the service line caused by the machine equipment.
- Pipe breakage due to vibrations

In case of existing ground service lines, the exact position and course of these service lines have to be identified and the appropriate safety measures have to be determined and accomplished in co-ordination with the owner or operator.

Operators of ground service lines are e.g. gas, water, electricity, district heating suppliers, the army, post and telecom companies, communities, public and private companies.

Position and course of ground service lines can be determined for example by setting up search pits.

Safety measures are for instance

- Clear marking of the course of the service line prior to start of work
- Displacement of endangered pipelines,
- Fastening, supporting or catching open cut service lines
- Hooking up pipes to protect them against vibrations

4.4 Investigation of occurring damages

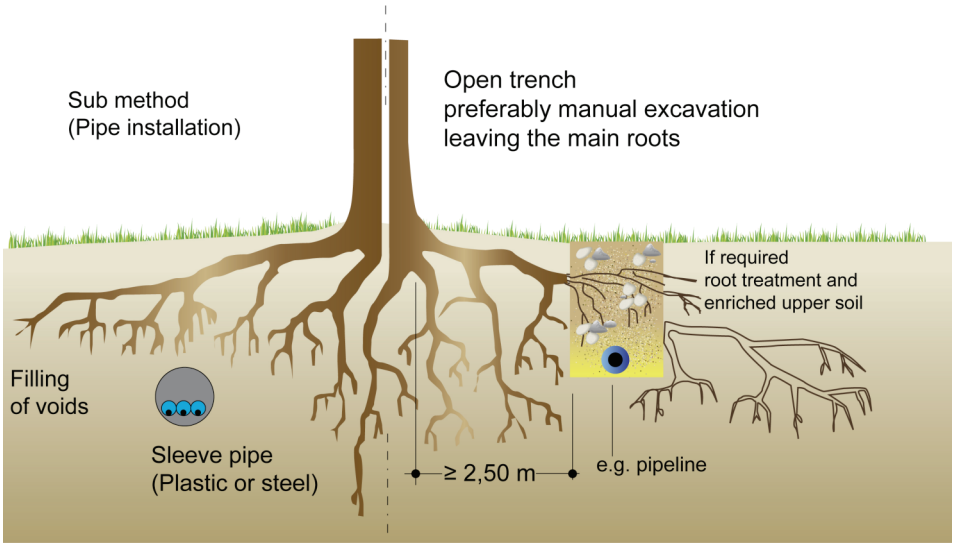
To ascertain which causes have lead to a damage, each damage has to be investigated subsequently.

- Could human error or lack of professional knowledge have caused the damage?
- Has a false technical estimation during the planning phase lead to the damage?
- Have all regulations and laws been considered?
- Has the actual exact position of pipes and cables in the working area been detected on site
- Has incorrect handling in an average case increased the damage?
- How much damage was caused in the surroundings and which reaction did the people concerned there show?

5. Protecting the environment

The open pipe installation method has a negative influence on trees and pavement plantation due to ground compaction and unintended drainage effects, harming vegetation and environment. Furthermore the tree root area is often cut through, with consequences for the stability and the root health of the trees (DWA M 162).

5.1 Tree protection



(Source: R. Köhler (1997) Graphic: TRACTO-TECHNIK, Lennestadt)

5.1.1 Tree protection during pipe installation work

In comparison to the conventional open trench method, which naturally requires higher compaction values for re-establishing the trenches and the ground (see section 6.2.), trenchless construction techniques have a minimal or no effect on the surrounding soil as the ground structure along the pipeline is hardly touched at all. Depending on pipe diameter, type of soil and groundwater content, soil penetrating methods can cause slight soil compaction in the immediate pipe surrounding ground which can affect overlying soil layers
The peripheral soil area above the old bore path is generally untouched.

5. 1.2 Effect of pipe installation work on tree populations

After completing open trench pipe installation works the applied filling material can alter the soil moisture content and have a negative effect on the water and nutrient balance of trees due to the drainage effects. The GSTT Information sheet No. 8 „Tree and ground protection" as well as the "DWA Information sheet M 162 "Trees, underground service lines and canals" indicates such consequent effects and possible tree damages.

5.2 Ground protection

5.2.1 Ground compaction

The re-filling of pits and trenches leads to high compaction values (detailed description under 6.2) which could cause harm to the new pipeline, adjacent buildings, existing facilities and flora and fauna.

