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2009 Industry Review
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PREMIER IN SOUTH AMERICA: FIRST SEA OUTFALL REALIZED USING PIPE JACKING TECHNOLOGY.

The city of Praia Grande, literally translated "Big Beach", with approximately 250,000 inhabitants, forms part of the conurbation of the Brazilian port city of Santos. Currently, the "Onda Limpa", meaning "Clean Wave" project is being realized here which aims to improve the treatment of sewage water. The core part of the project is the construction of modern sewage ducts and a new water treatment plant. The wastewater will be treated there and then channeled through an underground outflow pipe (sea outfall) far out in the ocean.

An AVN1500TB Herrenknecht Micromachine with a diameter of 1.8 meters is being deployed. It is the first sea outfall project in South America using the pipe jacking technology. The team used its experience to the full and after only six weeks of tunnelling, the South American premier was successfully accomplished. The machine reached its target precisely after 726 meters of tunnelling under the seabed and was then recovered from a pontoon. Now two additional sewage tunnels, each 700 meters long, are being excavated ashore. This brings the "Clean Wave" project to a successful end and guarantees good clean fun for bathers on "Big Beach".

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**PROJECT DATA**

- M-1125M
- AVN1500TB
- Diameter: 1.810mm
- Max. torque: 4704kNm
- Tunnel lengths:
  - 1x 726m, 2x 703m
- Geology: sand, groundwater

**CONTRACTOR**

- Construtora Norberto Odebrecht S.A.
Focus on Microtunneling

Welcome to North American Microtunneling — Trenchless Technology’s first-ever supplement devoted exclusively to this sophisticated installation technique. The idea behind this issue is to highlight the projects and technologies that have shaped this ever-evolving field over the past year.

Microtunneling has been established in the trenchless toolbox for many years now, however there has always been a bit of a stigma attached to it. It is considered by some as too risky or too expensive, but at the same time it has demonstrated success stories that show its abilities to save time and money and reduce disruption to the community.

Like any tool, it is best used in the proper application. Other available methods must be taken into consideration. Ground conditions and existing utilities must be examined. And, of course, the impact of construction on the surface is a key factor. In the cases of a deep alignment, the presence of groundwater and the need to avoid surface disruption (i.e., highway or rail crossing), conventional microtunneling has established itself as a go-to method.

Although the growth of microtunneling hasn’t taken off like some thought when the method was introduced to the United States in 1984, there has remained a constant demand. New developments, however, may expand its reach in the U.S. market as a record long drive in Portland and designed curve in Hawaii are bringing the state of the art in United States more in line with what is going on internationally. The successful completion of these projects may give engineers the basis for designing similar jobs without feeling like a Guinea pig. (For more information, see pages 8-9.)

The last 10 years or so has also seen an increase in the application of pilot tube microtunneling (pages 16-18). In this supplement we present a case history using this method, as well as an innovative adaption of the technology in Germany (pages 24-26).

Continuing Education

Another component of expanding the use of microtunneling is education. Engineers, owners and contractors need to understand the basic principles, as well as the capabilities and design considerations, to complete projects successfully. For nearly 20 years, no one has done a better job in doing this than the Colorado School of Mines.

Now entering its 17th year, the Microtunneling Short Course, presented by the Colorado School of Mines, has educated more than 1,000 professionals about all aspects of microtunneling — from geotechnical considerations to legal implications. I was fortunate enough to attend this event a few years back and was impressed by the cross section of the industry present and the quality of the educational programs.

Course presentations, coordinated by Course Directors Levent Ozdemir and Tim Coss, are given by leading individuals in the field.

The 2010 Microtunneling Short Course, which includes a one-day Pilot Tube Microtunneling seminar, will be held February 9-12 on the School of Mines campus in Golden (near Denver). For more information about the course, visit www.microtunneling.com.

Regards,

Jim Rush
Editor, Trenchless Technology
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Since the time it was introduced in the United States in 1984, the field of microtunneling has undergone a slow, steady transformation. Initially developed as a means of installing small-diameter lines (hence the term “microtunneling”), microtunneling jobs involving pipelines smaller than 36 in. are becoming less common. New technology and added capabilities have allowed these microtunnel boring machines (MTBMs) to adapt to 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 microtunneling in smaller diameters.

When microtunneling first appeared on the scene in the United States, it was viewed as a 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 MTBM manufacturers (Akkerman, Herrenknecht and mts) and about 25 contractors active in the United States.

However, there have been developments in U.S. microtunneling that indicate that the demand remains strong, and that continuing education efforts are beginning to take root.

Background

Before any discussion of microtunneling can begin, it is best to start with a definition. For microtunneling, however, the definition depends on where you are. In the United States, it is defined by the American Society of Civil Engineers 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 are practical. (Beyond this size, the slurry technique remains the same, but precast concrete segments are typically used.)

This definition is different than the one generally accepted in Europe and other parts of the world, in which microtunneling is limited to non-man-entry sized pipe, generally below 36-in. in diameter. Anything larger than 36 in. is considered pipe jacking.

Microtunneling began in Asia and Europe before migrating to the United States. In fact, it was a Japanese microtunneling 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 microtunneling in the United States 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 in 1994 to more than 110,000 ft in 1995.

The completion of the work in Houston – the city had accounted for nearly 50 percent of all U.S. microtunneling through the mid-1990s – saw a leveling off in the industry. By the end of 2001, changes within the market were apparent. The number of contractors actively engaged in microtunneling dropped by half from a high-water mark of about 40, and Iseki, the pioneering MTBM manufacturer, vacated the North American market (although some of its machines are still in use).

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 microtunneling has remained relatively constant over the last six to eight years.
Microtunneling Today

The state of microtunneling, just like its definition, depends on what part of the world you are in. Tim Coss, president of Microtunneling Inc., says that in many parts of the world microtunneling is much more common than in the United States. He estimates that 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 has sold more than 2,000 machines in Japan alone.

“There is a lot of microtunneling taking place in the Middle East and Asia, and the market in India is starting to develop,” Coss said. “In the United States, like Europe and Japan, we are more in the mode of maintaining our infrastructure rather than building it.”

While the use of conventional microtunneling has been flat, the use of pilot tube microtunneling or guided boring has been on the rise. The pilot tube method is a sort of hybrid between microtunneling and directional drilling that is effective for installing small-diameter pipes on grade in soft ground. Sales for these units have been strong.

“We are seeing continued growth in the pilot tube systems,” said Rob Tumbleson of Akkerman Inc., which manufactures both slurry systems and pilot tube systems (which it markets under the Guided Boring Machine line). “We are seeing a lot of jobs 30 in. and below being completed using pilot tube systems, while conventional microtunneling 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.”

The capabilities of conventional microtunneling machines continues to improve—allowing it to traverse practically any ground condition and in large diameters. Improved cutterheads help crews handle mixed ground conditions, improved solids control equipment allows more efficient circulation and economical spoil handling, and automated bentonite systems help reduce friction forces thus making longer drives more practical.

Pushing the Envelope

While the growth of conventional microtunneling has been relatively flat, recent projects are expanding its reach and opening the eyes of owners and engineers.

Perhaps the most noteworthy project was a U.S.-record 3,055-ft drive completed as part of the East Side CSO project in Portland. The previous record was a 1,625-ft drive completed nearly 20 years ago by E.E. Cruz on Staten Island. Originally designed as two drives, one 2,000 ft and another 1,050 ft, the contractor, owner and engineer devised the plan to combine the drives, thus eliminating the need to construct a shaft and reduce disruption in a congested urban area.

The contractor, a Kiewit-Bilfinger Berger joint venture, used seven interjacking stations and an automated bentonite system to help ease jacking forces. They used a Herrenknecht AVND-2000 to install 84-in. pipe. While the successful completion of the project marked a substantial increase in the state of the practice in the United States, long drives have been commonplace overseas. Coss says 2,500- to 3,000-ft drives are commonplace overseas, and Herrenknecht’s Julian O’Connell said the company’s equipment was used to complete a drive of 8,500 ft in Germany.

Another project that showcases the abilities of microtunneling machines is a project being done for the Bergen County Utilities Authority in northern New Jersey. The project involves the construction of five miles of sewer pipe in a heavily industrialized area with existing utilities. In some areas the alignment comes within 2 ft of an existing concrete pipeline. In an effort to reduce disruption, microtunneling was chosen as the method of installation for crossings of the New Jersey Turnpike, Highway 46 and a CSX rail yard.

Further complicating the project was the soil, which included very soft clays in addition to ground that included cobbles. As a result, the engineer, Hatch Mott MacDonald, and the contractor, Northeast Remsco, designed two different cutterheads for the different crossings. For the soft ground crossings, the cutterhead was designed with an open face and two steering joints—one at the face and one in the tail shield. The two steering joints were specified as a precaution in case steering was lost in the front, the joints could be locked and steering accomplished from the rear. During a crossing of Highway 46, the secondary steering joint was activated and worked well, according to HMM’s Zhenqi Cai, who added that the steering configuration had been used in South Korea, but it is believed to be a first in North America.

