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The efficiency of the horizontal directional drilling method in the rehabilitation and modernization projects of the underground infrastructure

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Abstract. The evolution of human society was and is dependent on natural resources (oil, natural gas, coal, ores, industrial water, drinking water, etc.) and, obviously, on their transportation through pipelines. The existence of resources in the earth's crust, at depths not always accessible, required the finding of methods for their exploration and exploitation. Consequently, in the last 30 years, drilling methods, techniques and technologies have been developed. Today, the Horizontal Directional Drilling method covers the entire geological spectrum, and in terms of rehabilitation and modernization projects of the underground infrastructure, it ensures high quality. Therefore, Horizontal Directional Drilling is the smart, clean and efficient solution for installing the network sections to be installed.
The authors, under the auspices of the Romanian Academy of Technical Sciences (ASTR) and the General Association of Romanian Engineers (AGIR), in this paper, highlight the use and advantages of Horizontal Directional Drilling. The main objective is to install such services in Romania without using traditional trenching methods, helping to avoid any unnecessary impact on the environment and, evidently, offering extra security.

Keywords: Horizontal Directional Drilling (HDD), efficiency, natural resources, pipelines, energy sector, security.

1. Introduction

Drilling represents the entire complex of works related to the crossing, consolidation, and isolation of the geological formations of the earth's crust, from the surface to a certain depth, in order to make the well. In the world of mines, oil and gas engineering finding

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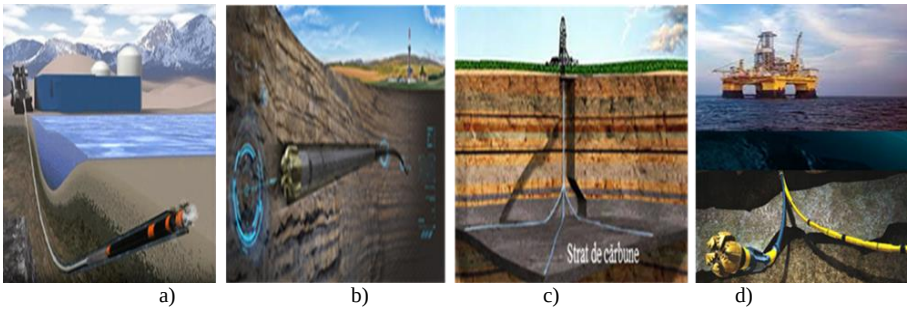
safer and faster ways to complete projects with minimal impact on the environment is the strong point for most organizations or companies.
Directional (or diverted) drilling is used in certain situations imposed by natural conditions, or for technical or economic reasons.
Horizontal Directional Drilling (HDD) means the drilling itself - including the investigation and completion of the well - along a set trajectory directed or deviated from the vertical direction to a given target (the method allows the use of a drill bit screed that can deviate, respectively, deviate from the trajectory of the vertical well), see Fig. 1. Most wells drilled for water, oil, natural gas or other underground targets are vertical wells - drilled directly into the ground.
However, drilling at an angle other than vertical can obtain information, pass through the target and stimulate deposit reservoirs in ways that cannot be achieved with vertical wells.
For example: the exploitation of methane from coal deposits, - the lignite layers contain a large amount of methane gas - through a network of horizontal wells along the coal layers in which air is injected and the formed methane is exploited (Fig.1. b, c).



a) b) c) d)
Fig. 1. Overall picture of the Horizontal Directional Drilling Method
{a) *and* d) – *HDD-offshore;* b) *and* c) – *HDD-onshore*}

In general, *Horizontal Directional Drilling* (HDD) uses the principle of high-pressure injection of drilling fluids simultaneously with the mechanical rotation of the drill bit screed [1,6,7,8,9,11].

2. The method of pipeline installation through Horizontal Directional Drilling (HDD)

Currently, the method of installation of pipes through the HDD is a feasible, effective and constantly developing method. With the help of this method, horizontal drillings and undercrossings are carried out on lengths ranging from 500m to 1500m. Rivers and other watercourses, swamps, lakes, industrial complexes, private properties, forests, railway lines, public roads, highways etc. can be undercrossed (Fig. 2). Also, pipes or tubes can be installed for any utility: crude oil, gas, water, geothermal water, telecommunications, electrical cables, protective pipes etc. The HDD method minimizes the impact on the environment or the work area, keeping a clean environment.
Mainly, the HDD system comprises the following: drilling instlation (drilling machines or tools); drilling fluid mixing plant; hydraulic installation for operating the drilling fluid mixing installation.
As for the laying of a pipe or tube by the HDD method, it is carried out in five steps, namely: 1) preliminary planning and inspection; 2) selection of drilling equipment and its