Trenchless construction methods have hardly any resp. no influence on the surrounding ground zone as the ground structure around the pipeline is generally not affected. Inherent to the method, slight ground compaction can occur in the area surrounding the pipeline. The soil mechanics of complete area above the existing pipeline also remains unaffected.

5.2.2 Ground drainage

The drainage effect with gradients, the flow potential in sandy soil (possible sand dislocation) and the effect of altered ground porosity of exchanged soil can be immense when using open trench installation methods.

These effects generally not occur when using trenchless pipe installation methods. Only rarely any influential effects emerge which require accompanying measures.

5.3 Groundwater protection

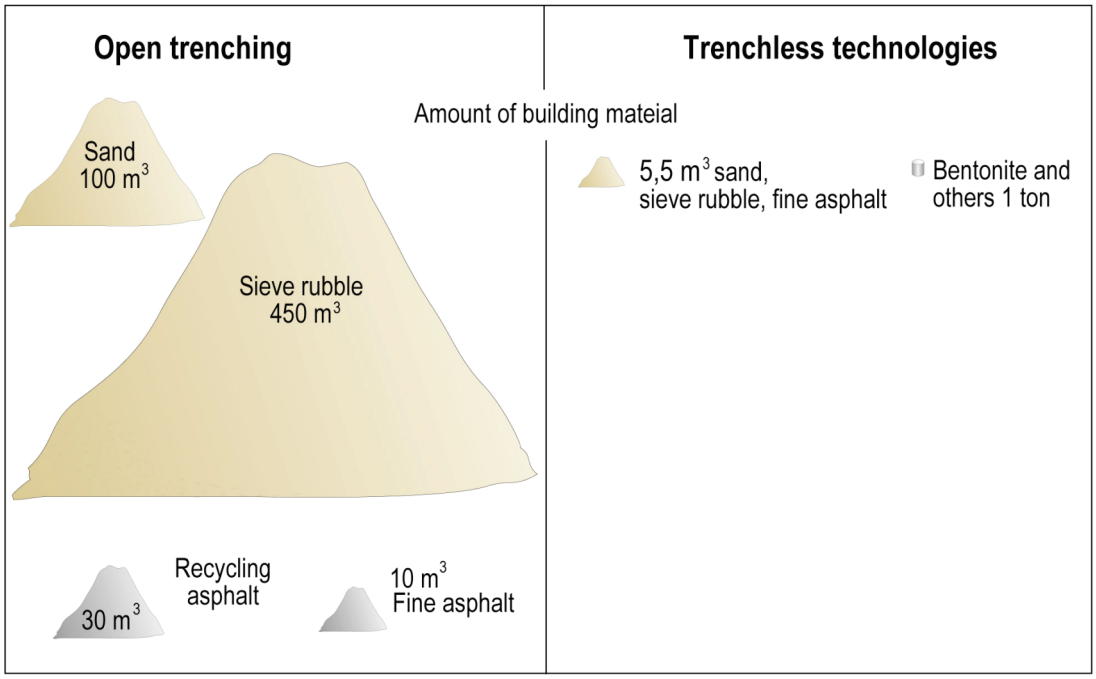
Open trench installations in soils with high groundwater level require extensive, costly and time consuming measures for water retaining to ensure a trouble-free execution of the construction task.
With groundwater retaining measures additional work and safety aspects have to be taken into consideration.

Trenchless constructions can be completed without lowering the groundwater level and the corresponding follow-on effects

