Equipment adds efficiency, safety to cross passage work

From a vast army of workers to gargantuan machines to immense volumes of material being moved, almost everything about the Port of Miami Tunnel (POMT) project points to tunneling on a massive scale. Almost. The star of this underground and underwater show is a Herrenknecht tunnel boring machine (TBM,) nicknamed “Harriet” by a local Girl Scout troop. With her 12.9-m-(42.3-ft-) diameter cutting head and a total length of 139 m (457 ft), Harriet is boring through thousands of cubic meters of clay, dirt and sand, which is often mixed with coral and other materials, to create two 1,280-m (4,200-ft) traffic tunnels connecting Watson Island and the Port of Miami (Dodge Island) beneath Biscayne Bay, FL.

But in the midst of all of the oversized equipment and machines, a strong contender for the best supporting nod goes to a relatively tiny machine: the Brokk 400. Bouygues Civil Works Florida crews are using the compact, remote-controlled and electric-powered machine to excavate five cross passages between the twin traffic tunnels. The passages will be essential to the safety of people who drive their vehicles under the bay every day.

Under-bay excavation

The POMT project, launched in October 2009, consists of three primary components: excavation and construction of the traffic tunnels, connections to the Port of Miami’s roadway system, and widening of the MacArthur Causeway Bridge. Bouygues Civil Works Florida is the design-build contractor and one of the lead companies on the project.

When the twin tunnels are complete, they will run under what’s known as Government Cut, the main shipping channel in Biscayne Bay. At their deepest points, they will be 36 m (120 ft) below the floor of the bay. Each of the 12-m- (39-ft-) diameter tunnels will comprise two traffic lanes, curbs, walkways, ventilation fans and other safety features. Eastbound traffic will be moving into the port and
westbound vehicles will be heading out.

The cross passages will provide emergency egress for drivers and passengers. They range in height and width from 3 – 4.2 m (10 - 14 ft), and from around 4.8 m (16 ft) to nearly 21 m (70 ft) in length. They are large enough to allow people to escape from one traffic tunnel to the other, and all five also will have additional room to store equipment for maintenance, pumping and other uses.

The Brokk 400 came to Miami courtesy of Bouygues plant and equipment manager Alain Mazzia, who first ran into one of the compact machines several years ago on a nuclear waste project in France. On that job, Mazzia was part of the team that dug two 500-m (1,640-ft) deep shafts, using a Brokk to excavate galleries at the bottom. When he looked at the complicating factors of excavating the POMT cross passages, the Brokk came to mind.

His reasons for bringing the Brokk 400 to Miami were straightforward. First, at only 4.2-m (14-ft) long, 1.5-m (5-ft) wide and less than 2-m (6-ft) tall, the Brokk 400 is small enough to stay out of the way when it’s working in the main tunnels, where crews and larger machines are

The Brokk 400 rests in one of the main traffic tunnels. The bucket is one of four attachments – beam manipulator, bucket, breaker and drum cutter – that crews are using to excavate the five cross passages between the main tunnels.
The Brokk 400 waits in one of the main Port of Miami traffic tunnels. With the machine’s small size, cross passage crew members can keep it out of the way of other crews and equipment moving in and out of the tunnels.

Dig, break, hold, repeat

The miners start and finish each cross passage by first cutting a rectangular hole through the concrete wall of the main tunnel, using the Brokk 400 to break up and remove the concrete. Once they move beyond the entry and before they come too close to the point where the passage will connect to the other traffic tunnel, they put the Brokk to work with four attachments — a breaker, a drum cutter, a bucket and a beam manipulator.

First comes the quantitative excavation in which the crews use the Brokk’s breaker to remove the largest amount of material, break it down and size it. In areas where the ground is reinforced with grout or frozen for stability, they use the drum cutter, which excavates with less vibration. Then they use the bucket to load material into carts and remove it from the passage. The crews also use the Brokk, along with a specially designed beam manipulator, to place support ribs in the passages.