necessary tools; 3) execution of pilot drilling; 4) widening the pilot hole; 5) laying (pulling) the pipe or tube to be installed.
As for HDD technology, it consists of a hydrodynamic rotary drilling system, directed and focused on three basic technological principles, namely: 1) drill bit; 2) horizontal advancement; 3) handling and monitoring.
As far as the site is concerned, it must be planned in such a way that there are no minimum interruptions or no interruptions in drilling activities. Also, the available space must be planned so that the lifting equipment (crane) can be positioned between the drilling pipe stacking area and the drilling rig. It is very essential to minimise the movement of the crane after lifting a drill pipe (obviously, the crane must be able to swing and position the drilling pipe on the platform).

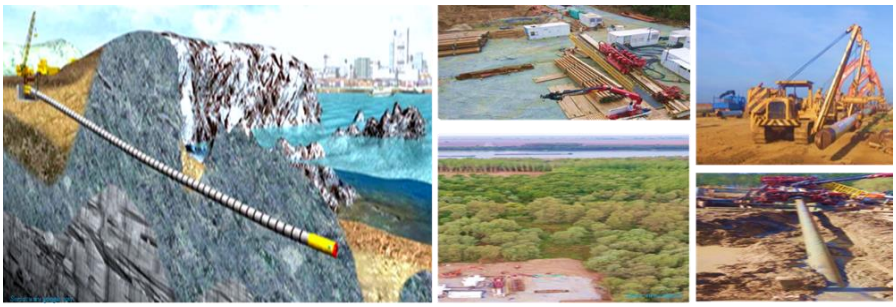


Fig. 2. Installation of fluid transport pipe by HDD method (*overview*).

{a) overall picture; b) photo image - undercrossing of the Danube River and the Borcea branch, L≈1471m}

Therefore, Horizontal Directional Drilling (HDD) is the ideal solution for underground installation of cables, pipes or other types of networks without digging on the outside, in areas with obstacles or in areas where open digging would lead to blockage. Through this method, undercrossing is done directed at a certain angle under a road, a railway, an access way etc. The most common types of horizontal drilling are horizontal percussion drilling, and horizontal pilot drilling.
The range of applications is wide and includes installation of pipelines for gas, water, sewerage, as well as protective pipes for TV cables, telecommunications, traffic systems, low, medium and high voltage cables, fiber optic cables etc. [9,10,12].

3. The technological process of Directional Horizontal Drilling

The directional horizontal drilling process comprises three consecutive technological steps [6,7,10,15]:
1. The initial stage, called the pilot drilling stage, includes: drilling the ground at the diameter described by the drilling screed when advancing, pressing the side of the detached material and fixing it in the walls, the drilling hole remaining permanently filled with the injected drilling mud.
Thus, the pilot hole is drilled along the prescribed trajectory using a hydraulically operated mud ″motor″ to rotate the drill screed and, at once, will act as an inverted helical transport pump. In order to monitor the profile during the execution of the pilot drilling hole, currently, systems are also introduced that instead of magnetometers use gyroscopes, in areas where there is magnetic interference (you can use routing systems with optical gyroscopes, although operations with them are much more expensive).

After the successful execution of the pilot drilling, the widening of the drilling hole follows.
2. Stage II, called the widening drilling stage, includes: the disassembly of the drill bit screed at the far end of the drilling, replacement with a widening head of the diameter superior to the screed by about 30% and the withdrawal of the drilling rods together with the widener at the initial starting point (where the drilling equipment is located).
With the withdrawal of the support column together with the widener, the column is completed behind with drilling support, so that although the widener is constantly approaching the drilling equipment, the length of the entire column remains constant and the extremity opposite to the equipment is always on the surface.
This operation is repeated consecutively, with increasing diameters, until it reaches the diameter required for laying the pipe.
According to the specialized technology of directional horizontal drilling, this diameter must be approx. 30% larger than the diameter of the pipe or pipe being photographed.
3. Stage III, called the stage of placing the pipeline underground, includes: the execution of a last widening with the final reamer to which is attached a device for fixing the pipe to be laid underground (land). The entire assembly consisting of: support, widening head, pipe clamping head, respectively the pipe are pulled through the opening made to the drilling equipment. When the whole assembly is brought to the surface, at the site of the equipment, the widening and clamping devices are detached from the pipe, which remains underground, thus achieving the purpose of the entire operation.
The consecutive stages of the HDD technological process, of building the shore crossing and the section of the pipeline near the shore, without digging open trench, are shown in Fig. 3. [10]
It is worth mentioning that the second widening executed when firing has the role of pushing into the walls of the drill hole the dug material and compacting it.
Thus, thanks to this operation and the drilling mud with the role of stabilizing and lubricating, the walls of the hole do not collapse and the drilling retains its diameter for a relatively long period of time (on the order of several days), sufficient to allow the pipe to be pulled without danger.
After laying the pipe / pipe, within a few days, by gradually draining the water from the composition of the drilling mud, the material excavated during drilling and the walls of the hole will tend to occupy the entire remaining space, so that in the end the laid pipe will be in direct contact with the earth over the entire surface.
The detritus resulting from the drilling will be stored intermediately, in an area specially arranged for storage, to be further dried and finally disposed of at an authorized warehouse.
The drilling fluid will be continuously recirculated during drilling to widen the drill hole and obviously reused.
Therefore, the greater the number of diversion data, the closer the calculated race will be to the real one.
In general, the entire technological process of execution of the HDD must include the following: radiation detection in the verification of the situation plans (made available by the beneficiary of the work); carrying out field investigations with the help of geo-radar equipment, in order to detect existing obstacles; processing of the information obtained; the choice of the drilling route, imposed by the obstacles detected and the type of soil; execution of the drilling itself, according to the described technological stages and laying of the pipeline; control of the depth of the pipe's posing (it is done either by means of the detection device or by making direct measurements in the intermediate pits); reception of the work.