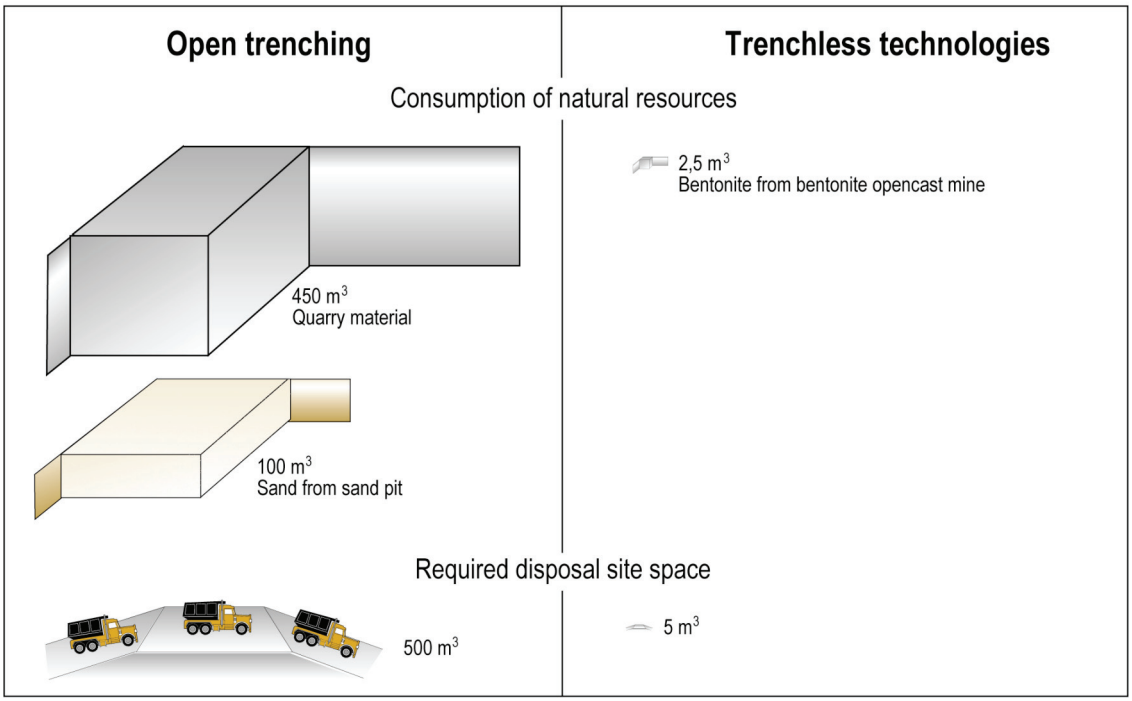
5.4 Protection of resources

In open trench construction, immense amounts of soil are moved. In our example 50 times the mass is moved compared to the trenchless method. Depending on the depth and type of pipe it can even go up to 250 times the amount. The number of transportation movements, the requirement for raw materials and for deposit space increases in the same ratio.
The following graphics from Tracto-Technik, Lennestadt refer to an example with an “open trench” over a 1.000 m length, at 1,0 m depth and 0,5 m width.

Comparison of pipe installation methods: Example 1000 m, PE-HD Ø 110 mm



Comparison of pipe installation methods: Example 1000 m, PE-HD Ø 110 mm

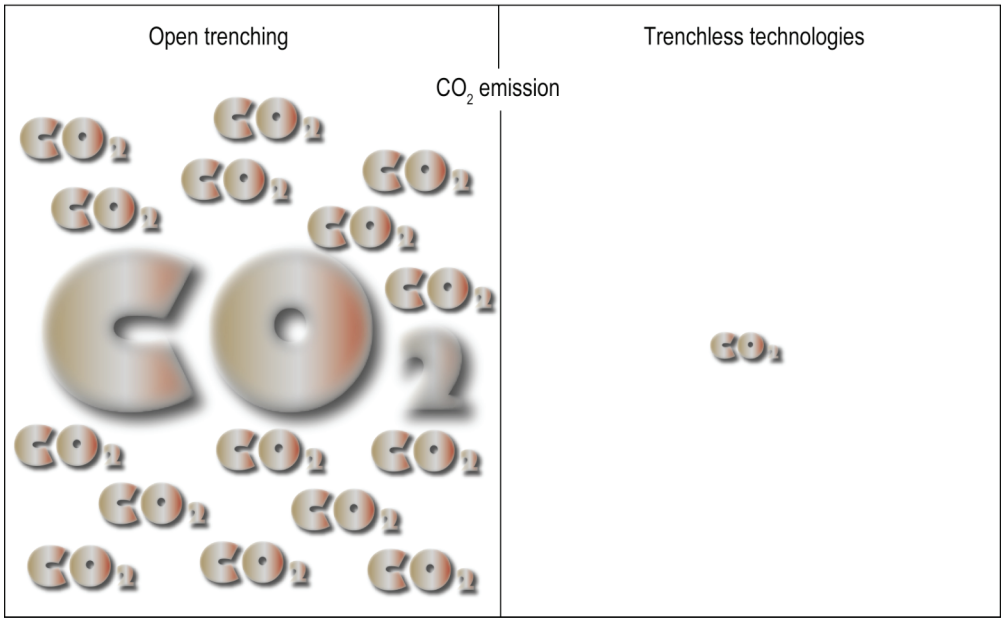


5.5 Emission protection

Moving large amounts of soil in the open trench method requires numerous transports with building site vehicles and numerous construction machines. In the comparison example the CO_2 emission is 50 times as much, fine dust even 100 times as much compared to the same task using the trenchless method.

