USE OF MICRO TUNNELING TO INSTALL PIPES IN AN ENVIRONMENTALLY SENSITIVE AREA

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This paper will discuss the installation of 700-feet of reinforced concrete pipe beneath an active railway, highway, and prime wetlands, near the Devils Creek section of Cambridge, Ontario, Canada. The tunneling portion of the project, referred to as Devil's Creek Sanitary Trunk Sewer, also took place below the natural habitat of an endangered species of salamander. Temperatures at the site remained below freezing for days at a time at the end of February. Tunneling operations on the project were completed in March. Since then, the project has become a "case study" on how Cambridge solved its problems of building a sewer through difficult conditions, including wetlands, and reached a compromise that satisfied both the municipality and the environmental-conscious residents. General description of the Iseki technique to install pipes using the Unclemole microtunneling machine.

Palabras Clave: MICRO TUNNELING, SENSITIVE AREAS

An Iseki Unclemole microtunnel machine has installed a new sewer beneath an active railway, highway, and prime wetlands, near the Devil's Creek section of Cambridge, Ontario, Canada. The project, referred to as Devil's Creek Sanitary Trunk Sewer, was the subject of recent media attention because tunneling took place below the natural habitat of an endangered species of salamander.

The new sewer, which operates on gravity, will service a new development in the west Galt area, and replaces an existing sewer with a pump station. The owner of the project, The City of Cambridge, specified microtunneling as the preferred method of pipe-installation under recommendation from engineering consultants Gore & Storrie Ltd. of Mississauga, Ontario.

Regional Sewer and Water Main Ltd. of Cambridge was awarded the project, and selected Iseki, Inc. of San Diego, Calif., to supply technical support and the tunneling system. A complete kit supplied by Iseki, Inc. included a 39-inch o.d. Iseki Unclemole, jacks, slurry system, and control cabin.

The tunneling portion of the project comprised three drives to install nearly 700-feet of reinforced concrete pipe, made by Waterloo Concrete Products of Cambridge. While tunneling, an operator and five-member crew averaged typical daily production levels of 75-feet of installed pipe. In the end, all three drives were successfully completed within their specified line and grade tolerances.
Additives, provided by Baroid Drilling Fluids, Inc. of Houston, were mixed in the slurry to improve settlement of the excavated spoils from the slurry in the settling tanks. The additives reduce spoil dispersion by ‘encapsulating’ the spoils excavated in the machine’s cutterface.

One of the challenging aspects of the project included temperatures at the site that remained below freezing for days at a time at the end of February. The crew compensated for the cold weather by keeping the slurry system circulating around the clock and heating and covering the shafts at night to prevent the valves from freezing.

The first drive included the installation of 105-feet of concrete pipe by direct jacking beneath the raised CP Rail tracks. Soils consisted of silty sand with some cobbles. The conditions were easily accommodated by the Unclemole, since the machine is designed to operate in the widest range of soils and can crush cobbles and boulders up to one-third the diameter of the machine's cutterface.

"At one point, the Unclemole unexpectedly ran into a large stone not indicated in the soils investigation report," says Iseki operator John Bowman. "Eventually, the machine excavated the obstruction and completed the drive on line and grade."

Tunneling beneath active railways is a common application for the Unclemole. That's because earth and hydrostatic pressures at the machine’s cutterface are continually counterbalanced, eliminating the possibility of subsidence or heave. Throughout the duration of the tunneling, rail services on the CP Rail line continued without interruption as the Unclemole installed the sewer beneath the tracks.

The second drive included the installation of 472-feet of pipe below a creek in a protected wooded area through mostly silty sand and sandy clay. During this drive the Unclemole unexpectedly encountered a boundary of gravel located above the machine.

"Engineers were not permitted to take the usual sample soil borings prior to tunneling because of sensitivities to the environment," says Bowman. "When we reached the gravel, we adjusted the machine's speed, steering, and slurry pressure remotely from the control cabin to maintain perfect line and grade."

For the past five years, critics have been calling city officials to avoid disrupting the wetlands at all costs out of fear there may be a negative environmental impact. Microtunneling, however, proved to be the ultimate solution since it minimized environmental disruptions to the area.

On the third and final drive, the Unclemole installed 128-feet of pipe through wet sand. When the machine arrived on target in the reception shaft, the crew noticed something peculiar in the cutterface.

