TRENCHLESS GOES HYBRID:

Old Tricks Are Finding New Applications

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The International Society for Trenchless Technology defines trenchless technology as "Underground construction methods of utility installation, rehabilitation, inspection, location and leak detection, with minimum excavation from the surface." Today, contractor innovations and technology improvements are responding to the demand for cheaper and faster trenchless construction at near-lightning speeds. Innovation is expanding the range of subsurface conditions where existing equipment can achieve owner-prescribed design criteria. Business sectors with linear underground infrastructure are realizing benefits related to reduced cost, schedule, permitting conditions, and avoidance of right-of-way surface and construction acquisition as a result of these advances and innovations in a maturing trenchless technology market. To understand the values of these advancements, some historical background offers perspective and context regarding their value.

EARLY TECHNIQUES

Early civilizations recognized the need for underground conveyances in the form of tunnels to provide common water and sewer infrastructure, while avoiding disruption and optimizing use of the ground surface. The industrial age accelerated urbanization for labor, resulting in the demand for cheaper and faster solutions for underground construction. The industrial age brought more efficient power and thermal sources such as coal followed by oil that replaced wood and charcoal. Having more reliable sources of heat allowed significant improvements in metallurgy and tooling to make machines and tools to produce higher volumes of quality goods than was possible with the Guild system. Demand for increased water supply combined with the increased availability of durable metals, like iron and steel led to the development of mechanized water well drilling equipment in 1808.

Mechanization indicated for the first time the importance of efficiency of the three construction tasks: excavation, removal of spoils, and support of excavation. Increased efficiency provided opportunity for more profit. For example, auger well excavation was soon followed by steel casing pipe ground support in the 1820s and 1830s all operated and installed by one drill rig.

The industrial age increased the need for reliable transportation to get goods to market. In response, railroad, canal, and roadways developed often using the same corridors. Heavy use of these transportation systems caused owners to demand no interruption of services should one cross another. Additionally, liquid product transportation still required the use of containers limiting the possible volume for markets, especially for the new and in high demand energy source, oil. Demand for larger volumes of oil without the use of the third-party railroad monopolies in bed with John D. Rockefeller resulted in construction of the world's first major oil transmission pipeline. Located between Coryville and Williamsport Pennsylvania, the pipeline consisted of about 112 statute miles of 6-inch steel pipe and was built by Byron Benson and the Tidewater Pipe Company. Opening May 28, 1879, this pipeline inflicted a small but significant defeat to the Rockefeller Standard Oil empire.

The pipeline concept provided a significant increase in the delivery of oil to market at a reduced cost per barrel. This

Pneumatic hammer 14-inch

6-inch pipeline was permitted by court action finding for the public good to allow pipelines to cross the railroad property with the condition that the pipeline must cross in culverts and not disturb railroad operations. This event provided the demand for trenchless culvert crossings under railroads to be used for pipelines.

The tunnel shield ground support system was invented in 1825 by Sir Marc Isambard for crossing beneath the Thames River in England. In 1851 hydraulic jacks were invented by Richard Dudgeon that provided small but high-powered force. Innovative mining/tunneling contractors recognized an opportunity to use newly developed hydraulic jacks combined with a concrete culvert ground support with shield followed by hand excavation to clear the spoils. This is the first documented application of pipe jacking and occurred in 1895 under the Northern Pacific Railroad.

Around 1936, contractors modified the pipe jacking method by turning water well

Auger bore through 42-inch casing

auger and casing equipment sideways to start auger boring for coal mining. Power was provided by hydraulic jacks and truck engines/transmissions. This technique advanced the pipe jacking two-step manual excavation and spoil removal to a single mechanized auger boring and spoil removal.

Transporting large volumes of liquids or gas using pipelines was soon recognized by municipalities and entrepreneurs to satisfy the increasing demand for water and sewer services. In the 1940s resourceful contractors saw an opportunity to adapt the auger boring techniques into efficient and relatively low-cost small tunnel construction for pipelines, satisfying industrial and municipal demand in urban areas without disturbing surface facilities like rail and roadways.