Lower emissions rates with alternative construction methods play a major part in improving environmental protection which is of growing in importance e.g. with regards to liability claims.

Comparison of pipe installation methods: Example 1000 m, PE-HD Ø 110 mm



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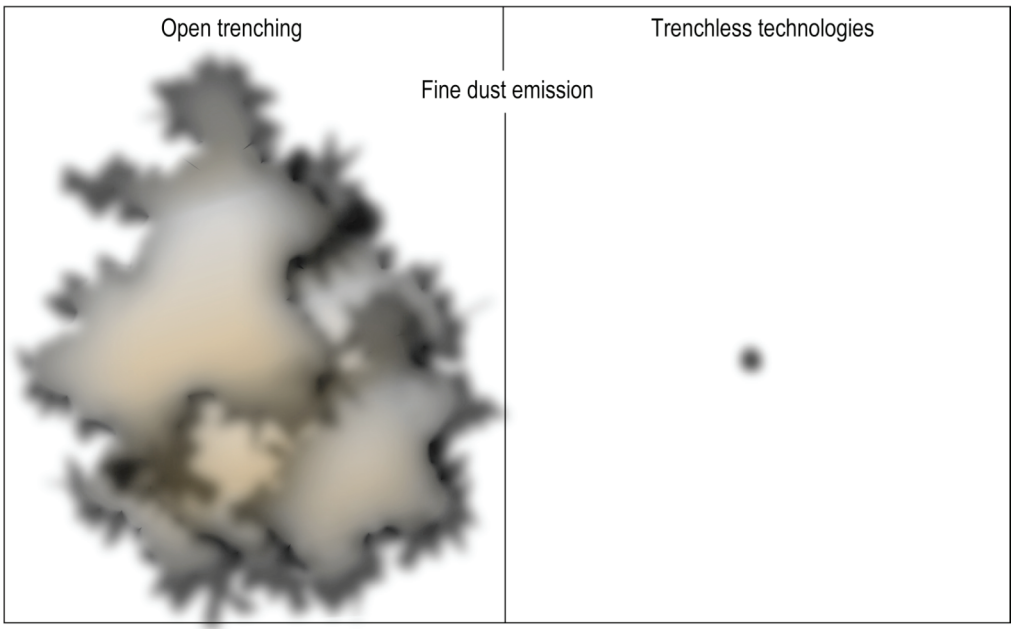
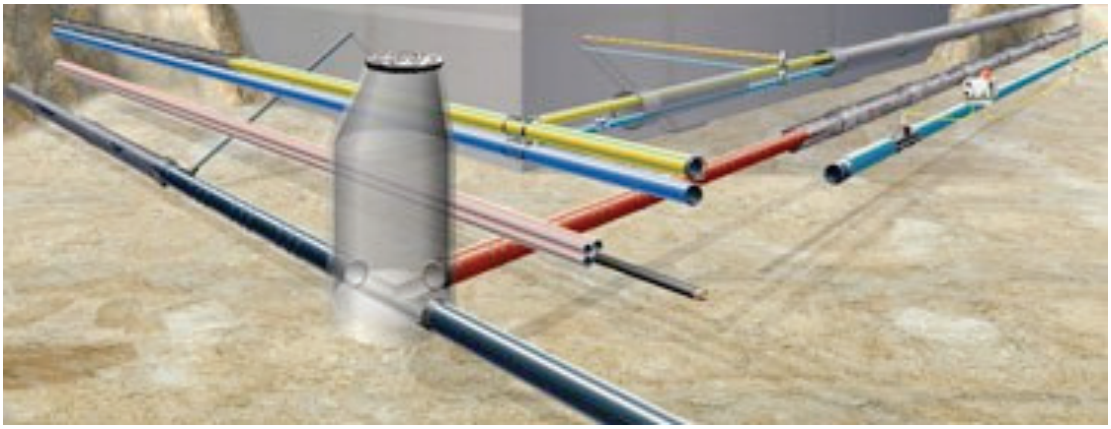


6. Underground usable spaces

Underground space can only be utilized to a certain extent. Due to an increasing number of infrastructure service lines in innercity areas the spaces get tighter and pipes have to be installed at greater depth In these cases the trenchless techniques offer economic and safer alternatives.

