Micro-Tunneling Technology for Replacement Electric and Telecommunication Lines

by Dr. Ragaei Sadek, PhD, CE

The Dissertation for the degree of
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UNDERGROUND ELECTRIC AND TELECOMMUNICATION DISTRIBUTION LINES IN URBAN AREAS USING MICRO-TUNNELING TECHNOLOGY

BY

Ragaei N. Sadek

THE DISSERTATION

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THE DISSERTATION

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In content, quality, and form for the degree of:

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Albuquerque, New Mexico
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ABSTRACT:

The author studied the cost-effective modern solution for placing electric distribution lines and telecommunications lines underground in the area of Maryland and Virginia States, also in the areas where the new micro-tunneling machine was used for some crossings in Egypt. The methodology of the study which included examining the cost and schedule analyses as function of pipe diameter and overburden depth. The study focused on the cases when trenching cannot be done. Cost-benefit analysis was performed, particularly in urban areas. The author discussed the cost and benefits of undergrounding both types of lines, but focused on electric lines in Maryland and Virginia states. The data collected for damage due to hurricanes and storms is from USA, but the data collected on micro-tunneling are collected from Turkey, Poland, Japan, Egypt, UK and also USA.

Analysis showed that costs will depend on ground conditions, volume type and size of installation and other variables. Costs will also vary according to geographical location; marked differences in prices are noted from one country to another for the same type of work. Within the same country there will also be significant differences. For example, the cost of undertaking the same type of pipe jacking installation in New York or Boston can be twice of the same job in Dallas or Houston. When indirect costs of disruption to the community is included total costs for installing a sewer in a heavily trafficked main street may be several times the costs for the same installation in a quiet side street in the same city. The nature of civil engineering work is such that each job has to be considered as a unique undertaking with its own specific problems, solutions and costs. This comment is particularly true when work is below the surface in developed areas of cities and towns.

The methodology of the study includes cost and schedule analysis as function of pipe diameter and overburden depth. The study also focused on the cases when the trenching cannot be done.

This doctoral dissertation also evaluated the pros and cons of project delivery methods with respect to trenchless construction. Trenchless technology methods not only provide solutions that are less disruptive to the social and ecological environment but also solutions that significantly reduce the life cycle cost of the project. With the choice of multiple project delivery systems available, this thesis evaluates each method for advantages and limitations that it brings to a trenchless construction project.

It is challenging to achieve the attractive and effective mechanized tunneling alternatives in saving both time and cost without a comprehensive and interdisciplinary consideration. The parties involved should be aware of the proper approaches in adopting the mechanized tunneling technology for a given tunnel project. Every TBM tunnel project needs to be feasible from both operational and engineering points of view, environmentally acceptable and value for money.

In this doctoral dissertation thesis, the author identified and described both the technical aspects and the economic impact of the critical interaction between the different types of micro-tunneling machines, including the author’s patent micro-tunneling machine which was manufactured and tested between 1996 and 1999 in different types of soil; soft clay, silty, clay, sand and rock; under the consultant of “The National Society of Egyptian Railways Lines” and the supervising of the author.

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CHAPTER 1

INTRODUCTION

The data collected for damage due to hurricanes and storms is from USA, but the data collected on micro-tunneling are collected from Turkey, Poland, Japan, Egypt, UK and also USA.

1.1 UNDERGROUND UTILITY

Installation Market:

Since the time it was introduced in the United States in 1984, the field of micro-tunneling has undergone a slow, steady transformation. Initially developed as a means of installing small-diameter lines, Micro-tunneling jobs involving pipelines smaller than 36 in. are becoming less common. New technology and added capabilities have allowed the micro-tunnel boring machines to adapt a greater range of ground conditions and applications; but at the same time advances in lower priced equipment have provided an alternative to conventional, slurry micro-tunneling in small diameters, [22].

When micro-tunneling first appeared in United States, it was viewed as growth market and compared to its adoption in other parts of the world that was understandably the case. However, a quarter of a century later, there are three micro-tunneling boring machines, Akkerman, Herrenknect and Mts. and about 25 contractors active in the United States. However, there have been developments in U.S. micro-tunneling that indicate that the demand remains strong, and that continuing education efforts are beginning to take root, [3], [22].

The definition of micro-tunneling depends on where we are; in the United States, it is defined by The American Society of Civil Engineering as a remotely controlled; laser-guided, pipe-jacked installation technique with continuous support at the face. The definition does not contain any restrictions to size, so micro-tunnels of 10 or 12 ft (300 to 360 cm) are practical. This definition is different than the one generally accepted in Europe or other parts in the world, in which micro-tunneling is limited to non-man-entry size pipe, generally below 36 in (900mm) in diameter,[3], [20], [22].