Perhaps the last frontier for microtunneling in the United States has been the completion of a designed curved drive—which are common practice elsewhere in the world. But that barrier is being addressed in Hawaii as the City and County of Honolulu has bid a contract that includes a curved drive.

In June, Frank Coluccio Construction Co. was low bidder on a $37.1 million job to install 72-in. sewer 40 deep by microtunneling. The last drive, which goes under a canal with limited surface access and in an environmentally sensitive area, includes the curve, according to James Kwong of Yogi Kwong Engineers.

“This was in an area with unstable banks, not accessible by barge and had protected trees—and the project has a mandated completion date,” Kwong said. “Going through the process of getting additional environmental and water quality permits would have added time and cost to the project. The best solution in this case was a curved drive.”

Conclusion

These recent projects are reason for optimism among those who have been involved with the microtunneling market. The successful implementation of new technology opens the door for other owners and engineers to follow suit.

“The impact of the Portland and Hawaii jobs could potentially be huge,” Coss said. “Engineers can now advise owners that we can save money by using these proven methods. Even though there have been countless long drives and curved drives around the world, owners and engineers in the United States have been reluctant to do them because they don’t want to be the first to try something new, or they are not current with the latest technology.

“The technology is there and the contractors are capable, engineers and owners just need to let them out of the pen.”

Jim Rush is editor of Trenchless Technology.
Sacramento is doing it again. The pioneering city is undertaking one of the largest microtunneling projects in the world, installing over 27,000 ft of microtunneled sewer pipeline for the UNWI-9, NEA-1 and NEA-2 projects. This joint project between the Sacramento Regional County Sanitation District (SRCSD) and the Sacramento Area Sewer District (SASD) proves once again that microtunneling is the key to meeting their long-term wastewater needs in a sustainable way.

SRCSD provides wastewater services for more than 1.3 million people in the greater Sacramento area, including an estimated 416,000 homes and businesses in the region. SRCSD accepts wastewater from the collection systems of other contributing agencies and is responsible for conveyance and treatment of the wastewater through 120 miles of interceptors to the Sacramento Regional Wastewater Treatment Plant in Elk Grove, where approximately 165 million gallons of wastewater are treated each day and safely returned to the Sacramento River.

SASD is a contributing agency to SRCSD, providing wastewater collection services in the unincorporated areas of Sacramento County and the cities of Citrus Heights, Rancho Cordova and Elk Grove, as well as portions of the cities of Folsom, West Sacramento and Sacramento. SASD owns a network of 4,200 miles of main line and lower lateral pipes within a 268 sq-mile area and is responsible for the day-to-day operation and maintenance of this system.

The collection system in the northeast area of Sacramento County, including the City of Citrus Heights, is capacity constrained. The limited capacity risked sewage spills, public scrutiny and regulatory fines if the existing capacity was not increased prior to the onset of the 2008-09 winter season. “Increasing the flow capacity to the collection system will prevent the potential of sewage spills during heavy storm events and provide the City of Citrus Heights capacity needed for planned growth,” says Bill Chavez of SRCSD.

The SRCSD and SASD agencies jointly sponsored the Upper Northwest Interceptor Section 9 (UNWI-9) and Associated Northeast Area Relief (NEA-2) projects to fulfill the need to increase the existing capacity of the collection system and avoid sewage overflows and spills. “This is a substantial effort between SRCSD, SASD and the project team to build a system of this magnitude while minimizing impacts to the public,” says Linda Peters of SASD.

The SRCSD UNWI-9 interceptor and the NEA-2 trunk sewer projects are a part of the overall Upper Northwest Interceptor Program, consisting of nine individual projects. SRCSD/SASD retained HDR, with Bennett Trenchless Engineers and Fugro West, to investigate and design upgrades that would relieve this capacity restriction. A deep gravity sewer option was selected.

“The selection of the deep gravity sewer alternative, instead of the shallow open-trench force main alternative, resulted in substantial savings in longterm electricity costs, while greatly reducing disrup-
tion to community residents along the heavily developed alignment,” says Dave Bennett of Bennett Trenchless Engineers.

**Meeting the Schedule**

To address operational and environmental issues, an aggressive schedule was required to complete the first phase of the project by Nov. 21, 2008, prior to the 2008-09 winter season, and the second phase by October 2010. Steve P. Rados, with microtunneling subcontractor Vadnais Corp., was the successful bidder, with a $52 million bid to build this project to meet the aggressive deadline.

The Rados-Vadnais team used three separate microtunneling machines to complete the job with 41 separate drives. A combination of Iseki TCC-800 and Herrenknecht AVN-800 machines were used for the 36-in. inside diameter pipe for the UNWI-9 and NEA-1 segments. Another Iseki, a TCC-600, completed the 24-in. inside diameter pipe drives for the NEA-2 segment.

Dan Schitea, vice president of tunnel operations for Vadnais Corp., believes no other project in the western United States has seen such significant tunneling effort for a single project in such a short time span. “The number of individual setups and drives [41 in total] for a single project is unprecedented in my experience,” says Schitea.

The project is nearly a year ahead of schedule due to contractor efforts to mobilize additional microtunneling equipment and the use of specialized equipment to more efficiently use the tight work areas allowed in the congested city streets. “From our use of gantry cranes, compact forklifts and customized slurry separation equipment built by Vadnais specifically for this project, this just might be the cleanest microtunnel project ever constructed,” Schitea says.

**Microtunnel Machine Naming Contest**

Innovative public relations techniques were crucial for a successful project. A contest for elementary school students was organized to name the three microtunneling boring machines (MTBMs) and to draw a sketch of the machine’s boring head. The class chose their favorite three names and drawings, and the names were painted on each MTBM. Photographs with the machine and crew were taken and presented to the winners as gifts from the project. The contest winners were photographed and their stories printed in the local newspaper.

As with the MTBM, pictures were taken with the excavator’s crew and given to the students as a memento. The success of the MTBM boring head drawing competition was so well-received that during the open-cut operation, as the work-zone passed another elementary school, the children were asked to draw and name the three excavators that were being used to perform the work.

**Shaft Construction**

Access shafts were auger-drilled by Anderson Drilling and ranged from 27 to 68 ft in depth and from 15 to 21 ft in diameter. Access shafts were expected to be the critical path activity for the project. However, the auger-drilling method was performed with a large truck-mounted drill that completed the work in a significantly shorter time than anticipated. The early completion of the access shafts allowed an uninterrupted microtunneling schedule, and the third microtunneling machine was then able to be mobilized, which shortened the tunneling duration.

The auger-drilling of the access shafts, though, presented numerous utility conflicts with the work. MWH, the project’s construction manager, identified the anticipated conflicts and presented options to either relocate the conflicting utilities or relocate the shafts around the utilities. Successes in this regard included the mobilization of Pacific Gas & Electric (PG&E) to relocate four gas lines ahead of shaft drilling. MWH worked with the owner and the contractor to develop plans to provide traffic controls, trenching, backfill and paving as a means to allow PG&E to respond quickly, which otherwise would have delayed the construction of several access shafts and subsequent microtunneling.

**Pipe Materials**

Polymer pipe was originally specified for the project. However, in October 2007, an injunction was ordered by a German appellate court on the pipe supplier effectively delaying the work and potentially compromising the November 2008 completion date. As a contingency plan, MWH worked with the SRCSD/SASD and HDR on the proposal by the contractor Rados to use an alternative pipe for microtunneling, manufactured by Can Clay of Cannelton, Ind. The VCP Denlok pipe was tested and witnessed by MWH and Rados at the Can Clay facility in November 2007 and subsequent shipments of pipe began immediately thereafter. The contractor pursued the remaining pipe supply with Can Clay to complete the project. The supply of Can Clay pipe mitigated the schedule impact of the polymer pipe injunction and allowed the contractor to complete the first phase of the project on time.

**Safety Measures Implemented for Tunnel Inspection**

MWH coordinated with two public emergency response agencies, the Sacramento Metro Fire Department and the City of Roseville Fire Department to conduct pipe inspections. During the safety planning for pipeline inspection between access shafts, consideration was given to how emergency responders would reach an entrant trapped inside the pipe, up to 400 ft from the entry point, and up to 57 ft below the surface. The two fire departments were invited to the work site to see the shaft conditions and to understand the nature of the pipe inspection.

Through this coordination with the Sacramento Metro Fire Department, MWH developed a safety plan so that an entrant could be extracted by the CM inspection team. The tunnel inspector was tethered to a leash line attached to a harness. In case of an emergency, the inspector could be extracted by the CM inspection team using the leash line and rescued from the shaft. The five-man inspection team included an entrant, a spotter at the ends of the pipe at each access shaft, and a spotter at the top of each shaft. Each member was fitted with appropriate fall protection equipment, provided adequate ventilation and air monitoring equipment.