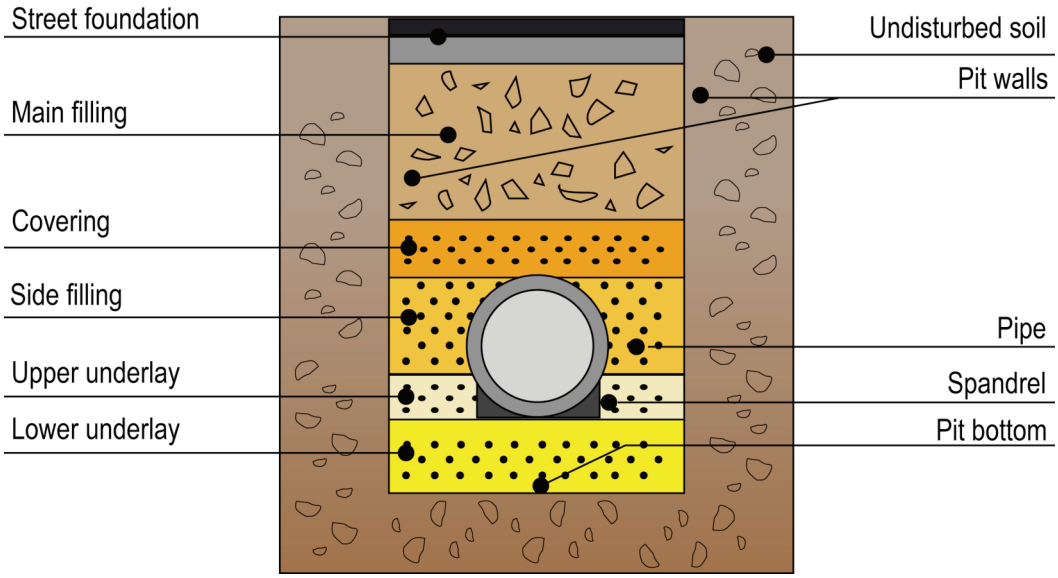


Graphic: Fa. Egeplast, Greven

6.1 Intersections and volumes, installation incidents

Installing pipes with the open trench method has a greater influence on the surface and larger ground volumes are moved compared to the trenchless

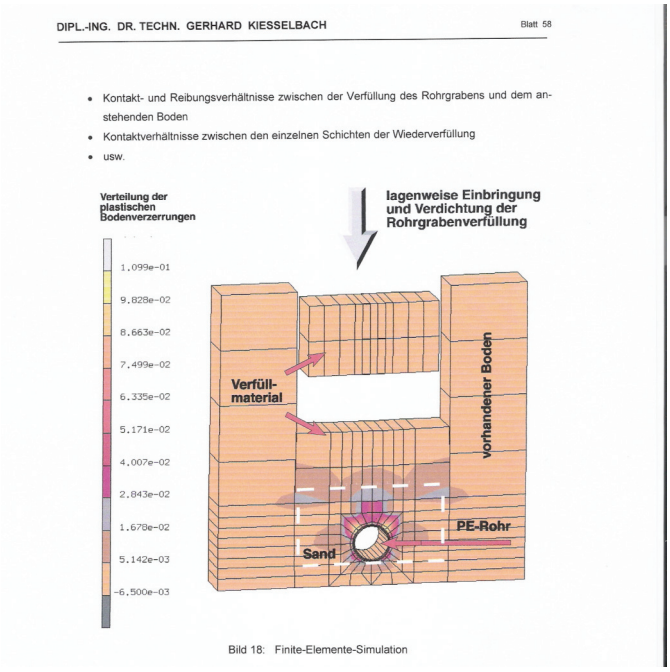
method which utilizes only the pipe cross-section and possibly a minimal area of the surrounding soil.



