Innovative Methods Tame Multi-Diameter Microtunneling Project

By Mark Bruce¹

¹ President, Can Clay Corp., Cannelton, IN

Abstract:

The contractors completing the work on the combined sewer overflow (CSO) Remediation Plan for the City of Atlanta are thought to have used one of the largest ranges of microtunneled pipe sizes in North America. The plan was implemented through three contracts for the Greensferry, Stockade and McDaniel basins. Soils varied from wet clays to solid granite.

What is thought to be a record length drive, 750 ln ft of 24-inch diameter pipe was installed at remarkable low jacking loads, 37 tons, using a recent innovation of protruding pins to mix the soils and the lubricant (Pin Lube). 42-inch diameter pipe was successfully installed in an area that was determined to be an old landfill site. 18-inch pipe successfully withstood 220 tons of jacking force to complete a difficult drive.

Granite rock created great difficulties with small diameter machines, but the innovative hammer systems and a persevering contractor, who overcame initial disappointments, resulted in solid granite tunneling for installation of 18-inch vitrified clay pipe (VCP).

The size of the projects, part of the $3.9 billion Clean Water Atlanta program exceeded $250 million and included both trenchless and open trench installations. The schedule was tight. The entirely urban setting, with narrow streets, was a challenge to the contractors.

The range of diameters installed is thought to be one of the most diverse in North America within a single plan. The project engineer’s criteria for long life materials and requirements for high jacking strengths limited many materials from consideration. Microtunneling pipes installed were 8-inch, 12-inch, 18-inch, 20-inch, 24-inch, 30-inch and 42-inch VCP using various pilot tube, hydraulic powered pilot tube, impact hammering pilot tube and slurry microtunneling systems.
Background:

In July of 1998, to settle a lawsuit brought against the City by the United States Environmental Protection Agency (EPA), the Georgia Environmental Protection Division (EPD), the Upper Chattahoochee Riverkeeper and a citizen downstream, Mayor Bill Campbell signed a Federal Consent Decree committing the City of Atlanta to an accelerated program of activities designed to further improve water quality in metro Atlanta streams and the Chattahoochee and South Rivers. The Consent Decree specifically directed the City of Atlanta to develop and implement, by 2007, a solution that would end water quality violations resulting from CSO’s.

The City of Atlanta accelerated its ongoing sewer improvements, including an intensive evaluation of sewer pipe conditions; rehabilitation or replacement of defected or capacity limited sewer lines; a grease management program; and a capacity certification program for new development. A series of construction projects designed to improve reliability of the City’s sewage pump stations is also underway. Sanitary sewer related improvements are to be completed by the Consent Decree deadline of July 1, 2014.

Sewer separation is the construction of new sanitary or storm sewers within a combined sewer service area. The existing sewers will then serve as either sanitary or storm sewers, depending upon the design intent of the newly constructed sewers. In a separate system, storm water is conveyed to a storm water outfall for discharge directly into the receiving water. The sanitary flow is typically piped to a treatment plant for screening and disinfection before being discharged.

Under the current Authorized CSO Remediation Plan, the City will fully separate the Greensferry and McDaniel CSO Basins and the Stockade Sub-basin (Custer CSO Basin). This plan will increase the City's total separated area from 85% to about 90% and eliminate two CSO facilities and one CSO regulator.
**Project Overview**

The construction of the three contracts were completed prior to the Fall of 2007 per the requirements of the Consent Decree and contract deadlines. Project engineers include PB Water, HDR, WL Jordan, MSE and GDH.

The Stockade basin required approximately 56,000 ln ft of new pipe installation, Greensferry required approximately 60,000 ln ft and the McDaniel basin required approximately 60,000 ln ft of sewer separation. Ruby Collins Reynolds EPR Joint Venture performed both the Stockade and Greensferry construction. Rockdale Pipeline, Inc. performed the McDaniels basin work.

Much of the installation was conventional cut and cover – open trench installation. However, extensive use of microtunneling was used to minimize the impact to the community on the three projects where depth, soils, site congestion or concern for impact to the residents dictated a trenchless solution. The Stockade Basin improvements are indicative of the urban settings of the work in all three basins (Figure 1.).