Stephen Chavez is Construction Manager for MWH Americas Inc.
The potential for settlement damage is a key concern for microtunnled installations. Settlements associated with trenchless installations include two types: large settlements and systematic settlements. Large settlements occur primarily as a result of loss of ground due to over-excavation. Large ground losses can lead to the creation of voids above the installed pipe. Large settlements are almost always the result of using inappropriate means and methods, improper operation or sudden, unexpected changes in ground conditions. The risk of large settlements can be minimized through a comprehensive geotechnical investigation, proper means and methods, and good workmanship by the contractor. The importance of a thorough geotechnical investigation and a skilled and experienced operator cannot be over-emphasized.

Systematic settlements associated with trenchless construction are primarily caused by the collapse of the overcut, or annular space, between the new pipe and the excavation. An overcut is a necessary component for all microtunneld and other pipejacked installations to reduce friction loads on the pipe string, to allow the injection of lubricant, and to facilitate steering.

During or after microtunneling, the soil surrounding the annulus may collapse or squeeze onto the pipe, filling the void created by the MTBM. The soil collapse continues upward until the void appears at the surface as a trough. These systematic settlements can be controlled by reducing the radial overcut, as well as by keeping the annulus filled with bentonite lubricant during tunneling, and potentially by grouting the annulus after pipe installation. Systematic settlements decrease:

- as depth and lateral distance from the centerline of the pipe increase
- as annular overcut decreases.
- as soil consistency (density, stiffness) increases.
- as bore diameter decreases.

### Identifying and Evaluating Risks

To evaluate the risks of excessive settlements that could damage roadways, utilities or other features, it is important to conduct a thorough geotechnical investigation to document ground conditions and behavior. This approach minimizes the risk of unanticipated adverse ground conditions that could result in large settlements and claims by property owners. Conditions that pose potential problems include weak, compressible soils, poorly graded clean sands and gravel (especially combined with low blow counts), and high groundwater.

It is also critical to identify any existing surface and subsurface features that could be damaged by settlement. This investigation should include site visits to look for key surface features, researching as-built drawings for other projects and utilities in the area, using the One-Call system to locate subsurface utilities, and potholing to confirm locates. Potential features that may be at risk from settlement include buildings, highways, railroads, levees and underground utilities. The risk for a given feature depends on condition, age and consequence of damage to the feature. In addition, permitting restrictions may limit maximum settlement tolerance.

The next step is to determine the maximum allowable settlement for each feature. Put simply, the maximum allowable settlement should be below that which would cause damage to the feature. Suggested preliminary design criteria are presented in Table 1. However, the values in Table 1 are preliminary guidelines only; always consult the facility owner for specific allowable settlements. In addition, the existing conditions at the time of the bore must be considered. For example, a large force main constructed in soft organic clay will almost certainly experience significant settlement over time due to consolidation of the soft soils. The pipe may be unable to accommodate any additional settlement caused by a trenchless bore beneath it.

### Evaluating Settlement Risk

Calculations can be made to evaluate the potential for settlement damage to surface facilities and subsurface utilities, and whether mitigation methods are necessary to protect existing facilities. The detailed calculations are discussed in Wallin, et. al, (2008). Settlement magnitude depends on soil conditions, pipe outer diameter, overcut, depth of cover and lateral distance from the pipe center.
depth or clearance will help to reduce the maximum settlement, ideally into a more stable ground condition. Increased reduce settlement risk during design is to deepen the alignment allowed for a given feature, the design should be modified to reduce the risk of damage. The simplest way to reduce settlement risk during design is to deepen the alignment, ideally into a more stable ground condition. Increased depth or clearance will help to reduce the maximum settlement above the centerline of the bore, but will also widen the zone of impact at the surface. This may not be desirable if there are surface features nearby that would be influenced by the new wider settlement trough. It also may not always be possible to deepen the alignment because of bore geometry, gravity flow installations, or unfavorable ground conditions.

Reducing the maximum allowable overcut is another method to reduce settlement risk. However, reducing the overcut too much raises other risks such as high jacking forces, steering difficulties and seizing of the jacked pipe string. Therefore, all aspects of design must be considered when addressing settlement risk to ensure a constructible project.

Grouting the annular space soon after installation can be effective for reducing settlement risk by preventing the annulus from fully collapsing on the pipe. Grouting is most effective where the soil has enough strength to hold an open annulus until pipe installation is complete. Grouting must be initiated soon after completion of the bore to maximize effectiveness. Grouting can also eliminate preferential seepage paths along the new installation, a major concern when passing beneath rivers with levees.

Utility Protection

When the bore alignment or profile cannot be altered and an existing utility is at risk of damage from settlement, the utility may be protected by hardbacking, or exposing a utility and physically supporting it. Hardbacking can be costly, and may not be practical in many situations. In soft or low density soils, grouting the area around and/or beneath the existing utility and then tunneling through the grouted zone may be effective. Jet grouting, permeation grouting and compaction grouting methods may be applicable depending on ground conditions, age, condition and pipe material of the existing utility, as well as other factors. When grouting, it is important to use a grout strength that is easily excavated by the MTBM, and yet has sufficient stability to support the existing utility. If in-place protection of the utility is not feasible, relocation is required to avoid damage.

Pre-Construction Survey, Monitoring and Inspection

Before construction begins it is important to conduct a survey of critical crossing features and the surrounding area. The survey will allow the contractor to assess the extent of any settlement that occurs during construction, and will protect the owner and contractor from frivolous claims of damage that occurred before construction began. Existing conditions should be documented with video and still camera footage, with date and time stamps and locations noted.

Several different kinds of settlement monitoring points can be used to monitor settlements, including:

- Surface monitoring points
- Subsurface monitoring points
- Inclinometers
- Multiple-point borehole extensometers (MPBXs)
Surface monitoring points, such as PK nails, are simple, but are often unreliable for monitoring settlement. Due to the shear strength of soils, and the rigidity of pavement and other structures, voids created at depth may not appear at the ground surface until long after the trenchless crossing has been completed.

Subsurface monitoring points, such as illustrated in Figure 2, provide an inexpensive, reliable method for detecting settlements before voids propagate to the surface. By monitoring ground movements much closer to the drilling operations, at strategic locations before passing beneath the critical features, ground losses, if any, can be detected in time to alert the contractor and the engineer to the problem. The construction team can then decide to alter the construction procedures to prevent further ground loss, or possibly initiate ground improvement.

Multiple-point borehole extensometers (MPBXs) measure settlement below the surface but are expensive and can bridge over settlement until heavy loads pass over the affected areas. Subsurface monitoring points (Figure 2) are easier to install and are effective and inexpensive monitoring tools for subsurface settlement. These simple settlement points have been shown to perform more reliably in soft ground than surface points and MPBXs, which are more complicated and expensive.

In general, a few strategically located subsurface monitoring points provide more reliable data at reasonable cost to allow performance to be evaluated. Inclinometers and MPBXs may be useful on extremely sensitive projects or locations.

Regardless of what type of monitoring point is used, measurements should be made on a systematic basis before, during and after trenchless installation to confirm that no damaging settlements have occurred. Measurements before construction commence are critical to establish a baseline. Monitoring locations should be installed near sensitive facilities to assess the contractor’s operations before passing under critical facilities. Contractor submittals should be required to describe their plans for avoiding excessive settlement. A contingency plan should also be required to establish how the contractor will mitigate any excessive settlements.

Finally, on-site inspection can help to identify potential problems so that they can be rectified before further damage occurs. If the MTBM torque readings are very low or erratic, or the volume of spoil is dramatically greater than the estimated theoretical volume of the bore, it is likely that the bore has been over-excavated. Tension cracks in the surface clearly signal that settlement has occurred.

Through a combination of thorough geotechnical investigation and planning, careful design, conscientious workmanship, evaluation, mitigation and regular monitoring, settlement risks can be actively managed on microtunnel installations.

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David Bennett, Ph.D., P. E., is the principal, Kathryn Wallin is an engineering assistant and Matthew Wallin, P. E., is an engineer with Bennett Trenchless Engineers, Folsom, Calif.
Practical Guidelines for the Application of Microtunneling Methods
This book offers a source of information guidance for the planning and execution of sewer construction measures.
- 85 figures and pictures
- Covers pilot tube and conventional microtunneling.
- More!
Author: Professor, Dr. Dietrich Stein; Stein and Partner GmbH
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Reviewed by Prof. Ray Sterling, Director of the Trenchless Technology Center, Louisiana Tech University.
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Produced: In partnership with the American Public Works Association
159 pages/softbound
Price: $40.00*

*Shipping and handling not included. Selling price subject to change without notice.
After an experience with directional drilling that was less than satisfactory, the Metropolitan St. Louis Sewer District (MSD) was hesitant to consider another trenchless approach for installation of gravity flow sewer lines. But upon further evaluation, pilot tube microtunneling (also referred to as guided boring) was the only method of installation that met all of the demands of the Black Creek Sanitary Relief Sewer project.