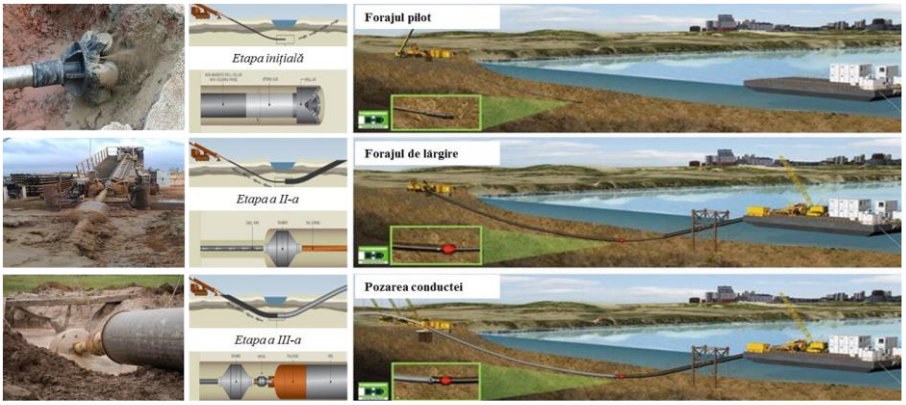


Fig. 3. Stages of the technological process HDD

Figure 4 schematically represents the technological process of the HDD regarding the operation of installing a fluid transport pipeline under the riverbed.[10].

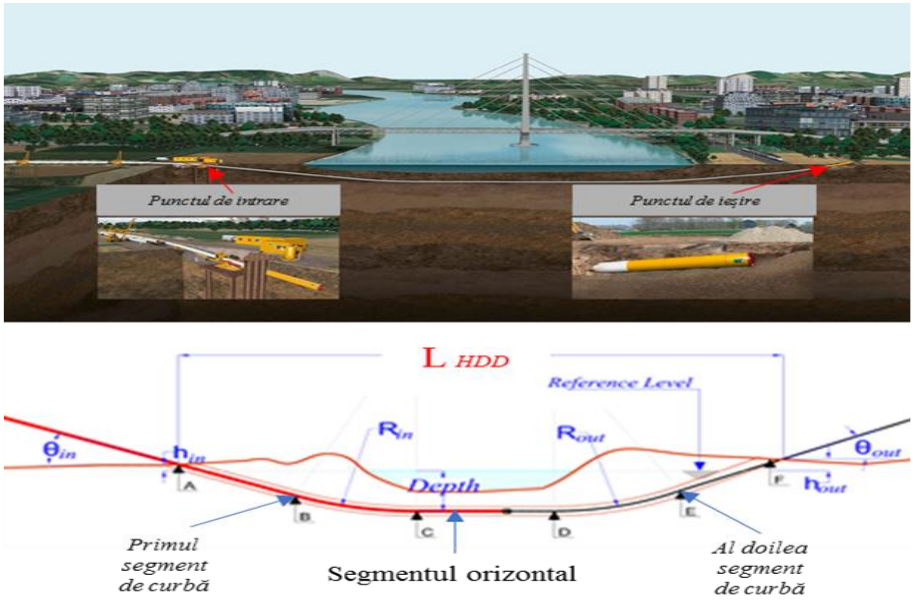


Fig. 4. Application of HDD technology for the installation of a pipeline (case: river undercrossing).