Westcon was the primary subcontractor for the Stockade and Greensferry basins. Additional, rock tunneling for 18-inch (450 mm) pipe was accomplished by McCowein Drilling on the Stockade project. The microtunneling subcontractor for the McDaniels basin was Huxted Tunneling, Inc with the guided boring tunnels by Allied Contracting, Inc.

VCP was selected for all microtunneling installations for jacked pipes of size ranges from 8-inch through 42-inch nominal internal diameter. Vitrified clay pipes were selected to meet the minimum 100 year design life required by the city, their ability to withstand high jacking loads and resulting economical installation costs. Jacking strengths of the pipes ranged from 200 tons for 8-inch diameter to 1700 tons for 42-inch diameter jacking pipes. Joints were made of #316 stainless steel sleeves and elastomeric seals in combination with precision diamond ground profiles on the pipe ends. Jacking strengths of the pipes ranged from 200 tons for 8-inch diameter to 1700 tons for 42-inch diameter jacking pipes.
Jacking shafts used a variety of techniques including drilled shafts, modular shaft panels and stacked conventional trench boxes. Shafts were completed in soils that were predominately clays with occasional intrusions of granite which caused some delays and re-design of some of the microtunnel drives. In a few shaft constructions upper levels of clay surface material covered more than 20 vertical feet of solid granite. Maintaining the court mandated agreed schedule was paramount and the three contracts met the required deadlines.

Engineering adjustments were often made to accommodate the actual field conditions of the soils and sites as needed. Time lines to avoid sensitive community needs such as schools were adjusted. Tunnel designs and drive lengths were extended to minimize the impact to a elementary school while still maintaining the sensitive completion schedule for the project.
Notably, one pilot tube microtunnel drive placed 220 tons of jacking load on the 18-inch VCP jacking pipe to re-start the push without exceeding the pipe strength. This was accomplished by using a combination of an additional jacking frame to pull and extra separate hydraulic jacks to assist the original jacking frame.

Traditional and Innovative Equipment

The sizes of tunneled pipe jacked on the project were 8-inch, 12-inch, 18-inch, 20-inch, 24-inch, 30-inch and 42-inch (200, 300, 450, 500, 600, 750 and 1100 mm). It is thought that this range may be the broadest most comprehensive range of sizes within such a short time frame used on a separate project in North America. The VCP jacking pipes were manufactured by Can Clay Corp. and NoDig Pipe, Inc.

The variety of equipment, some with special modifications, incorporated special modifications that are unique to North America.

Notable equipment used for tunneling operations:

1. Slurry microtunneling
   a. Akkermann
   b. Herrenknecht
   c. Iseki
   d. Soltau
2. Pilot tube microtunneling (Guided boring), Figure 2
   a. Akkerman
   b. Herrenknecht
   c. Soltau
3. Special adaptations
   a. Pin lube system – Microtunneling, Inc.
   b. Guided boring with rock hammers - McCowein Rock Drill Solutions
      i. Custom modifications to pilot hammer used on an Akkerman jacking frame
      ii. Halco Storm 500 air hammer
The pilot tube systems used the conventional multipass system with casings powered from the drive shaft as well as newer methods where a hydraulic powered reaming heads back reams to widen the hole. The processes varied from the two pass method for 8-inch diameters to three pass on 12-inch through 18-inch diameter pipes.

**Records of Notable Achievement**

The team of city managers, contractors, engineers, combined with their suppliers to keep the project on schedule. Individually, separate sections of installations may not have been so notable, but taken together with a tight deadline in difficult urban conditions, the Stockade-Greensferry-McDaniels combined sewer separation project for the City of Atlanta must be recognized for what it was, a difficult project.

In acknowledgement of the difficulty and timeline the combined three projects came in at 60% of engineers estimates, for a total in excess of $240,000,000. The combination of techniques, some that were not yet invented at the beginning of the project, was a tribute to the innovators, the construction managers that used them and the City that allowed their use.

Ultimately, 2024 ln ft of 42-inch, 4963 ln ft of 30-inch, 1912 ln ft of 24-inch, 200 ln ft of 20-inch, 2233 ln ft of 18-inch, 2204 ln ft of 12-inch and 1312 ln ft of 8-inch vitrified clay jacking pipes were installed for a total of nearly 15,000 ln ft of microtunneling.