The demands of this project weren’t all that different than the requests system designers hear on a regular basis:

- maintain safe, pleasant ingress and egress
- limit the loss of parking spaces during the construction
- protect and maintain underground power, communications, water and gas utilities
- protect trees, landscaping, sidewalks and signage as much as possible, and
- minimize dust and debris

These demands were driven by a property owner who also represented an important community resource – a large regional mall. Other concerns on the site included a delivery truck and emergency vehicle access tunnel to avoid, multiple crossings under existing RCP storm sewers and a concern about the depth to rock and other undesirable materials for a pilot tube project.

Horner & Shifrin (H&S) worked closely with MSD to design the Black Creek Sanitary Relief Sewer, which included approximately 46 ft of 8-in. and 1,900 ft of 18-in. vitrified clay jacking pipe. Numerous design meetings and brainstorming sessions were instrumental in building a team that successfully reduced construction costs, enhanced schedule coordination, minimized contractor claims and improved the technical quality of the contract documents.

A thorough subsurface investigation was carried out in the design phase to identify the geologic conditions that would be encountered along the sewer alignment and their influence on the design and construction of the project. Subsurface investigations were performed by Geotechnology, Inc. of St. Louis, Mo. A total of 17 borings were drilled along the alignment of the proposed sewer. One at each proposed jacking/receiving shaft and a maximum spacing of about 200 ft between borings. Generally the soil along the sewer alignment was comprised of fill, silty clay, shaley clay, and clay.

“If I were to offer a general recommendation to engineers or cities considering undertaking a PTMT project, I’d strongly recommend that you take the old carpenter’s adage to heart,” said Ed Sewing, design engineer for Horner & Shifrin. “Measure twice and cut once. Only in this case that means make sure you thoroughly understand the soil conditions you’ll be operating in. Good geotechnical information is critical when doing any kind of trenchless work.”

The final selection of pilot tube microtunneling as the installation method was driven by smaller construction staging footprint requirements and smaller jacking and receiving shafts, all facilitated by the diameter of pipe to be installed.

“This project was a great illustration of how things should be done,” according to Jeff Boschert of the National Clay Pipe Institute. “The owner, designer and contractor all appreciated the importance of planning as a critical element in the success of the overall project. If I were to make one recommendation to an owner considering a pilot tube microtunneling project it would be to emulate this planning and teamwork approach.”
Two different pilot tube microtunneling installation methods were used on this project – one for each diameter of pipe installed. The first two steps were the same for both methods.

**Step 1: Install the 4-in. pilot tubes on line and on grade.**
During this installation, soil was displaced by the slant-faced steering head on the tip and no spoil was removed.

The pilot tubes were then directed on line and grade by rotation during advancement. The hollow stem of the pilot tubes provide an optical path for the camera to view the LED target housed inside the steering head. This target also displayed the head position and steering orientation. This established the center-line of the new sewer installation; the remaining steps follow this path. Once the pilot tubes reached the reception shaft, the theodolite target, video camera and monitor (guidance system) were no longer needed and were removed from the jacking pit.

**Step 2: Follow the pilot tubes with a reaming head.**
The front of an 11-in. reaming head was attached to the last pilot tube in the same manner the pilot tubes fasten to each other. The remaining pilot tubes and the reaming head were then advanced using 11-in. (OD) thrust (auger) casings, which transported the spoil to the jacking shaft for removal. The contractor removed the spoil conventionally using a muck bucket, but a vacuum method is sometimes a good alternative. During the installation of the auger casings, the pilot tubes were dismantled and removed as they were advanced into the receiving shaft. This step was completed when the reamer and auger casings reached the reception shaft and all spoil was removed from the bore.

**Method 1**
This method was used on the part of the project that included 8-in. diameter pipe.

**Step 3: Install pipe.**
The jacking pipe was used to advance the auger casings into the jacking shaft where the casings were uncoupled and removed one-by-one. There was no spoil removed in this step since the pipe had the same outside diameter as the auger casings.

**Method 2**
This method was used for all the 18-in. diameter pipe on this project and is the newest innovation to pilot tube installation.

**Step 3: A powered cutterhead (PCH) is installed behind the auger casings advanced by the product pipe.**
The cutterhead increased the diameter of the bore to match the outside diameter of the larger pipe. The remaining soil around the previously installed 11-in. auger casings (Step 2) was taken into the PCH and discharged via the reception shaft by reversing the auger flight direction. The final product pipe was then installed directly behind the PCH. As each section of auger casing was removed from the reception shaft, a section of pipe was installed in the launch shaft. This step was completed when the PCH entered the reception shaft.

The outside diameter of the PCH matched the OD of the vitrified clay jacking-pipe. There are two hydraulic motors housed in this particular PCH; the first to drive the auger flights and the second to drive the rotating cutterface. Housed inside the cutterface are three jetting ports connected by one hose for water distribution to keep the face clean and ease spoil transport. Lubrication ports keep jacking pressures down and were located in the rear of the machine connected by a single hose.

A total of seven hoses (four hydraulic, one for lubrication, one for jetting and one from a check valve) ran through the pipe to the PCH unit. Staging the pipe at the surface with the hoses installed before the start of this step was crucial to production times.

**Conclusion**
This project was delivered on time and on target. The pipe was installed on a 0.5 percent grade. Even with the longest drive at 280 ft, the greatest deviation from the exact target, both horizontally and vertically, was less than ¼ in. The success of this project demonstrates why pilot tube microtunneling can be a viable or even preferred method for trenchless installation of gravity sewers.

The considerations that drive a decision to undertake a pilot tube project are generally the same goals community-
ties always plan to achieve:
• High levels of worker safety
• Minimal disruption to the community
• Reduced requirements for site restoration
• Maximization of long-term value to the community

The selection of pilot tube installation methods is becoming more common as added emphasis is placed on the social costs of traditional open-cut construction. The inconveniences, business disruptions and property destruction, as well as engineering, environmental and safety issues involved with open-trench sewer construction, are beginning to challenge the practicality of open-cut in urban areas. Pilot tube microtunneling technology virtually eliminates the social costs of open-cut trenching and reduces basic construction costs in congested urban settings.

Some of the other important considerations when considering a pilot tube project include:
• Low equipment costs.
• Small topside footprint, small jacking pits and minimal surface disruption.
• No need for slurry separation tanks.
• Serious reduction in the amount of excavated material to be stockpiled or removed.
• Elimination of bedding. No materials purchase, no stockpiling and no trucking it in.
• Minimization of problems in contaminated soils as soil is not removed with a slurry.
• Eliminates the need to dewater an open-cut pipe trench.
• Significantly reduces the risk of collapse/settlement to surrounding structures and roads.
• Pipe movement/settlement from soil disturbance in an open trench and in the surrounding pipe zone is eliminated by tunneling.

This particular project used No-Dig pipe from Mission Clay. “Vitrified clay jacking pipe is well suited to this application,” Boschert said. “Its compressive strength is unmatched and no other pipe material can reasonably challenge the life-cycle offered by clay pipe.”

This article is abridged from a white paper on this project by Ed Sewing, Horner & Shifrin (www.hornershifrin.com), Mike Luth, Luth & Sons (www.fredmluth.com), and Jeff Boschert, National Clay Pipe Institute (www.ncpi.org). For a copy of the complete paper, visit the library page of the National Clay Pipe Institute’s Web site.
Geotechnical Aids for Microtunneling: Making the Right Choice

Paul C. Schmall, PE.

Microtunneling projects are subject to similar potential problems as those encountered in large-diameter tunneling. The presence of groundwater above planned subgrade at break-ins and break-outs may need to be addressed. In potentially unstable soils, ground treatment is typically required outside the shaft to prevent cave-ins when the eye is cut for launch or retrieval of the MTBM. Windows in shaft excavation support, uncovered as excavation proceeds downward, can cause blow-ins, creating voids in the soils outside the shaft that lead to surface settlement. Anticipated mixed-faced conditions or poor soils along the tunnel alignment will require some form of ground modification to present a more homogeneous horizon. And unexpected conditions encountered during tunneling operations must be addressed proactively to minimize costly delays.

Geotechnical methods such as dewatering, artificial ground freezing and grouting are tested, effective tools for addressing microtunneling challenges. In some situations, more than one method is available that will meet the basic objective. Jet grouting or ground freezing can be used to impart compressive strength and stabilize loose soils, for example. However, arriving at the optimum solution must take into account more than simply the physical end result. Cost and scheduling are often driving factors. Whether the problem is anticipated or unexpected, timely input of an experienced specialty geotechnical contractor to the project team is vital in ensuring that the selected method is one that is not only appropriate for the prevailing above-grade site conditions and in-situ soil characteristics but can also meet cost considerations and minimize the impact to the overall schedule.