The qualitative excavation takes advantage of the precision and sensitivity of the Brokk’s remote control to approach what Gregory Berger-Sabbaté, the cross passages field engineer, calls the “theoretical excavation limits” without overexcavating. These are areas outside of the passage’s predetermined dimensions, or near the end of the passage where it will intersect with the traffic tunnel.

Steel support rib installation has provided a unique challenge, and Brokk retooled its standard beam manipulator specifically for the job. The ribs are horseshoe-shaped or circular, depending on the passage in which they are being placed. They come in several sections that need to be connected, and the full assembly needs to be attached to the inside diameter of the cross passages before excavation can move forward. In all of the tunnels, the ribs are placed at 1-m (3.5-ft) intervals.

The Brokk 400’s three-arm design, which expands its reach horizontally and vertically, comes into play in placing the ribs. The beam manipulator grasps the top section of a steel rib, carries it to the installation point, lifts and positions it, then holds it in place while miners bolt the lower sections to it. With the ribs in place, the miners install...
wire mesh around the walls and ceiling and a contractor applies shotcrete. Then the process starts over again: mine, break and remove materials, reinforce with ribs, install wire mesh and apply shotcrete. Changing attachments before each task takes no more than 15 minutes.

“The multiple attachments, and how easy they are to put on and take off of the Brokk, really save time,” said Eric Deltour, the Bouygues cross passages superintendent. “We keep them at the entrance to the cross passage so they’re ready when we need them. When we change tasks from excavation to spoil removal to rib installation, changing tools is quick and efficient.”

But before speed and efficiency, the primary concern for this type of project is safety. “The main danger in any mining is a ground collapse, and there is more of a chance for that during the quantitative excavation,” said Berger-Sabbatel. “With the Brokk, the operator can stay out of the way with the remote control. The machine is the only thing out front, so everybody is safe.”

**Power and intensity**

August Scafici, the field sales application expert at Brokk and an experienced miner himself, trained Deltour, Berger-Sabbatel and the crew members who are now excavating the cross passages. “It’s an intense process,” he said. “They have to keep water out while they’re digging the passage and, when it’s done, it has to be water tight and withstand the extreme pressure of the dirt on top of it. These guys are pros, and it’s pretty interesting to see how it’s all getting done.”

Getting it done, Deltour said, requires leveraging all of the strengths of the Brokk that attracted Mazzia to the machine in the first place. For example, the small size comes into play not only inside the cross passages, where the Brokk can maneuver easily compared to other machines, but also in getting into the cross passage in the first place.

“The most challenging aspect is definitely the confined space,” Deltour said. “This is different than traditional mining, where the miners have room to excavate. Also, the openings from the main tunnels into the cross passages are relatively small compared to the size and volume of the excavation we’re doing. With the Brokk, our crews are able to get right in there and easily get the excavated material out.”

The Brokk’s power has been on full display as it has broken through materials being used to reinforce the soil and reduce the potential for cave ins. “We’re treating the ground prior to the excavation, and in some cases during the excavation, to increase the ground strength,” Berger-Sabbatel explained. “It keeps the cross passages stable and minimizes risk.”

The soil is being stabilized around the cross passage excavation areas in two ways. The first method consists of creating a cohesive and watertight plug from the surface with Cutter Soil Mix panels completed by Malcolm Construction Co. out of San Francisco, CA. The second method is to freeze the ground by super cooling the water in the soil. This is accomplished by circulating chilled liquid brine through small pipes. Nicholson Construction Co. (Cuddy, PA) is drilling and installing the freeze pipes and More-trench (Rockaway, NJ) is handling the freezing process.

Not to be overlooked is the Brokk’s precision, which has been a must because the locations of cross-passage openings in both traffic tunnels are predetermined. “Before the excavation even begins, our surveyors align a laser along the cross passage,” Berger-Sabbatel explained. “This gives us offsets from the laser point so we know how much left, right, up or down we need to excavate. The accuracy of the Brokk makes it much easier to follow the alignment given.”

**The little big guy**

If everything remains in alignment and on schedule—in the tunnels where Harriet is eating her way from one side of Biscayne Bay to the other and in the small cross passages where the Brokk continues to make headway rib by rib—the POMT project will be completed and open to traffic in May 2014.