(Source: IRO Oldenburg, Graphic TRACTO-TECHNIK, Lennestadt)

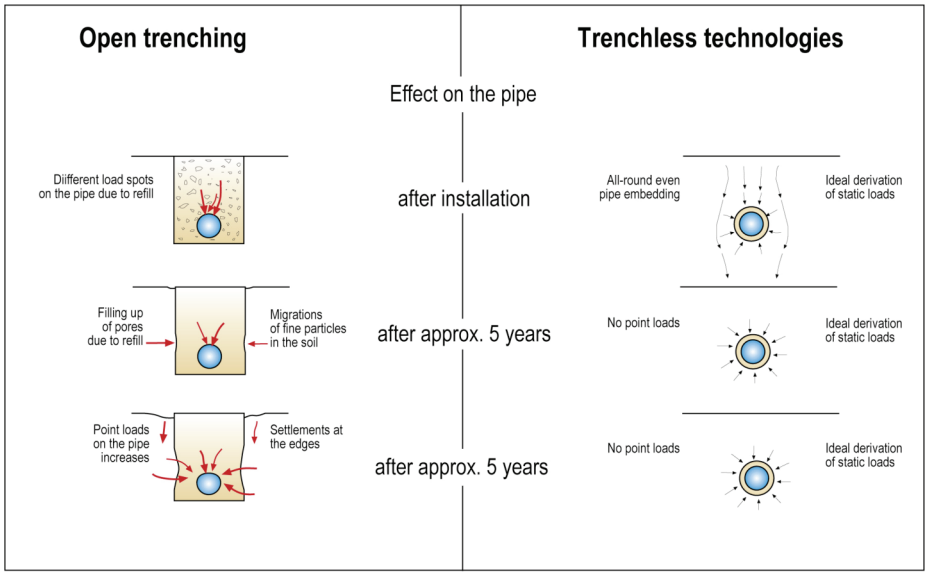
6.2 Ground zones influencing the pipe

While being installed with the open trench method, many pipes are exposed to immense undirectional and unequal pressure loads (Dr. Kiesselbach, Vienna), which shorten the pipes' planned service life of immensely. Pipes installed with the trenchless method are in a better soil static condition, thus a longer service life can be expected.



(Source: G. KIESSELBACH (1997))

Comparison of pipe installation methods: Example 1000 m, PE-HD Ø 110 mm



Graphic: TRACTO-TECHNIK, Lennestadt)

When applying the open trench installation method the underground is physically separated into two halves up to the installation depth. After refilling the trench three spatial segments continue to react physically different, as the refilling of the trench itself leads to a physical reaction which is the highest when the ground is completely replaced by another material and generally the lowest when refilled with the previously excavated soil. Thus after closing the trench there are three road segments which act differently depending on the outer and inner physical parameters (temperature, dampness, retained water binding in the soil, water ducting, corn structures, roughness, susceptibility to vibrations etc.). Especially after stronger climatic alternating effects e.g. from winter into spring, these different reactions lead to interactions in the area of the former trench walls, which are subject to the aforementioned fine material exchange and emerge as edge tear-off and disruption at the road surface. The cause is the movement of material in the fine corn area due to the various porous spaces between trench filling and trench shouldering. With vibrating loads fine corn particles can migrate towards stronger hydraulic gradients and coarse porous structures. Depending on the diversity or porosity settlements take either place in the former trench or in the neighbouring road area.

Initially the damages on the road and path surfaces will only show in the form of fine open tears and seldom in the form of larger level differences. These arise from the intrusion of frost or constant traffic strains which result in forming of edges, asphalt outbursts and partial debonding. When it gets to this stage then repairs are inevitable in order to prevent further exponential damage increase.

With the trenchless construction method the exact situation and bedding conditions of existing service lines are generally known. The course of these lines is permanently documented during installation (after every 3 m at the latest in the longitudinal course) and the actual depth is always recorded. The service line is bedded tightly (e.g. according to guidelines of DCA or the GW

321) in a completely surrounding Bentonite bed, which protects the pipe much more gentle than sand. The ground static loading ratio is much more ideal thanks to the function of the efferent roof bearing function of the surrounding soil than with open trenching, which has a positive effect on the service life of the pipes installed. With the trenchless repair and replacement methods the condition and the statics of the old pipe have precisely been recorded in advance. The renewal and the repair methods are designed to improve the statics in a good manner, prepare the pipe for the next decades and extend its service life.

6.3 Utilization of old pipe trails

Only the trenchless method offers the major advantage of using old pipe trails without the need for excavations. Old pipes can either be repaired from the inside, reinforced, lined with new pipes or completely exchanged trenchlessly. The latter is also applies for cables.

7. Costs and economic efficiency

Please refer to the GSTT Information sheet No. 11 „Cost comparison open and closed construction methods taking direct and indirect costs for pipe installations and pipe sanitations into consideration”.