DEWATERING METHODS

Dewatering, the lowering of the natural or “static” groundwater table to below the depth of excavation to permit the work to proceed “in the dry” is commonly used for tunneling applications. For microtunneling, dewatering is required only at the shafts for the excavation of the shaft and the break-out at the eye below the natural water table. For pipe jacking, often the alignment of the bore must be dewatered if it is below the water table.

The method used to excavate and support the shaft excavation determines the dewatering effort required. A tight steel sheeted excavation, and an H-beam and lagged pit in the same ground will require different degrees of care and dewatering effort. The characteristics of the soils within the excavation profile and below it represent the single most important determining factor with respect to how much water must be pumped and what techniques will be used.

Open Pumping

Open pumping techniques, such as sumps and drains, may be solely used to accomplish the dewatering of a pit or shaft in situations where the ground will remain stable when wet. Those situations may be where the soil is of low permeability, the groundwater levels are only slightly above subgrade, and where the source of recharge is not immediately adjacent to the pit. Open pumping, when appropriate, is generally the least expensive means of dewatering.

Predrainage Methods

Predrainage differs from open pumping in that it involves the installation of a dewatering system typically located outside of the work area and implemented prior to excavation. Predrainage is necessary when the soils are of moderate to high permeability, the groundwater level must be lowered more than several feet, and there is the potential for unstable soil conditions, i.e., the movement of soil under flowing groundwater. The three main tools of predrainage are deep wells, wellpoints and ejectors.

Where appropriate, deep wells are often the most cost-effective means of dewatering and present the least interference to the excavation and support of a shaft. They are typically installed outside of the excavation area and may be activated well in advance of any excavation work. Generally, deep wells are most effective where the soils are of at least moderate permeability, and the depth of permeable soils extends appreciably below the shaft subgrade so that well yields may be maintained while the shaft is dewatered.

Where soils are of low permeability or changes in geology are anticipated within or close to subgrade, wellpoints may be the most appropriate tool to accomplish the dewatering. The relatively low unit cost of wellpoints makes them most suitable for shallow dewatering in fine-grained and stratified soil where tight well spacing is required, or where water levels must be lowered very close to an underlying impervious layer, such as clay or rock. For shallow microtunnel shafts, generally less than 15 ft in depth, wellpoints may be installed outside of the shaft. For shafts deeper than 15 ft, the wellpoints are generally installed from within the shaft with the suction manifold (header pipe) supported from the shoring. In an H-beam and lagged shaft, it is common to back lag down to the water table, install the wellpoints immediately adjacent to the lagging, and then front lag down to subgrade to keep the wellpoints from being exposed within the shaft.
Where the depth of shaft below water table would require multiple stages of wellpoints installed and supported from within the shaft, ejectors may be used. The ejector well is a hybrid between wellpoints and deep wells. The ejector (sometimes called eductor), similar to wellpoints, pumps by suction, but overcomes the ordinary limitations of suction lift by employing a nozzle and venturi located within the ejector body, which in turn is positioned at the bottom depth of a well. The ejector mechanism can create high vacuum, which makes ejectors a rather effective tool in stabilizing fine-grain soils. Ejectors are commonly used to lift water as much as 100 ft. Due to the inefficiencies inherent with ejectors, they are typically utilized only in low permeability soils.

GROUND FREEZING

The ground freezing process converts in-situ pore water to ice through the circulation of a chilled liquid via a system of small-diameter pipes placed in drilled holes. The ice acts to fuse the soil or rock particles together, creating a frozen mass of improved compressive strength and impermeability. Brine is the typical cooling agent, although liquid nitrogen can be used in emergency situations or where the freeze is only required to be maintained for a few days. The technique is most cost-effective in a relatively well-defined niche where both support of excavation and groundwater cutoff are required and the ground improvement must be provided at significant depth or in difficult, disturbed or sensitive ground.

For microtunneling applications, ground freezing is primarily used for the support and groundwater cut-off for the construction of shafts and the modification of ground at the break-in or break-out.

In emergency situations, ground freezing is sometimes the only viable option. When unanticipated loose, subsurface conditions mired a jacked pipe TBM some 25 ft below the Garden State Parkway in New Jersey and just 35 ft from the receiving pit, the contractor’s jacking pressures were already near capacity. The likelihood of the need for excessive jacking pressures to re-initiate movement increased with each day the TBM was stuck. Liquid nitrogen ground freezing rapidly created a canopy of frozen ground above the TBM to stabilize the loose material and allow mining to continue.

Liquid nitrogen ground freezing was also the best option to address an emergency situation at the Newtown Creek WWTP in Brooklyn, N.Y. A new pipe was to be installed using microtunneling techniques. The access shaft to launch the microtunneling operation was located in an extremely congested area of the plant, adjacent to active tanks, and was supported by tight steel sheeting on all four sides. During excavation within the shaft, a split was uncovered in the sheeting through which the eye was to be cut. Approximately 13 to 20 cu yd of material blew into the excavation, displacing the ground behind the eye and replacing it with naturally sloughed-in material. Although slurry grouting was performed to fill the voids in the now highly unstable soil, it was not possible to accurately determine subsurface conditions since the disturbed zone lay beneath a concrete slab that abutted the excavation, and myriad underground obstructions were present above the proposed tunnel alignment. Since cutting the eye and installing a sacrificial concrete liner in preparation for future tunneling was a one-day operation, liquid nitrogen ground freezing was selected to stabilize the soils, allowing the eye to be cut and the liner installed without incident.

GROUTING SYSTEMS

A range of grouting systems is available that can be applied to meet anticipated and unexpected subsurface conditions related to microtunneling.

Jet grouting is accomplished with high-pressure, high-velocity jets located on a drill-mounted monitor. Simultaneous jetting and grouting hydraulically erodes, mixes and partially replaces the in-situ soil or weak rock with cementitious grout slurry to create an engineered soil-cement product of high strength and low hydraulic conductivity.

Jet grouting has a number of applications related to access and retrieval shaft construction and microtunneling or pipe jacking operations. The technique has been used to homogenize the tunnel horizon and minimize post-construction settlements prior to shallow, small-diameter tunneling through soft soils. Existing pipelines have been underpinned in preparation for tie-in to new systems. Where subsurface structures protrude into the shaft excavation or overhead obstructions prevent traditional excavation support from extending to full depth, jet grouting can provide complete closure. And jet grouting can provide a fully stabilized soil face at break-in and break-out points to counteract collapse potential under high groundwater and soil pressures.

Permeation grouting, typically accomplished with sleeve port pipes, is the injection of low-viscosity grout (most commonly sodium silicate) into the pores of granular soils without displacing or changing the soil structure. The characteristics of the ground are modified with the hardening or gelling of the grout. Permeation grouting is used to either increase the strength and cohesion of the soil or to decrease...
its hydraulic conductivity for groundwater control.

For shallow pipe-jacking operations beneath roadways or railway tracks, or for pipeline installation beneath existing utility lines, permeation grouting using horizontal drilling techniques provides a strengthened soil mass above the new tunneling alignment to protect against settlement. Sodium silicate grouting is also an effective measure of stabilizing soils loosened as a result of blow-ins through excavation support windows or gaps.

Fracture grouting is the intentional fracturing of the ground by high-pressure injection of a cement-based grout, creating intertwined lenses or veins of grout in order to provide reinforcement and improvement of the soil matrix. It is typically performed in lower permeability soils that cannot readily be permeation grouted. Grouting is performed through sleeve port pipes in several phases, with repeat injections at each port to ensure the formation of multiple fractures through the soil.

Compensation grouting is accomplished utilizing the fracture grouting technique but with the specific design intent of inducing tightly controlled ground heave to compensate for potential structural settlement or to control/reverse ongoing settlement. Compensation grouting has found a niche in protecting overlying structures during shallow, soft ground tunneling beneath. Fracture grouting applications for pipejacking include treatment of an unstable excavation face.

CONCLUSION

While these improvement methods are effective in resolving soil- and groundwater-related microtunneling challenges, it is worth restating that their application is highly specialized and subject to site-specific geotechnical, and logistical constraints. The input of a geotechnical contractor and/or engineer with the experience to evaluate the problem and develop the best approach is a critical component of timely and successful resolution.

Paul Schmall, P.E., is vice president and chief engineer at Moretrench Inc., a specialty geotechnical contractor based in Rockaway, N.J.
Open-cut construction methods were not an option. In order for a proposed sewer line to flow by gravity, the pipeline required an alignment through the hills surrounding the Carbon Canyon Dam in Brea, Calif. This would put the pipeline at depths greater than 100 ft below the surface in some areas. Installation using a trenchless form of construction was the only feasible option. The trenchless method chosen was conventional microtunneling.