When it’s all said, done and dug, there will be lessons learned for the companies who took on the project. For the men who relied on the Brokk 400 to excavate and fortify the five cross passages, it’s this: even when you’re talking about tunneling on a massive scale, never underestimate the little guy.
Every two years, industry leaders and practitioners of tunneling and underground construction gather at the Rapid Excavation and Tunneling Conference (RETC) to learn from their peers about the most recent advances and breakthroughs in this unique field. Industry experts from around the world highlight their most recent projects and share real-world experiences. They also share with their colleagues new technologies and methodologies that attendees can take home to their respective projects.

The 2013 RETC was held June 23-26 in Washington, D.C., itself home to several major tunneling and underground construction projects. The conference is sponsored by SME. Attendance was 1,384 professionals. The accompanying exhibit hosted 159 companies in 188 booths.

A few of the topics covered in the technical sessions dealt with caverns and large spans, contracting practices, tunnel linings, design and planning, geotechnical considerations and instrumentation.

The conference was preceded by four short courses, all well attended. They were “Grouting in Underground Construction,” “Tunnel Lining Design,” “Microtunneling Application” and “Risk, Uncertainty and Hard Decisions.” In addition, a sold-out field trip to D.C. Water’s Blue Plains Tunnel took place following the conference. The Blue Plains Tunnel is part of the agency’s Clean Rivers Project.

Also during the meeting, three students each received $5,000 scholarships from the UCA of SME, while another three students each received $2,500 scholarships from RETC (See page 53).

Technical programming

The technical programming during RETC included more than 100 papers presented in 22 sessions. Each paid attendee received a copy of the proceedings. The 1,364-page proceedings volume, edited by Michael A. DiPonio and Chris Dixon, is available from SME as a hardcopy, including a CD, or as an eBook. Contact SME Book Sales Coordinator, phone 303-948-4225, 303-948-4200 or 800-763-3132, email books@smenet.org or kisert@smenet.org, online www.smenet.org/store; $139 member; $119, student member; $179, nonmember.

The following is a sampling of some of the presentations.

Highly successful ground support for high cover: A case study of the West Qinling rail tunnels. China’s West Qinling rail tunnels are being excavated under high cover of at least 1,000 m (3,280 ft), for the entire length of the bored tunnels. B. Khalighi, of the Robbins Co., described a unique system of ground support that was designed to combat difficult ground conditions. Two 10.2-m (33-ft) diameter main beam tunnel boring machines (TBM) were engineered around the concept of those versatile support systems, which allow a variety of types of support to be installed in varying conditions.

Tunneling in Belgium. Three major infrastructure projects in Belgium are currently being built by Germany’s Van Wijck & Freitag Ingenieurbu. K. Rieker discussed a few of the construction challenges of the projects and some of the unique construction methods that were developed and successfully implemented. Some of the challenges included tunneling beneath five runways at Brussels International Airport, construction of a rail tunnel under an existing road tunnel in Brussels using hand-dug diaphragm walls and pipe-jacking and slurry TBM tunneling beneath the harbor of Antwerp with minimal cover.

Challenges of EPB tunneling in Prague. In November 2012, two earth pressure balance (EPB) machines completed two 4.8-km (3-mile) long tunnels as part of the Prague Metro V.A.’s subway extension in Prague, Czech Republic. This was the first time EPB technology was used in the country and, as a result, according to K. Rossler and D. Cyron, of Metrostav a.s. Praga, the project became a testing ground for various solutions to overcome challenges of the mechanized excavation.

To comply with the subway extension construction schedule, the excavations of three stations and EPB tunnels had to run in parallel. So mining of the three underground stations had to be done before the EPBs arrived. To allow for an early start of the station’s finishing works, an intermediate openpit was built for relocating the EPBs. This cleared the first two stations for final lining formworks.

Summary and lessons learned from New York City tunneling instrumentation. New York City has a number of major tunneling and underground construction projects. Three large tunnel projects for subways and regional rail systems are currently under way, along with several smaller projects. D. Roy, of GZA GeoEnvironmenal,