"There was some kind of steel object—maybe a cable anchor—wedged between the Unclemole’s cutterface arms," says Bowman. "Fortunately, the steel piece had no impact on our production levels."
Tunneling operations on the project were completed in March. Since then, the project has become a "case study" on how Cambridge solved its problems of building a sewer through difficult conditions, including prime wetlands, and reached a compromise that satisfied both the municipality and even most of the environmental-conscious residents.
THE ISEKI MICROTUNNELING TECHNIQUE
A TYPICAL METHOD STATEMENT
FOR THE UNCLEMOLE SYSTEM

GENERAL DESCRIPTION OF SLURRY SHIELD SYSTEMS

The principles of the Iseki microtunneling system are:

A. To counter balance earth pressures automatically by mechanically coordinating excavation speed, cutting face pressure, and jacking force.

B. To balance ground water pressure by coordinating slurry pressure, flow, and density.

The microtunneling system is composed of four major components:

1. **The UNCLEMOLE Shield**

Iseki shields are normally powered electrically, although hydraulic drive is an option. The cutter heads are driven by induction motors which vary in power with the machine size. The shield has an articulated head operated by hydraulic steering rams, and slurry flow control valves are operated hydraulically by a low pressure power pack (140 Bar).

The line and level control is achieved by a laser beam transmitted from the jacking shaft to a target mounted in the shield.

In remotely controlled shields, all information is transmitted to the operator by a CCTV camera. The television monitor shows the laser beam position on the target, together with other machine information - such as face pressure, roll, pitch, steering attitude, and valves open or closed - to a console on the surface from where the system is operated. The machines are built to withstand 100 ft head of water in both working and shut down conditions.

The cutter head of the UNCLEMOLE consists of a spoke-type crusher head and a cone rotor. The front part of the shield is conical shaped so that the spoil is progressively crushed down into fine material as it passes through the space around the eccentrically rotating cone. The crushed material then pass into the slurry chamber and are pumped to the surface through the slurry discharge line (Figure 1). As the shield is pushed forward, the soil is compacted into the open face of the shield, and the conical rotor crushes the soil and forces it through a circular orifice at the back of the cone and into a slurry chamber.
2. **UNCLEMOLE Slurry System**

The slurry system is designed to suit two requirements.

1. To enable soil transport speed to be matched to excavation rate and achieve a minimum velocity to prevent settlement in the pipeline.

2. To balance ground water pressure which is measured in the shield by the a face pressure gauge.

These two requirements are satisfied by using a variable speed discharge pump and a pressure control valve on the charging line.

By opening the pressure control valve, the charge rate is increased and the face water balancing pressure is increased. By increasing the speed of the discharge pump, the discharge rate is increased, but the face pressure is reduced.

The discharge rate is measured by an electromagnetic flowmeter located after the discharge pump. The signal is transmitted to the control panel, which enables the operator to manage the flow rate properly.

Other equipment includes a Pit Bypass flow reversal unit, which is used to:

A. Isolate slurry flow when new sections of pipe are being added.

B. Enable blockages to be cleared by reversing the flow.

Settlement tanks are included in the slurry system to separate the excavated soil from the water, which is then re-used. (Figure 3)

3. **The Jacking Systems**

Hydraulic jacks are located in the drive shaft to successively push the shield, followed by a string of pipes, out of the shaft. The capacity of the main jacks and the speed at which they extend is synchronized with the excavation rate of the tunnel shield.

When long tunnels are to be driven (in excess of 400 ft), the capacity of the pipes or the backwall of the drive shaft to resist the required jacking force may be a limiting factor. In this circumstance, intermediate jacking stations along the length of the tunnel are required. The intermediate stations must also be controlled and linked into the system to match the excavation rate of the shield.

The jacks are set up as a complete package including pressure plate, thrust ring, and guide rails. (Figure 2).
**Pressure plate**: A steel plate installed between the jack and the thrust wall, for distributing and transmitting the jacking force into the thrust wall.

**Thrust ring**: A steel ring placed between the main jacks and the rear end of the jacking pipe for distributing the jacking force around the end face of the pipe.

**Guide rails**: A pair of steel beams for supporting the UNCLEMOLE shield and the pipe to them with the required line and grade.