The purpose of the project was to eliminate the Carbon Canyon Pump Station, which is owned and operated by the Orange County Sanitation District (OCSD). The Carbon Canyon Pump Station pumps wastewater up and over the Carbon Canyon Dam through a 4-in. and a 6-in. force main. By installing a new gravity sewer pipeline, OCSD could abandon the existing pump station and eliminate the operational, maintenance, and upgrade costs associated with owning the pump station. OCSD hired RBF Consulting of Irvine, Calif., as the consultant for design and construction support.

Agency coordination played a major role during design and construction of the project. Agencies having jurisdiction included the U.S. Army Corps of Engineers, California Department of Fish and Game, County of Orange, OCSD and a private oil company that owned the land on the downstream side of the dam. The microtunneling alignment was in an environmentally sensitive area that was home to various bird species during breeding season.

The total project consisted of approximately 5,000 lf of gravity sewer, with 1,540 ft installed by microtunneling and the remaining portion using open-cut trenching. Design for the microtunnel portion called for 36-in. diameter pipe, and 24-in, and 33-in. diameter pipe for the open-cut portions. The microtunneling portion consisted of two drives, approximately 870 ft and 670 ft. The depths of the three microtunneling shafts were approximately 10 ft, 20 ft and 55 ft.

The drive lengths and shaft locations were optimized during the design. As mentioned previously, portions of the pipeline are at depths greater than 100 ft below the surface. It was evident that a very deep shaft and a microtunnel drive of significant length would be required. The only logical location for the intermediate shaft was at a depth of 55 ft. This created the drive lengths of 870 ft and 670 ft. The drive lengths and shaft locations were optimized during the design. As mentioned previously, portions of the pipeline are at depths greater than 100 ft below the surface. It was evident that a very deep shaft and a microtunnel drive of significant length would be required. The only logical location for the intermediate shaft was at a depth of 55 ft. This created the drive lengths of 870 ft and 670 ft.

Trying to decrease the long drive by just 100 ft would require a shaft 70 ft deep. It was concluded that the 55-ft deep shaft and the 870-ft drive was the best combination. Although 870 ft can be a long microtunnel drive, it was determined that the use of an intermediate jacking station would be used to keep jacking loads below the maximum allowed for the pipe.
An accurate geotechnical investigation was an essential component of the microtunnel design. Once the microtunnel boring machine (MTBM) has begun a drive, it can only keep moving forward. If the MTBM cannot advance or something goes wrong mid-drive, the only way to rescue the MTBM is by excavating. With depths greater than 100 ft, excavating a shaft this deep would not be feasible, which is why it was essential to complete a thorough and accurate geotechnical investigation during the design phase. For this project, a total of 11 borings were taken along the microtunnel alignment, which included the shaft locations. The borings were used to develop a geotechnical profile for the entire pipe alignment so the contractor would have a good understanding of the type of soils that would be encountered. The borings revealed that the predominant soil type to be encountered in the microtunnel drive would be Fernando Formation Bedrock, which is described as a soft bedrock that can be broken down by hand or light tools. There were also cemented zones to be expected on the order of 12 in. thick.

Frictional jacking forces to be anticipated were calculated using the soil parameters and various pipe materials. Based on the soils investigation, jacking load calculations, installation history and discussions with OCSD, a pipe material was chosen. The pipe chosen was 36-in. centrifugally cast fiberglass reinforced polymer mortar pipe, manufactured by HOBAS Pipe USA. Although hydraulically the pipe only needed to be 24-in. diameter, the predicted jacking loads required at least a 36-in. diameter pipe. It was also assumed that contractors would be hesitant to microtunnel a 24-in. pipe for that long a drive and would most likely bid the job with at least 36-in. diameter pipe.

Ken Thompson Inc. of Corona, Calif., was the general contractor and hired Vadnais Corp., of Vista, Calif., as the microtunneling subcontractor. The contractor bid the project to install 42-in. HOBAS pipe since he already had an MTBM for 42-in. pipe. The 55-ft deep shaft was constructed as the jacking shaft. The contractor’s plan was to microtunnel in one direction and complete one drive, and then retrieve the MTBM and microtunnel in the opposite direction for the second drive. This was a cost savings measure for the contractor since it only had to construct one microtunneling shaft, although it was very deep. The contractor chose to use an MTBM cuttinghead suited for mixed ground conditions, which meant it had cutting tools to grind through the softer soils as well as disk cutters to handle any rock it may encounter.

Dimensions of the 55-ft deep microtunneling shaft were 18 ft by 12 ft. The shaft was excavated and shored with steel piles and 1-in. steel plates. The base slab and the thrust block were completed at the bottom of the shaft to accommodate the microtunneling equipment. When the 870-ft drive got under way, it was soon realized that the soil conditions were ideal for microtunneling. The soft bedrock was soft enough where the MTBM could easily move through, yet stable enough to not fall against the pipe and create increased frictional jacking forces. Once the contractor was able to install the first few pipe segments, production was averaging between 40 and 50 ft per day. The biggest surprise during the microtunnel was the low jacking forces required to advance the pipe. During the design phase, HOBAS Pipe USA literature stated that its 36-in. jacking pipe could safely handle a 250-ton jacking load, and its 42-in. jacking pipe could handle a 295-ton jacking load, all with a factor of safety of 3.0. However the actual jacking loads experienced during construction were far below the pipe’s limit.Maximum jacking loads throughout the 870-ft drive were regularly in the 40 to 60 ton range.

The drive began on Jan. 13, 2009, and reached the receiving shaft on Feb. 6, 2009, 19 working days later. The MTBM was retrieved and the microtunneling shaft was prepared for the second drive. For the second drive, which was 670 ft, the microtunnel was completed with similar production rates and jacking loads. Construction of the Carbon Canyon Dam Sewer was successfully completed in July 2009.

Tori Yokoyama P.E. is a Project Engineer with RBF Consulting. He can be reached at (949) 472-3431 or tyokoyama@rbl.com.
Despite the fast-paced development of the technology of pilot tube microtunneling in the past 10 years, these techniques can only be used in displaceable grounds. Therefore the conventional ground displacing pilot drilling technology cannot be used in dense material (SPT values of standard penetration tests > 35) and obviously in rock.

With the development of a patented steering technology called “Front Steer,” Bohrtec has for the first time overcome the application restrictions and enabled applications in very dense strata with SPT values > 35 and in moderately strong rock with strengths of up to 20 MPa. This is accomplished with the help of a guided auger boring system that excavates the ground as it advances. The expanded possibilities offered by this application does not affect the economic advantages of the pilot tube method – also known as guided boring – because the system with the Front Steer retains the advantages of quick and easy set-up of the equipment on site and simple operation.

**Boring with the Front Steer**

Just like the conventional ground displacing methods – the Front Steer system uses the proven optical guidance system consisting of theodolite with CCTV camera, monitor and LED target board. As shown in Figure 1, the ground/rock is continuously excavated by the cuttinghead and then transported to the starting shaft by augers with a hollow center for the optical path. The steering pipe uses the ground reaction force for steering. The machine operator can steer remotely by tilting the steering pipe in either manual or automatic mode and the control panel shows the respective steering position of the head.

**Pipe Eating in Berlin**

Although the Front Steer technology was developed for non-displaceable soil and weak rock, the system had a special challenge on the first project in Berlin. In the Berlin district of Wilmersdorf, an existing sewer 175-mm pipe needed to be replaced by a new 300-mm sewer on
the same alignment. From the beginning, Berlin Water Service plans included on-line replacement by trenchless construction using the pipe eating method because the 60-m long line passed below six mature trees with trunk diameters of 300 to 350 mm.

When the Berlin company Frisch & Faust, which already had different Bohrtex pilot drilling systems, received information about this project, it found this to be the perfect occasion to use the new guided auger boring method with Front Steer, which excavates the ground as it advances.

The company already had the BM 500 optical measuring system and the appropriate steel casings with hollow augers for the job. Only the Front Steer and the operation and control panel had to be provided. The six house connections on this length of sewer were diverted in advance. When doing this it was found to be necessary to remove the house connection branches before beginning the drilling works because they were all fixed to the old sewer with three metal clamps. Due to water pipes, gas pipes and electrical lines across the starting shaft the pit was supported with wood sheeting with a concrete thrust wall. One week before beginning of the drilling works the existing sewer was grouted.

![Fig. 1: Front Steer system excavates the ground as it advances](image1)

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After completion of all preliminary works, the Bohrtec team arrived with the Front Steer equipment and after a few hours had successfully drilled the first few meters. From the beginning, the crew had no difficulty controlling the steering head even with the different soil conditions, which included a sand/gravel bed below the old pipe, stone bedding and soils of the classes LBM 2/LBM 3, as well as the grout in the old line. These challenges, however, did not lead to any problems with regard to the soil clearing or steering.

Already after a short induction period with the new steering system, John Adams, an experienced machine operator with Frisch & Faust, was able to steer the head independently and without any problems due to the simple operational handling. The team of Frisch & Faust, well-trained in many conventional pilot tube projects, achieved an advance rate of about 4 m per hour, including all coupling and other activities on its first day. At the end of day, 25 m of 419-mm OD steel casings had already been driven successfully, even though the drilling only begun late in the morning.