8. Hazard and accident potentials

Even when planning correctly or after intensive preparations of construction measures, disturbance, hazard or even accidents can happen during the realisation of the task. For the open and trenchless construction methods the hazard and accident potentials are examined for the main working steps.

Evaluation criteria are indicated and compared using the traffic light method.

Hazard and accident potentials	Open trenching	Trenchless technologies
Jobsite arrangement		
Working environment (jobsite)	**over compete length of trench**	**localised, sporadically**
Falling objects	**over compete length of trench**	**localised**
Building edges	**over compete length of trench**	**localised**
Load handling devices	**application spots localised, frequent**	**application spots sporadic**
Movable construction machines	**over compete length of trench**	**localised**
Traffic routing	**over compete length of trench**	**sporadic**
Repositioning (of machines etc.)	**continuous repositioning**	**localised**

Source: GSTT Work Group 'Safety'

Table 1 Evaluation criteria "Jobsite set-up"

Hazard and accident potentials	Open trenching	Trenchless technologies
Earthworks		
Surface break-up	**complete bore path**	**single trenches**
Excavation works (volume)	**significant**	**very low**
Danger of trench collapse	**significant**	**very low**
Dewatering (ground water)	**significant**	**localised**
Total number of transports	**significant**	**very low**
Crossing pipes and cables	**low**	**low**
Parallel pipes and cables	**significant**	**low**
Covering and compaction	**significant**	**very low**
Surface sealing	**low**	**very low**

Source: GSTT Work Group 'Safety'

Table 2 Evaluation criteria "Earthwork"

Hazard and accident potentials	**Open trenching**	**Trenchless technologies**
Pipe and cable installation works		
Installation	Improper handling when transporting and lowering the pipes	Unpredictable sideward moving of the pipe string during pulling in
Connection	Danger of squeezing as connection works are usually carried out in the pit	Connection of the pipe segments outside the pit (reset force)
Handling, transport and storage	Danger during repositioning of the pipe stack and difficult handling (weight of pipes)	low
Hose lining works		low

Source: GSTT Work Group 'Safety'

Table 3 Evaluation criteria "Pipe and cable installation work"

Hazard and accident potentials	**Open trenching**	**Trenchless technologies**
Indirect effects		
Construction time	Longer construction times increase hazard and accident potential	Shorter construction reduce hazard and accident potential
Traffic	Increased transport volume (cubage of excavation) and more congestions	Low transport volume, only punctual traffic interference
Resources	High material consumption from digging to installation	Low material consumption
Subsequent surface damage	Danger of stumbling and falling, danger for vehicles	low

Source: GSTT Work Group 'Safety'

Table 4 Evaluation criteria "Indirect effects"

Hazard and accident potentials	**Open trenching**	**Trenchless technologies**
Persons		
Construction workers	significant due to procedure	low due to procedure
Public	in the immediate vicinity of the jobsite	significantly reduced danger due to smaller jobsites and shorter construction times

Source: GSTT Work Group 'Safety'

Table 5 Evaluation criteria "Persons"

Hazard and accident potentials	**Open trenching**	**Trenchless technologies**
Environment		
Emissions (esp. CO_2)	significant	very low
Ground water	Defective construction machines Infiltration of substances that are hazardous to water	Discharge of indirect materials and not completely cured reactive substances
Vegetation	Long-term damages due to ground water lowering and soil compaction	depending on method and process
Soil	Infiltration of harmful substances (lubricants, sealants, etc.)	depending on method and process
Traffic ways	Dirt, discharge of soil and building materials, subsequent damages for vehicles and persons	depending on method and process

Source: GSTT Work Group 'Safety'

Tab. 6 Evaluation criteria "Environment"

9. Conclusion and perspective

The aforementioned descriptions and comparisons of alternative construction methods to the standard, open construction methods show clearly that trenchless pipe installation methods have in fact proved to be innovative, cost effective and safe alternatives.

It is always worthwhile to check each construction project regarding direct and indirect costs, safety aspects as well as the emissions and the effects on nature and the environment and to take these aspects into consideration when choosing the installation method to be applied.

The continuous increase of alternative installation techniques in recent times speaks for these methods. Planners, contractors and executing companies, which feel obliged to a holistic approach regarding safety, economic efficiency and sustainability of construction projects, can use this GSTT information to help make appropriate decisions.

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