**Need is the Mother of Invention**

These projects demonstrate that ingenuity and perseverance can triumph in the face of new challenges. Two extremely noteworthy cases of this occurred on this project.

**Case 1**
Microtunneling in relatively small diameters has limitations on distance achievable on a single drive. Jacking loads can be segmented with the use of Intermediate Jacking Stations on larger diameter pipes, greater than about 30-inch (750 mm) internal diameters. Smaller diameter do not allow for sufficient space for manned entry after completion of a drive for removal of the intermediate jacks.

Specifically, as the project schedule advanced, the timeline for completing a particular microtunneling drive for a 24-inch (600mm) nominal inside diameter pipe was in conflict with the class schedule for an elementary school. If the drive was delayed until after the school session was over in June, 2007 the completion date of the project would be in jeopardy. The general contractor, Ruby Collins Reynolds EPR J.V. considered the options. The original planned alignment was to cross the school parking lot in two drives, with a shaft and equipment in the middle of the school parking lot. Total distance for the designed two drive segments was 750 lineal feet.

The microtunneling contractor, Westcon, and the pipe supplier, Can Clay Corp., were both consulted on the viability of attempting the distance of 750 ln ft in with only one drive. Westcon calculated the estimated jacking loads to be 403 tons (2000 lbs/ton), based upon 0.05 tons per square foot of pipe surface. The pipe is rated at 1,008 tons by the manufacturer, Can Clay Corporation, based upon compressive strengths of 10,875 pounds per square inch (75 N/mm²). The theoretical safety factor was therefore calculated to be 2.50, which is normally thought to be marginal.

Can Clay reported significant actual jacking strengths above the standard published rating of 1008 tons and agreed that its pipe would be suitable for this length of drive and the expected jacking loads. Good practices for microtunneling require that the steering of jacked pipes be kept to a minimum. ASCE 36-01 recommends a steering ratio of no more than 1:250 during microtunneling operations. This is equal to 0.23 degrees.
The microtunneling contractor, Westcon, was prepared to make all efforts to minimize steering. With the pipe manufacturer and the microtunneling contractor providing assurances, the project engineers approved the proposal to drive 750 ln ft across the parking lot.

At this time Westcon management was in contact with Microtunneling, Inc. On earlier drives on the project a new system was installed on a machine used to install 42-inch VCP pipes. The concept is known as the Pin Lube system and is generally suitable for use in soils free of cobbles, boulders and rock. The system is designed with multiple rows of pins that can be threaded outwards through the trailing section behind the microtunneling machine’s first section. After the machine is inserted into the entry seal at the jacking shaft wall and the machine is advanced to the point where the pin locations are past the seal, the rings of pins can be threaded outward in to the soil beyond the overcut, 1-inch to 2-inch. The system also provides automatic injection at multiple points of lubricant, typically bentonite with or without polymers, to the exterior of the microtunneling machine in the same location where the pins interact with the soil on the outside of the tunnel bore.

The pins’ protrusion into the soil effectively plows and loosens the existing soil simultaneous with lubricant injection. The goal is to achieve a matrix of soil and lubricant that is more uniform around the pipe, provide a seal that improves the ability to pressurize the matrix more evenly and ultimately decrease the jacking loads resulting from pipe friction. The microtunneling machine which was used for the 750 ln ft (229 m) drive was retrofitted in the field with the Pin Lube system (see Figure 7 and Figure 8 for the configuration).
The 750 ln ft school parking lot drive went without incident and was completed with the recorded jacking load of only 37 tons (2000 pounds/ton), 34 metric tons. The recorded jacking load included the load from the face pressure and tool engagement forces. The drive was deemed a great success. It has since been published as the longest drive in the world for a 24-inch (600 mm) internal diameter, 30-inch (769 mm) outside diameter, pipe. More importantly it allowed for economically maintaining the project deadlines without interruption to the school’s schedule.

Case 2

As often experienced, Mother Nature is not as cooperative to good engineering design and soil investigations as we would like. Past projects in some areas of Atlanta have been an extreme test of machines and contractors where rock is encountered unexpectedly or it has higher strength than reported.