After two days, 54 m of casing were driven without incident. Although the installation of the steel casings could have been completed on this second day, work was stopped short before reaching the target shaft in order to demonstrate the Front Steer driving into the target shaft and to explain the operation to owner representatives the next morning. After reaching the target shaft, the steering head was uncoupled and the team started to push in the 300-mm clay jacking pipes.

It took only four days to complete the 60 m drilling length to the satisfaction of all parties involved and the pipe eating process with Front Steer proved to be a success.

**Breaking New Ground**

Inspired by the successful use of the Front Steer on the Misdroyer Street project, Frisch & Faust prepared an alternative proposal for the Berliner Strasse/Treskow Allee project. An existing 200-mm clay sewer pipe had been in operation for several years but because of further development an additional connection to main sewer became necessary.

One section of this replacement sewer, which passed beneath the rails of a tramway, was planned to be performed in trenchless construction while open trench was intended for the installation of the rest of the pipe run. The original plan involved leaving the abandoned and backfilled sewer in the ground since laying the new pipe on the same alignment would not have been possible without disturbing the rails.

As an alternative proposal, Frisch & Faust proposed the on-line replacement of the existing sewer by pipe eating with the Front Steer system. The essential advantage of this proposal was the fact that the risk of meeting unknown obstacles was minimized by following the existing line.

After approval from Berlin Water Service, the preliminary works were done and the Bohrtec Front Steer was used a second time for the on-line replacement of an existing sewer. After a smooth beginning of the drilling works, after 5 m there was a dramatic increase of the pushing force and the cutting wheel torque. It was presumed that a sheet pile had been struck since according to the construction plan there had been some sheet piles at this position of the old line which should have been cut down to a depth of about 3 m, but this was obviously not the case. Despite the risk of drilling head damage, it was decided to continue boring because the cost of disturbing the rails and the consequential cost for the rail replacement bus service would have been much higher. The sheet pile remains were passed despite much wear and tear of the cutting tools and the full length of 28 m was completed successfully. The choice of the Front Steer proved to be a lucky choice especially with regard to the sheet pile. If a conventional ground displacing drilling system had been used – as originally planned – the drilling would have had to be stopped when the sheet pile was encountered, thus inevitably requiring the rails to be disturbed and the provision of a special bus service.

**Conclusion**

Although the described projects of trenchless pipe replacement using the pipe eating method to remove the old line do not really represent the planned standard use of the new Front Steer system, it has proved to be effective for guided auger boring even under these extreme conditions.

With the development of the Front Steer system, Bohrtec has extended the range of application of the well proven and economical pilot tube technique successfully used for small diameters and short lengths into non-displaceable ground (SPT > 35) and rock with strengths of up to 20 MPa.

Dr.-Ing. Gregor Nieder is managing director at Bohrtec GmbH, Aldorf, Germany.
Asset Protection & Business Succession Strategies

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CALIFORNIA

Byron
Walter C. Smith Co. Inc., Clovis, Calif., completed a 900-ft crossing of Old River as part of the Victoria Canal Conveyance Pipeline for the Contra Costa Water District. Walter C. Smith used an Akkerman SL-74, skinned up to 96-in., to install 10-ft lengths of 96-in. welded steel pipe through sand with 45 psi of ground water in the early part of the alignment, followed by predominantly clay in the second half. The Akkerman SL-74 was equipped with high-pressure jetters to help the machine mine through the clay. Modifications to the slurry plant were also required to adjust to the change in conditions. Two shafts, one 90 ft deep and one 50 ft deep, were constructed. The project began in spring 2009 and finished in late summer/early fall. The estimated value of the microtunneling work was $4 million.

Concord
The Central Contra Costa Sanitary District (CCCSD) and the City of Concord are constructing the A-Line Relief - a 6-mile long gravity relief interceptor sewer located in the northern portion of service area. Part of the project involved 870 ft of 72-in. pipe installed by microtunneling. The MTBM pipe jacking for the 72-in. concrete pipe occurred in two drives of 410 and 460 ft from a common jacking shaft. The microtunneling contractor was Nada Pacific of Caruthers, Calif. Crews used an Akkerman MTBM and Ameron International reinforced concrete pipe.

COLORADO

Aurora
BTrenchless, a Division of BT Construction Inc., of Henderson, Colo., in October completed the last of 4,200 ft of tunnels and bores for Aurora’s Prairie Waters project. These tunnels were crucial to the completion of the $754,000,000 project. BTrenchless utilized various construction methods to account for the diverse ground conditions, including seven microtunnels, four TBMs, two hammer bores and six auger bores. Sizes of the installed tunnels ranged from 60 to 79 in. in diameter.

The Prairie Waters project for the City of Aurora, is the first large-scale water reuse project in Colorado's history. Slated for completion in 2010, water will be pumped from the South Platte River, undergo a six-step treatment process, and ultimately replenish the diminishing drinking water supply.

The microtunneling consisted of seven drives totaling 2,051 ft. The drives ranged in length from 149 to 585 ft and depths ranged from 15 to 35 ft. Ground conditions consisted primarily of wet, running sands with some clays. Crews used an Akkerman SL-74 to install 78-in. Permalok.

CONNECTICUT

Hartford
Northeast Remsco has completed three of five drives as part of the Homestead Avenue Interceptor Extension. Crews are using a Herrenknecht AVN-1800 to install 72-in. RCP 12 to 35 ft below the surface through soft clays. Drives cross under active railroad tracks and city streets. The longest of the drives is 1,180 ft. Work is expected to be complete by June 2010.

FLORIDA

Cocoa
Huxted Tunneling completed the South Mainland Water Transmission Main for the City of Cocoa. The project consisted of four drives of 66-in. Permalok steel casing pipe 40 ft deep in clay, sand and silt. The project included two crossings of I-95, a crossing of an I-95 ramp and one canal crossing. The drives totaling 950 ft, were completed using a 67-in. Iseki Unclemole. The project was completed in two phases. The first phase was completed in April and the second phases was completed in October. Globetec Construction was the general contractor.

MIAMI

Huxted Tunneling completed a crossing of I-95 with limited construction easement for the Miami Dade Water and Sewer District. The project involved installing 260 ft of 30-in. Permalok steel pipe in one drive. The pipeline crossed 25 ft below the surface of the pavement through limestone and sand under groundwater. Crews used a 31-in. Iseki Unclemole.

Port Manatee
Huxted Tunneling is preparing for the Port Manatee Casing Installation project for the Manatee County Port Authority. The project consists of two drives, each 150 ft long and 20 ft deep in silty sand and groundwater. Crews will use a 67-in. Iseki Unclemole to install 66-in. Permalok steel pipe and a 61-in. Unclemole to install 60-in. Permalok. The project is part of a dredging project in conjunction with a CSX railway crossing. The general contractor is Spectrum Underground. Crews were expected to mobilize in mid-November and complete tunneling by the end of the year.

INDIANA

Indianapolis
Bradshaw Construction Corp. is constructing the Belmont North Relief Interceptor – Section 1, a 5,300-ft sewer relief interceptor consisting of 4,100 ft of 72-in. RCP installed by pipe jacking beneath local roads from 10th to 19th Streets on the west side of the White River. The tunnels will be mined utilizing a microtunnel boring machine manufactured by Rasa Industries Ltd. An additional 1,200 ft of 72-in. RCP will be installed by open-cut.

IOWA

Centerville
Huxted Tunneling will mobilize Dec. 1 for the Lake Rathbun Intake Structure project for the Rathbun Regional Water Association. The project consists of one
drive of 545 ft of 36-in. Permalok steel pipe 50 ft deep in lean clay. The project also includes an underwater recovery of the 37-in. Iseki Unclemole. Expected completion date is January 2010.

LOUISIANA

Shreveport

Huxted Tunneling completed the JLS Surface Water Intake Project for JLS Partners in February. Huxted, working as a sub to Reynolds Inc., completed a 165-ft drive of 30-in. Permalok steel pipe, 50 ft deep through hard clay, using a 31-in. Iseki Unclemole. The project, which was needed for a cooling water intake for a power plant, included an underwater recovery.

MASSACHUSETTS

Boston

The Massachusetts Water Resources Authority is in the midst of a nearly $60 million project to minimize overflows to Chelsea Creek and Boston Harbor. The project involves the construction of 2.5 miles of new sewer lines, primarily using microtunneling. Barletta Engineering, Canton, Mass., was selected as the primary contractor. Cruz Contractors, Holmdel, N.J., is the microtunneling sub.

The microtunneling totals approximately 11,000 ft – more than 10,000 ft of 48-in. RCP and 825 ft of 66-in. Hobas. Crews are using a Herrenknecht AVN-1200 and AVN-1500 for tunneling. The project includes 19 drives, the longest of which is 1,200 ft. Depths range from about 25 to 45 below surface. Soil conditions include glacial tills and Boston blue clays, which required high-pressure pumps to cycle through the separation plant. Tunneling began after six months of set up and utility relocations. Tunneling is approximately 70 percent complete.