Micro-tunneling began in Asia and Europe before migrating in the United States. In fact, it was a Japanese micro-tunneling machine manufacturer, Iseki that was the first to enter the U.S. market. Soon after, German manufacturers Herrenknecht and Soltau entered the fray. Rasa from Japan is the latest entrant. The use of micro-tunneling in the U.S. really took off in 1995 at the height of the Greater Houston Wastewater Program. That year saw roughly a two-fold increase in installed footage from the year before, going from 55,000 ft (16,763 m) in 1994 to more than 110,000 ft (33,527 m) in 1995, [3], [20], [22].

By the end of 2001, changes within the market were apparent. The number of contractors actively engaged in micro-tunneling dropped by half from a high-water mark of about 40, and Iseki, the pioneering Micro-tunneling Boring Machines, MTBM, manufacturer, vacated the North American market.

Since the early 2000s, the U.S. market has been relatively flat. The number of contractors has stayed the same, with some new entrants filling the void left by others leaving the market. Experts agree that the total length of pipeline installed by conventional micro-tunneling has remained relatively constant over the last 6 to 8 years, [22], [25].

1.2 THE DISSERTATION PROBLEM:

The problem of the study is the possibility to use the author's patent micro-tunneling machine to replace the power and communication lines in urban areas to be underground to void the losses and damage of hurricanes and storms, which costs billions of dollars every year.

Several methods currently are used by utilities to lessen the financial impact of disaster restoration costs. But there is little consistency in how these methods are applied throughout the industry, or even within a company, from disaster to disaster. This creates uncertainty and invites political intervention. A formal and uniformly applied structure for disaster restoration cost recovery is needed.

When large storms or other disasters damage electric systems, utilities launch massive round-the-clock efforts to restore power as quickly as possible. The logistics associated with these restoration efforts can be daunting. In addition to deploying their own crews, utility companies must call upon crews from other parts of the country to help, with the "host utility" paying for wages, equipment rental, transportation, hotel rooms, meals and even laundry. Added to that are equipment costs, miles of new wire, thousands of new poles, new transformers, cross arms, fuses— the list goes on and on and so do the costs.

The key is restoring power as quickly as possible. Utilities mobilize outside resources at substantial additional costs in their effort to shorten the duration of power outages. When the final costs are tallied, the utility gets a bill that can be devastating financially.

Often there is not an established plan for how this bill will be paid. When the utilities meet with their regulators to discuss disaster restoration costs, the process often becomes highly politicized, and in at least one instance, the ensuing uncertainty has invoked a negative reaction from Wall Street.

The costs data for 81 major storms that occurred between 1994 and 2004 are summarized as following, [9]:

- Utilities incur substantial costs to repair their systems after disasters strike. Based on survey data obtained for 81 major storms from 14 utility respondents, these disasters cost utilities approximately $2.7 billion between 1994 and 2004.

- The economic impact of not having electric service in an area hit by a disaster is much larger than the cost of repairing the damage. This suggests that the utilities' current practice of incurring additional costs to mobilize outside resources to restore power as quickly as possible is appropriate.

- The financial impact of disaster restoration can be devastating if it is not mitigated. For some companies, restoration costs can exceed net operating income for the year.

- Several utilities rely on special storm reserves and/or deferred accounting treatment to lessen the financial impact of disasters.

- In at least one instance, Wall Street changed its credit outlook for a utility, in part because of concerns over how quickly a decision favorable to the utility would be reached to mitigate the financial impact of restoration expenses.
- There is little consistency in establishing which events do, or do not, qualify for disaster mitigation. For example, one company was required to expense approximately $160 million of storm costs associated with a major hurricane against current year earnings, while another utility was allowed to recover a $1 million storm expense over a four-year period.

- Storm reserves provide a type of self-insurance to pay for major storms, however, they may not be funded sufficiently to pay for catastrophic storms. In most instances these reserves do not provide a ready source of cash to pay for storms.

- When faced with significant restoration costs that could require a substantial write-off, many companies are granted permission by their commissions to defer these costs, but there is often a lengthy delay in providing this relief and the approval process can become politicized.

1.3 MICROTUNNLENG TECHNOLOGY:

1.3.1 Micro-tunneling Today:

The state of micro-tunneling depends on what part of the world we are in, in many parts of the world micro-tunneling is much more common than in the United States. In Singapore alone, there are about 75 MTBMs, predominantly Iseki and Rasa machines, operating roughly the equivalent of the number of machines active in the entire United States. He also estimates that Iseki sold more than 2,000 machines in Japan alone. A lot of micro-tunneling is taking a place in the Middle East and Asia, and the market in India is starting to develop, in the U.S., like Europe and Japan we are more in the mode of maintaining our infrastructure rather than building it, [2], [3], [8], [25].