Small diameter trenchless lateral and short road crossing flourished after World War II responding to demand from transportation and communications providers to deliver underground construction with less interruption to existing infrastructure. In addition, increasing energy demand required pipelines to move volumes of oil and gas that far exceeded railroad transportation capacity. To meet these demands, contractors developed unguided piercing technology to install small-diameter cables across congested roads. First used in the early 1900s with pneumatic hammers, this method evolved through the development of stronger piercing tool materials during the 1950s and 1960s, in Poland and Russia, which provided a faster and more economical trenchless alternative. Further advancements in the 1970s ultimately led to present-day pipe-ramming methods, applicable to both small- and large-diameter pipes.

In 1964, a semi-steerable horizontal directional drill was invented to install power cables without surface disruption under streets for the Sacramento Municipal Utility District. The longest drive was a 1,530-foot installation below a curved street. The first successful HDD river crossing in 1971 involved the installation of a 4-inch gas pipe under the Pajaro River in the Central Coast region of California.

Sewer and water pipeline projects eventually required larger pipe installations in unstable ground that could not be accomplished using auger boring or HDD methods. During the early 1970s, Japan responded to the need for trenchless excavation in unstable ground by developing microtunneling that borrowed slurry technology from the drilling industry to stabilize the excavation face.

Pilot tube guidance system for the tunnel - Thinking out of the box.

Cleaning the 42-inch casing

RECENT INNOVATIONS

Just over the last decade, the trenchless construction industry has pioneered the use of curved microtunnels, bursting methods to replace every type of pipe material, HDD projects with lengths exceeding 12,000 feet, and a large assortment of flexible and rigid rehabilitation lining systems that can rehabilitate pipes with diameters of over 100 inches. In fact, innovation has advanced at such a rapid pace that no one person or professional group can be reasonably expected to remain current with the state of the art, but teams of trenchless professionals can provide successful projects nonetheless.

Today's successful trenchless construction involves innovation through teamwork with strong cooperation and communication among the owner, the engineer, the contractor, and the equipment manufacturer. Recent overall advances by the specialized team members include:

- Owner – Performance-based contracting, assignment of risks, and proper funding
- Engineer – Risk-based engineering studies, risk identification and management options, and the definition of ground conditions along the bore path
- Contractor – Current knowledge of tooling, implementation of available tooling for solving stability and excavation issues, and field implementation of means and methods with contingency options

Innovation grows from the recognition of an opportunity to make money and to reduce exposure to losing money on similar projects. Trenchless knowledge and capabilities have led to recent and rapidly developed innovations as problems are identified and solutions developed in a team environment. Opportunity thus exists for all as education and experience from individual members permeate these teams.

Innovation can occur when a project team encounters costs that exceed the perceived gains. Perceived high costs are often associated with a lack of team knowledge regarding variable ground conditions at a project location. The range of properties posed by hard rock and loose silty sand can impact daily production rates by a factor of up to 100, even when conditions are known. Trenchless operating cost per day is a relatively predictable and constant, but based on a review of hundreds of HDD projects by the American Gas Association, an advance rate of 10 feet per day can be expected in hard rock, while soft, stable ground may result in rates of 1,000 feet per day. The resultant cost range significantly increases when conditions are unexpected and both tooling and production require delays and modification.

Trenchless failures provide opportunities for innovation, often arising from inadequate delineation of common ground layers and proper tooling for common ground behavior. "Common ground" is defined as having similar reactions to the excavation process. For example, silty sand and sandy silt react in a similar manner during excavation. In addition, groundwater, clay content, permeability, density, and compression or dilation during shear can all affect material behavior during excavation. Therefore, a portion of the trenchless design should include similar interaction stability analyses of each common ground condition anticipated along a bore path.

Owners and engineers have achieved lower pricing and improved schedules by using performance-based specifications that include fair change condition clauses for distributing risk among the project participants. Owners understand that contractors provide more competitive prices for projects with understandable risks that can be controlled. For example, an owner-specified pipe grade of 0.022 percent, where 1.50 percent would suffice, can have significant impacts on contractor equipment selection and production rate. Specifying the use of equipment requires knowledge of the ground reaction to that equipment.

Contractors' and manufacturers' innovations in tooling and in means and methods have expanded the range of

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> -Tom Loyer, Trenchless Technologies Market Director, ECI - Engineers Construction Inc.

Spoils removal

Akkerman weld-on reaming head

subsurface conditions that specific tools can economically mine. For example, guided pipe ramming has captured auger boring work; steering tools on auger boring casing allows earlier and less aggressive steering, and thus requires accuracy to capture pilot tube tunneling work; and pilot tube tunneling with auger boring equipment in soil or rock provides accurate and precise casing placement, thus capturing grade line microtunneling work.