At the water undercrossings executed by the HDD method, the calculation of the minimum radius of curvature R of the fluid transport pipe is made with the relation:

$$R = \frac{E \cdot D_e}{2 \cdot (\sigma_a - \sigma_l)} \quad (1)$$

where:

R is the radius of curvature of the pipe, [mm];

E- modulus of elasticity of steel pipe, [N/mm^2];

D_e *- the outer diameter of the pipe,* [mm];

σ_a *- allowable voltage,* [N/mm^2]

σ_l *- the longitudinal voltage calculated at the maximum allowable operating pressure,* [N/mm^2];

$$\sigma_l = \frac{0{,}0785 \cdot p_{max} \cdot {D_e}^2}{A} \quad (2)$$

p_{max} *- the maximum allowable operating pressure,* [bar];

A - the section of the pipe from which the pipe is made, [mm^2].

In conclusion, beyond the drilling of oil and natural gas wells, the method HDD can be generally useful in the construction of pipelines or under traverse utility networks that must undercut a river or an existing building. Moreover, this method must also be applied in Romania, both for the installation of fluid transport pipelines, as well as for the installation underground of electricity networks and fiber optic cables.

4. Intelligent solutions for installing ducts, connectors and cables without open trench

The technical solutions used in the new installations involve the use of dynamic or static methods of breaking pipes or tubes, depending on the structure of their material.

HDD is a fast, accurate and clean method that successfully replaces the installation of pipes by classic open excavation. The more, is the technical, intelligent and efficient solution for the sustainability of underground infrastructures and can also be applied in complex and difficult projects for the installation and rehabilitation of pipelines or tubes, connectors and underground cables, even in the busiest urban areas, and beyond.

Therefore, HDD method can be an effective solution both in hydrotechnical construction designed for drainages for groundwater abstraction in order to prevent landslides, and in the decolmatization of pipes by cleaning with water at very high pressure.

The advantages of this HDD method are: 1) it is a fast, efficient method, it does not require a large working space and it can be done over long distances relatively long; 2) eliminates the scraping of the land and the digging of ditches; 3) has great economic efficiency in relation to other technologies, such as: high speed of work, execution time is reduced; 4) execution costs, but also social costs are reduced to a minimum; 5) by tracking from the surface the entire technological process has exact precision in carrying out the works; 6) the soil structure along the drilling route remains intact; 7) the method has the same efficiency regardless of the degree of unevenness of the terrain (flat, sloping, rugged terrain); 8) significantly reduces noise, dust and CO_2 emissions; 9) operations can be performed in any season etc.

In addition to these fundamental economic and environmental benefits, the permanent technical improvements brought by the innovators of HDD equipment manufacturers guarantee the maintenance of a high standard of quality, in full accordance with the ever-increasing requirements imposed by the intense major economic development in the local, regional and global context. [9,10]

5. Conclusions and recommendations

The Horizontal Directional Drilling (HDD) method is a process of installing underground services without digging open trench, it is an effective and powerful method, widely used because it allows bypassing possible obstacles with great precision, but applied less in Romania.

As for the onshore HDD method, it is used in certain situations imposed by natural conditions, such as: 1) in the case of coal, oil and gas deposits existing in difficult access areas (urban areas, lakes, rivers, seas, mountains); 2) in the case of complex and difficult projects for the rehabilitation and modernization of pipelines or pipes, underground connectors and cables, even in the busiest urban areas

As far as the offshore HDD method is concerned, this is an optimal solution, since the cost of building a marine platform can only be amortized by an assembly of horizontally directional drilled wells (directed or deflected), either production wells or multiple probes (branched, inclined and horizontal probes, group probes, twin probes, bifurcated probes etc.). The number of drilled wells on a marine platform, without the risk of collision between them, may be increased if inclined or curved conductors, oriented towards the intended targets, are used. When large horizontal displacements are needed, azimuth corrections are reduced during drilling and the increase range of inclination is reduced.

When installing fluid transport pipelines, it is often necessary to cross roads, streets, railways, concrete tracks, rivers etc. In such situations, in order to make the sub-crossing process as efficient as possible, pipeline operators are recommended to apply the HDD method, which represents the ideal solution.

As a general conclusion, the quality of operations performed with the conventional HDD method is influenced by several factors. Therefore, for the projects of pipeline operators who want to invest in such transport pipeline installation services (oil, natural gas, geothermal water, water and waste water, as well as electricity pipelines and fiber cables) and to avoid any unnecessary environmental impacts, we recommend a careful evaluation of potential operators (this includes: history, experience, quality, equipment at their disposal and, not least, the success of the company).

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