While the use of conventional micro-tunneling or guided boring has been flat, the use of pilot tube method is a hybrid method between micro-tunneling and directional drilling that is effective for installing small-diameter pipes on grade in soft soil; sales for these units have been strong, [2].

Mr. Rob Tumbleson of Akkerman Inc., which manufactures both slurry and pilot tube systems, PTSs; said that we are seeing continued growth in the pilot tube systems, which it markets under the Guided Boring Machine Line, also he said that we are seeing a lot of jobs 30 in. and below being completed using PTSs, while conventional micro-tunneling is being done for jobs where there are issues with depth or groundwater; it's more of a niche tool when there is not another choice, [2], [3].

The capabilities of conventional micro-tunneling machines continues to improve allowing it to traverse practically any ground condition and in large diameters. Improved cutter-heads help crews handle mixed ground conditions; allows more efficient circulation and economical spoil handling, and automated bentonite systems help reduce friction forces thus making longer drives more practical, [2], [6], [22].

1.3.2 Applications of Pipe Jacking and Micro-tunneling:

There are four main applications for pipe jacking and micro-tunneling:

- Line installation - gravity sewers - pressure pipes.
- Installation of ducts.
- Crossings.
- Pipe replacement.

1.3.3 Advantages and Limitation of Pipe Jacking and Micro-tunneling:

- To work in a wide range of ground and water table conditions.
- To cause minimal damage to property and existing utilities.
- To minimize disruption to the public and environment.
- To ensure safe conditions for workers and the public.
- To install to the owner's specifications.
- To provide a cost- effective solution.

1.3.4 Installing Owner's Specification:

The owner is concerned more with permanent works, the pipes and the access shafts, and less with the methods of construction. His needs are the same whatever the method of installation and the objective must be to meet these. Pipejacking and microtunnelling have now developed to the extent that, in nearly all cases, they can meet these client needs for pipe, accuracies, drive spans and curves. It must be said, however, that in some countries this ability has still to be fully achieved and acceptance has still to be given.

1.3.5 Providing a Cost-Effective Solution:

At shallow depth where the costs of reinstatement or disruption are minimal, open- cut trenching remains the economic choice. As various factors come into play, singly or in combinations, costs of open-cut escalate rapidly, at which point pipe jacking and micro-tunneling become more cost- effective. Undoubtedly all three methods – open trenching, tunneling and jacking – have their role to play in utility installation programmers. What has become apparent in the last two decades is that micro-tunneling pipe jacking offers technical and economic advantages for an increasing number of situations, and particularly in sewer construction. It is therefore not surprising that these trenchless methods have already achieved significant market penetration at the expense of the more traditional approach.

1.3.6 The Author's Patent in the Field of Micro-tunnels:

There are many types of micro-tunneling machines which are working in the field of micro-tunnels, as mentioned before. The power, communication cables and gas, sanitary and water pipelines; under the highways, water channels and railways lines, these projects are constructed by using the micro-tunneling methods to pass the cables and pipelines; because of the difficulty and the high expenses of up-surface or open cut.

The micro-tunnels are constructed at different underground levels, which these depths depend on the type of the project and the urban environment. Micro-tunneling machines have different methods as:

a. The method of excavation and fixing the casing.
b. The machine and the equipment's volume.
c. The methods and systems will be used to control the piezometric pressures of water-table or underground water, even if no scouring or failure happened in the soil.

The author patent's machine was manufactured and tested between 1996 and 1999 in different types of soil; soft clay, silty, clay, sand and rock; under the consultant of "The National Society of Egyptian Railways Lines" and the supervising of the author. The machine was registered at "The Egyptian Patent Office, Cairo" on August 31st, 1996; No.: 795-8-96, and registered at "Patent & Trademark Office, Washington DC" on March 8th, 2000; No.: 470429. The machine has the certificate of:

"The National Society of Egyptian Railways Lines, Engineering Department" on September 20th, 1999.

1.4 IMPORTANCE OF THE PROBLEM:

According to EEI, building a new overhead distribution line costs between S 136,000 and $ 197,000 per mile, depending on several factors including population density of the area served (urban areas being the most expensive). The cost of new underground lines ranges between $ 409,000 and $ 559,000 per mile. The Virginia commission estimated the cost of new underground lines to be four to six times more expensive than new overhead lines, [5], [11], [12], [18].

1.4.1 As the report of the State Corporation Commission, Commonwealth of Virginia:

Placement of Utility Distribution Lines Underground:

Summary Review of Economic Costs and Benefits:

The total "overnight" costs of relocating the currently existing overhead distribution lines to underground were estimated to be approximately $75 billion for the investor-owned electric utilities,
$8 billion for the electric cooperatives, and $11billion for the telecommunications providers. These cost estimates do not reflect a high level of confidence, but probably represent an upper bound. The IOUs' estimates include significant general and administrative overhead costs, as well as various contingency additions, which would