The Stockade basin had four significant tunneling drives in high compressive strength rock. The rock was encountered at elevations much closer to the surface than originally expected in the design. These difficult conditions developed into a major concern for completion by the required timeline. The metamorphic granite gneiss ranged from 34,000 to 50,000 psi in the first three drives while over 50,000 psi was reported in the fourth drive. The quality of the rock in its appearance would have been suitable for making high-end counter tops. It was impressive to view the shaft walls in the jacking shaft, note Figure 9. This material was a challenge to any installation method for 18-inch diameter pipes.
McCowein Rock Drill Solutions was selected by Reynolds Ruby Collins JMT, J.V. to attempt to tunnel through this material after considerable evaluation of the situation. Four drives that encountered these conditions were required. Not only was the rock hard, only part of the drives were completely in rock. Soft clays were encountered as well. The combination of mixed face conditions prevents selecting optimal tooling for a single particular strata. Project deadlines were approaching in September, 2007. There were not any other appealing options to open cut or install a much larger tunnel as options to complete three drives of less than 250 ln ft each. McCowein had previously gained some experience with rock conditions using horizontal direction drill techniques.

The project requirements dictated a very flat grade with tight tolerances. Such conditions for accuracy of a trenchless installation usually requires precision guidance using microtunneling methods. High strength rock, above 20,000 psi, usually requires tunneling machines with special rock cutting cutters. However, the geometry of placing rolling cutters on a tunneling machine usually is limited to outside diameters of approximately 39-inch (1000 mm).

McCowein was contacted on February 27th, 2007 and began work during the first week of March. McCowein attempted the first drive using a Halco Storm 500 hammer to drill the pilot hole with a 5.25-inch diameter on an Akkerman 308 GBM guided system. The
Akkerman system included jacking frame, Theodolite, and a computer processing the LED target information. Progress was slow initially. The length of the first drive was 295 ln ft with a mixed face condition encountered midway through the drive. McCowein persevered with additional modifications of their own design over a several week period to finally complete the first of four bores. The initial 5.25-inch pilot hole was upsized to 12-inch then to 26-inch using a total of 3450 cfm air compressor capacity.

The last drive was in granite which exceed 50,000 psi and brought added difficulties. The drilling tools failed due to fatigue at 170 ln ft into the drive causing the unique LED target housing to crack. Immediate replacements were not available. A new tool was designed and built in seven days. The 210 feet bore was completed to an accuracy of less than 1-inch deviation from the design line throughout the drive and at the 0.4% design grade.

The conditions on these four drives were identified as warranting a change order for extra compensation to the contractor. An arrangement was made for continuing support to compensate for the changed conditions. The needed drives were completed 12 days ahead of the required September 26th deadline by going to 24 hour per day shifts. Since the work area was in an insecure portion of the City, 24 hour police protection was provided to ensure the safety of the employees and equipment. The final drive was completed in two weeks, excluding the time to redesign and manufacture the special head.

McCowein Drilling’s persistence and ingenuity established their company as the first company to complete a tunnel in high strength rock using a guided boring machine. New tooling and methods were developed as the four drives proceeded. Success was not assured. The accuracy achieved by the pilot tube system to tunnel in solid rock achieved controlled accuracy of line and grade to break in to a new frontier of trenchless technology, small diameter guided bores in hard rock.

The success was achieved by the cooperative effort in the face of difficult choices. It is a tribute to the personnel of the general contractor, Ruby Collins Reynolds EPR J.V., McCowein Drilling, the project engineers and the City of Atlanta.
Conclusion:

The City of Atlanta has completed a major milestone in achieving their goals for clean water. Nearly 15,000 ln ft of microtunneling was completed using a variety of methods some innovative and setting new records.

The efforts of the City, engineers, contractors and vendors found a combination of new and old technologies to meet the challenges successfully including the use of proven and innovative trenchless technology.

\[\text{http://www.cleanwateratlanta.org/SewerSeparation/}\]

\[\text{ii ASCE 36-01, Standard Construction Guidelines for Microtunneling, American Society of Civil Engineers}\]