NEW YORK

New York

Cruz Contractors, working as a sub to Perini, is completing 11 runs of microtunneling as part of the MTA East Side Access project. The microtunnels are primarily needed for relocation of utilities including drainage, sewer and electric.

Cruz is using a Herrenknecht AVN-1200, AVN-1500 and AVN-1600 for tunneling. The project includes 19 drives, the longest of which is 1,200 ft. Depths range from about 25 to 45 below surface. Soil conditions include glacial tills and Boston blue clays, which required high-pressure pumps to cycle through the separation plant. Tunneling began after six months of set up and utility relocations. Tunneling is approximately 70 percent complete.

NEW JERSEY

Englewood

The Overpeck Valley Parallel Relief Sewer Project for the Bergen County Utilities Authority is a $65 million CSO improvement program to meet a state consent order by 2010. One major program component included a total of 6,000 ft of 72-in. RCP installed by a Herrenknecht AVND-1800AB. The alignment includes drives through 2,788 ft of extremely soft glaciolacustrine varved clay, 3,214 ft of loose to medium dense mixed soils containing silty sands, gravels, and boulders, and crosses under the New Jersey Turnpike, U.S. Highway Route 46, and a CSX Railroad Intermodal Yard and a branch mainline. Two types of MTBM cutterheads were used, one configured for the weak varved clay, and one for the mixed soil conditions. The MTBM was also equipped with a double-steering system consisting of a standard front steering joint and a second trailing steering joint to assist grade control should adequate steering not be achieved by the front primary steering in extremely weak soil conditions. The entire microtunnel project was completed successfully within schedule, under budget, with zero claims. The contractor was Northeast Remsco Construction and the engineer was Hatch Mott MacDonald.

WISCONSIN

Milwaukee

Super Excavators Inc., Menomonee Falls, Wis., is in the final stages of the $29.5 million Barclay/4th and Chase MIS Replacement for the Milwaukee Metropolitan Sewerage District. The job includes more than 10,000 total ft of microtunneling. Crews are using an Akkerman SL-74 to install 6,071 ft of 72-in. RCP in nine drives. The longest drive is 1,068 ft. Average depth for the project was 35 ft. Ground varied from 0 blow count organics, to hard silty clay with boulders. Additionally, crews are using an Akkerman SL-60 to install 4,643 ft of 48-in. RCP in eight drives. The longest drive of 48-in. was 800 ft. The average depth was 51 ft. The ground conditions for this portion varied from hard silty clay with boulders, to full face dolomite rock with average psi of 12,000. Mining began in August 2008 and is on track to complete in November 2009.

Arlington

Bradshaw Construction Corp. is preparing to construct three sewer tunnels under Arlington National Cemetery as part of the Potomac Interceptor project. Two of the tunnels will be direct jacked 48-in. RCP and the third is a 60-in. steel casing. Ground conditions range from rock to loose wet sand. A Herrenknecht micotunneling machine will be used.

Suffolk

Huxted Tunneling completed the installation of a 200-ft drive of 42-in. Permalok under the foot of dam as part of a new intake structure. The pipeline, part of the Lake Burnt Mills Dam Safety Modifications Phase 2 project, was completed through soft, sandy silt at depths of 40 ft and under high groundwater. Crews used a 43-in. Iseki Unclemole.
Akkerman Inc.

Akkerman Inc. of Brownsdale, Minn., has created a new product for its Guided Boring Machine (GBM) line. The Powered Reaming Head (PRH) is an upsizing tool that is part of the third step of the GBM process.

The PRH can be configured to 14, 16 and 20 in. OD, and is designed to work in 96-in. minimum ID or trenchbox shafts. The PRH features separate jetting lines on reaming head arms to lubricate spoils and separate lubrication lines on the rear section to reduce jacking forces on the pipe. The PRH features an auger drive for spoil removal to the reception shaft. The PRH operates with a standard jacking frame, P100Q and P150Q power units, uses standard GBM 11” OD thrust casings, and is controlled by the GBM operator in the launch shaft.

For more information on this and other Akkerman Inc. products, contact (800) 533-0386 or visit www.akkerman.com.

Derrick Equipment

Derrick Equipment Co. presents the 20-ft Modular Separation System with a versatile platform strategy for various civil engineering applications including horizontal drilling rigs, microtunneling systems and slurry wall millings. An integrated base tank with centrifugal pumps for feeding hydrocyclones accommodates a complete slurry separation system for a wide range of ground conditions.

Up to three equipment platforms can be mounted on the 20ft base tank, providing continuous production. Flexible platform configurations such as an FLC 2000 four-panel shaker, an FLC 2000 four-panel mud cleaner with 6in. cones, or a DE-1000 hydraulically driven centrifuge provide optimal slurry separation. FLC-2000 machines feature Super G vibrating motors for continuous high G-force linear motion and hydraulic adjustable while drilling (AWD) mechanisms achieve maximum solids conveyance. Derrick’s patented, performance-enhancing polyurethane screen surfaces or corrugated Pyramid screen technology, offering 57 percent more screening area, result in the most efficient solids removal. For information visit www.derrickinternational.com.

Herrenknecht AG

Pipe overloads and angular deflections during pipe installation can cause pipe or tube sheet damage. Sometimes splittings on the tube sheet or longitudinal cracks in the pipe are only detected years later, when leakages occur. Herrenknecht now offers the Online Load Control (OLC) System to avoid overloads in advance.

Four distance sensors measure the gap widths of selected pipe joints. The angular deflection is calculated, compared and recorded in detail by the data acquisition system. But OLC from Herrenknecht offers more than that: The admissible load of the joint is calculated based on the angular deflection, thrust force and material specification of the pressure transfer ring. Actual and admissible thrust forces are compared and visualized. The operator can intervene and adapt the thrust force through the high-precision operation of the interjack stations. Therefore overloads can be avoided before critical limit values are reached.

HOBAS

HOBAS centrifugally cast, fiberglass-reinforced, polymer mortar pipe is ideal for nearly every trenchless application including microtunneling/jacking, sliplining and tunnel lining for both pressure and gravity applications. It provides inherent corrosion resistance, superior hydraulics and a long, maintenance-free life. Key applications are sanitary sewers, potable water and corrosive environments.
Sections join with push-together, leak free, gasket sealed couplings. After more than 45 years of reliable service, the use of HOBAS pipe is expanding faster than ever and it can be found in most U.S. municipalities. Non-pressure and pressure classes are manufactured in diameters from 18 to 110 in.

For more information, call (800) 856-7473, e-mail info@hobaspipe.com or visit www.hobaspipe.com.

ICON – Bohrtec

ICON adds the most powerful guided auger boring machine to its extensive product line. The Bohrtec BM600LSC machine has been designed to install large diameter jacking pipes with a maximum outside diameter of 50.39 in. from a 13.8-ft shaft for a 2-m long pipe and a 10.5-ft shaft for a 1-m long pipe with 262 tons of jacking force, 112 tons of pull back force and 36,878 ft-lbs of torque. The BM600LSC is specially designed to work with a 156-hp hydraulic variable speed pack. Unlike other machines, the jacking frame of the BM600LSC can be easily extended to accommodate a variety of pipe and lengths up to 60-ft in length. The BM600LSC can work with existing augers without the use of a theodolite guidance system and bore conventionally through all types of ground conditions, or it can be used with the pilot tube method. Information: (800) 836-5011 or d.crandall@iconjds.com.

Vermeer

Underground contractors now have a new option for the trenchless installation of water and sewer lines. The AXIS guided boring system from Vermeer is a pit-launched, laser-guided tool to install 10- to 14-in. pipe. The system can achieve pinpoint, on-grade accuracy and has the ability to install up to 350 ft of steel, clay, HDPE or PVC pipe in one bore. Spoil is removed from the cutterhead via a vacuum excavation system, thus keeping the pit clean and the system can either push or pull the product pipe into place, providing flexibility in the type of product installed.

The AXIS system is made up of four main components — the power unit, rack, vacuum pump and vacuum tank. Because of the flexibility of the four major components, various setup configurations can be used to adjust the machine’s footprint based on jobsite and transport characteristics.

VMT

VMT is known as one of the leading navigation system supplier for tunnel boring machines and excavation machines for more than 15 years. VMT technology is helping contractors all over the world to complete projects quickly and efficiently. In addition to the navigation technology, VMT developed several other system solutions, which are all part of the modular SLS product family. The contractor benefits are the flexible usage of the VMT equipment. In addition to the complex navigation solutions for microtunnelling, VMT is able to provide automatic bentonite lubrication systems, inter-jacking station control systems, telephone and communication systems, network camera systems and monitoring systems for pipe stresses and load control. For more information, contact a.sellert@vmt-gmbh.de.
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