4. **The Control Cabin**

The slurry tunneling system is an integrated circuit of excavation and removal of soil and its replacement by a pipe. This process never leaves an exposed unsupported soil face in the tunnel, and the control system automatically balances all parts of the system, while keeping the operator informed of the situation through a television monitor and instrumentation.

**CONSTRUCTION PROCEDURE**

The construction of a pipe installation using the microtunnel method proceeds in the following order:

1) **The jacking shaft** is constructed together with a concrete base slab. The concrete or steel thrust wall is built for transmitting and dispersing the jacking reaction force to the ground in the jacking shaft.

2) **The jacking equipment**, the laser, the pit by-pass unit and the discharge pump are set up in the jacking shaft. A support structure is provided to permit the movement of the microtunnel machine and jacking system around the periphery of the tunnel to each drive location.

3) **An entrance ring** with a rubber seal is fitted in the wall of the shaft around each bore location to form a seal against both groundwater, if present, and slurry ingress into the shaft.

4) **The slurry settling tanks** are installed near the jacking shaft on the surface. The piping between these tanks and to the jacking shaft is placed to form a slurry circuit. The charge pump is set up near the slurry tank.

5) **The control cabin** containing the operation board of the UNCLEMOLE microtunneling machine and the distribution board for the electrical equipment is set up and the power and control cables are connected to the operation board, the main power supply and other ancillary equipment.
6) Hydraulic hoses between the power pack and the jacking equipment are connected.

7) The UNCLEMOLE shield is lowered into the jacking shaft and set on the guide rails.

8) The flexible hoses for slurry lines are connected to the UNCLEMOLE shield from the pit by-pass unit, the power and control cables are connected to the machine and the slurry tanks are filled with water and any admixture, such as bentonite, required in the slurry.

9) The functions of the system are then test run to ensure that the whole system is ready for operation.

10) The hydraulic jacks are then engaged to push the UNCLEMOLE close to the work face through the entrance rubber seal.

11) The pit by pass unit and the slurry pumps are operated to circulate the slurry between the UNCLEMOLE shield and the slurry tank.

12) The cutter head of the UNCLEMOLE shield is rotated, and the jacks extend to push it forward and start the excavation.

13) During driving, the operator controls the jacking speed, the torque of the cutter head, the slurry flow rate, the slurry pressure at the work face, the earth pressure and the inclination of the UNCLEMOLE shield.

14) After the UNCLEMOLE shield is driven into the ground, the operation of machine and slurry pumps are stopped and the jacks are retracted. The electric cables and the slurry lines are disconnected in the jacking shaft, in order to allow the placing of the first pipe onto the guide rails.

15) The hydraulic jacks are extended to push the pipe forward until it is fits to the tail of the UNCLEMOLE shield.

16) After making sure that the pipe is joined properly to the tail of the UNCLEMOLE shield, the electric cables and the slurry lines are reconnect to the UNCLEMOLE shield.

17) The slurry pumps are restarted, the pit by pass unit operated, the cutter head of the UNCLEMOLE rotated and the hydraulic jacks extend to resume the microtunneling operation.

18) The microtunneling operation is repeated as a cycle to jack the pipes one after another into the ground.
19) While the pipejacking operation is carried out, a lubricant is pumped continuously to the periphery of the concrete pipes to reduce the jacking friction. The lubricant is a mixture of water and bentonite or polymer.

20) Before the microtunneling operation, the receiving pit is also constructed for the recovery of the UNCLEMOLE shield on completion of each drive.

21) When the UNCLEMOLE shield is about 12 inches away from the receiving pit, the jacking operation is stopped. A small hole is drilled through the sheet pile at the front wall of the receiving pit, in order to confirm the position of the UNCLEMOLE shield and to check for the ingress of groundwater.

22) The exit ring and rubber seal are fixed and the guide rails are set to receive the UNCLEMOLE shield.

23) The wall of the receiving pit is cut and the jacking operation resumed to push the UNCLEMOLE shield into the receiving pit.

24) After the UNCLEMOLE shield is completely driven into the receiving pit, it is removed and lifted to the surface.

25) At the completion of jacking operation the shield is cleaned, checked and returned to the jacking shaft to start the next drive. The slurry lines and the control and power cables are removed and prepared for reuse on the next drive.