INNOVATION IN ACTION

Engineers Construction, Inc. (ECI) of Williston, VT provides an excellent example in the use of teamwork to accelerate recent innovations, and application of new tooling addressing common issues are cited in the following example of an urban sewer under wetlands and highway.

According to Tom Loyer, Trenchless Technologies Market Director at ECI - Engineers Construction Inc., "Without this type of collaboration and cooperation project like this could not be successfully completed."

An urban gradeline sewer required the installation of a 12-inch PVC pipe crossing approximately 378 feet under wetlands and a major four-lane highway. Limited workspace prevented pre-assembly of the pipe. The installation depth was 25 feet with a 0.5 percent vertical alignment. The subsurface conditions consisted of loose saturated silty sand to silty clay with uncorrected SPT N-values in the range of 3 to 4 blows per foot. The deposit was placed by marine glacial fluvial processes, and thus common ground was unpredictable and contained pockets of clean material. The original design called for steel casing installed by auger boring or slurry tunneling between two watertight work shafts, including external dewatering systems, but no dewatering was permitted under the highway.

The project bids were higher than the municipality could afford, and rebidding would have violated the court-ordered construction schedule. A solution was devised to engage the apparent low bidder in a design-build contract and to rely on contractor innovation to lower costs while maintaining the necessary program schedule. Team cooperation is critical to the success of this type of construction contract.

The contractor's risk assessment identified several areas of concern. First, the required gradeline accuracy suggested using a microtunnel to meet the slope tolerance, but the project's funding was insufficient for an auger bore, or for the more expensive microtunnel. Additionally, there was a high risk that the weight of the microtunnel equipment would sink in the very soft soil. The solution was to first install a 5-inch laser guided steel pilot-tube pipe to achieve the required

Water flows steadily into pit

Theodolite guidance system

precision and accuracy. Then a single pass string, consisting of 100 feet of 24-inch steel casing, followed by a 42-inch steel casing, was attached to the pilot tube. Each step-up in diameter consisted of an open structural adapter welded into the string. Thrust would be provided by a 14-inch pneumatic hammer with an option to increase to a 24-inch pneumatic hammer. Augers would only be used when necessary, to lighten the casing by removing spoils. Telescoping casing provided for lighter tooling to manage construction settlement. Pneumatic hammers provided the potential to accelerate the construction and offer reduced cost.

The contingency should the hammer run out of power was to cut out the adapter between the 24-inch and 42-inch casing, then drive a heavy wall, 24-inch casing the remainder of the distance to better transmit energy to the cutting head. The 12-inch PVC pipe could then be assembled by cartridge methods into the casing using spacers to achieve grade. The resulting annulus would be filled with grout to secure the alignment and to fill voids to prevent settlement of the highway above.

During construction, the initial pilot tube lost grade when it encountered very loose saturated fine sand and silt. However, the small-diameter assembly allowed for removal and successful reinstallation on line and grade and within the same corridor path. As the subsequent casing drive progressed, an unexpected pocket of clean, saturated fine sand was encountered, which stopped the advance. Hammer vibration on the stalled casing caused the saturated fine sand to flow into the 48-inch casing through the adapter, causing a sinkhole between the drive shaft and the highway. The contractor converted the sinkhole to a dewatered shaft, removed the adapter, installed heavy wall 24-inch casing as called for in the contingency plan, and successfully completed the installation.

PROGRESS CONTINUES

Trenchless construction has and always will demand a combination of art and skill. But subsurface conditions and their reaction to excavation are not always easy to predict. Significant innovations have evolved to tackle these challenges, but there remains much to be learned by all stakeholders. Residual risk always remains, but there is room for improvement with innovative contracting in a team environment, with all parties listening

Ready to launch

Saturated fine sand flowing into the receiving shaft.

and contributing. A contractor's experience and ability to adapt tooling and processes to address unexpected conditions can be effective when given the opportunity to participate as a project team member. Letting contractors select the means and methods based on project-specific and meaningful subsurface information, along with proper funding and a project-team focus, will benefit owners, contractors, and manufacturers, and stimulate new, cost-effective innovations.

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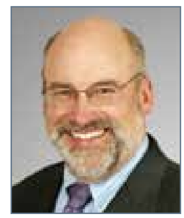

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