UP FOR THE **CHALLENGE**

UNDERGROUND INNOVATIONS

ISSUE 3 + 2016

Kare Solhaug of Robbins Field Service stands proudly in front of the 7.2 m (23.6 ft) diameter TBM on the day of its breakthrough December 10, 2015.

ROBBINS MAIN BEAM SETS MILESTONE FOR TBMs IN NORWAY

A crowd of crew members gathered to celebrate in front of a newly emerged hard rock TBM on December 10, 2015 in northern Norway, but their celebration was about more than just a breakthrough. The 7.2 m (23.6 ft) diameter Robbins Main Beam machine had traversed incredibly hard rock, water inflows, and more to become the first TBM in the country to break through in over 20 years.

The 7.4 km (4.6 mi) long headrace tunnel for the Røssåga Hydroelectric Project offered up a number of challenges to the crew. "We bored through hard, quartz-rich rock with rock strengths up to 300 MPa (43,500 psi) UCS and softer karstic limestone with water ingress," explained Tobias Andersson, TBM Manager for contractor Leonhard Nilsen & Sønner (LNS). Despite the geological challenges, the TBM performed very well and achieved a record production of 250 m (820 ft) advance in one week, as well as a high of 54 m (177 ft) in one day. Advance rates consistently ranged from 180 to 200 m (590 to 660 ft) per week throughout the project.

The hard and abrasive rock required both fine-tuning of the disc cutters and a learning curve with regards to TBM operation. "We overcame the rock by adapting driving parameters to the different geology, cutter wear and vibrations of the machine. We had regular maintenance, but most important of all we got really good at changing the cutters, with times down to 10 minutes per cutter change, which couldn't have been done without good team work," said Andersson.

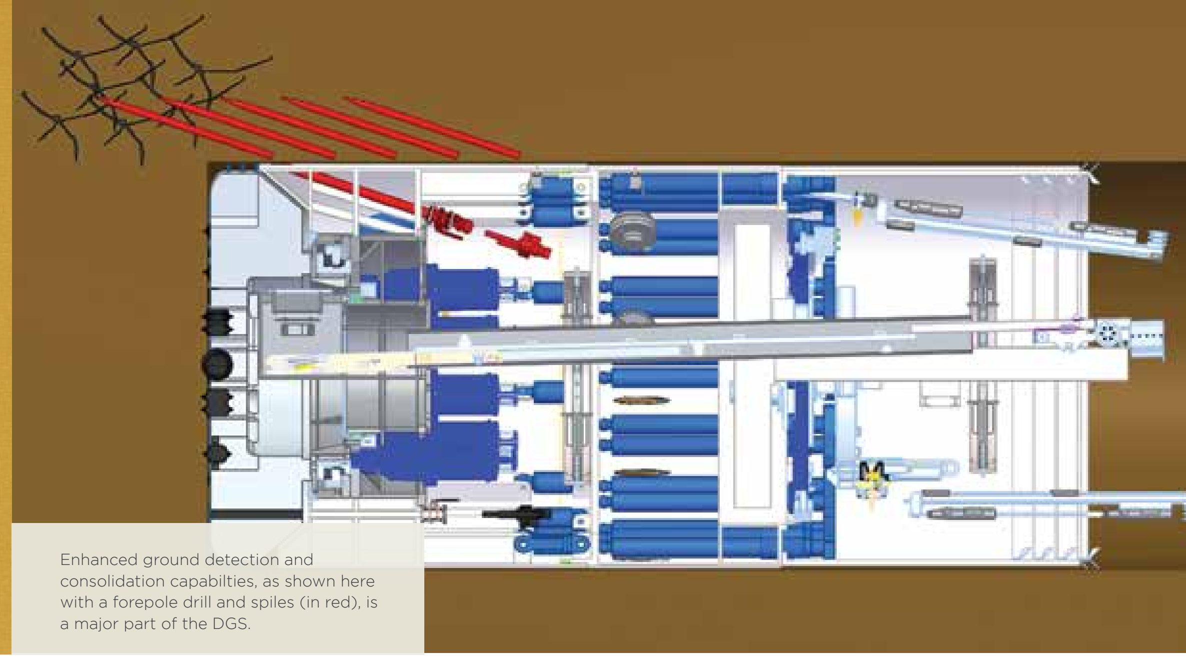
It was the many cutter changes that prompted the close-knit team of LNS and Robbins to look for a better solution. "Extremely hard rock (above 250 MPa/36,300 psi) will always be a great challenge for any cutter. The very special features of the rock encountered combined with the extreme hardness made us go back to the Robbins Cutter Department to develop special cutter rings for the project. These rings increased the cutter life significantly for the project and contributed to the good production," said Sindre Log, General Manager of Robbins Norway.

"OUR WHOLE JOBSITE WAS GATHERED FOR THE EVENT: LNS MANAGEMENT, ROBBINS, AND OUR CLIENT STATKRAFT. PEOPLE SAID IT WAS THE BEST BREAKTHROUGH EVENT THEY HAD SEEN." -TOBIAS ANDERSSON, TBM MANAGER, LNS

The Robbins TBM was launched following Onsite First Time Assembly (OFTA) in January 2014, less than twelve months after contract signing, and was from the outset designed for hard rock conditions. A Measurement While Drilling (MWD) system was included to analyze the ground conditions ahead of the TBM, while probe drilling was done systematically throughout the project. "This is a strong and simple machine ready to tackle hard rock conditions, but also designed to handle softer rock, which allowed for fast excavation. We had good support from competent Robbins field service," said Andersson.

After all the obstacles, it was clear that the breakthrough ceremony celebrated a triumph of teamwork as well as a new chapter for TBMs in Norway. "Our whole jobsite was gathered for the event: LNS management, representatives from Robbins, and our client Statkraft. People said it was the best breakthrough event they had seen," said Andersson. Project owner Statkraft is planning to commission the tunnel this spring 2016.

Visualization of the ground through monitoring and data collection is of paramount importance in difficult conditions.



Enhanced ground detection and consolidation capabilties, as shown here with a forepole drill and spiles (in red), is a major part of the DGS.

DIFFICULT GROUND:

What are Today's TBMs Truly Capable of Excavating?

LOK HOME, PRESIDENT

In many rock projects, the occurrence of squeezing ground, high inrushes of water, blocky rock, and other challenges is a real possibility. Today's highly adaptable TBMs are capable of tackling these tough conditions using cutting-edge technology coupled with modern ground investigation methods.

We've based an entirely new ground investigation system on real field data and experiences, particularly Turkey's Kargi Hydroelectric project, where a machine required in-tunnel machine modifications to overcome challenging geology. Traditionally, shielded hard rock and mixed ground machines have provided limited visualization of the ground in front of and around the TBM, but we'd like to change that.

The new system, known as Difficult Ground Solutions (DGS), consists of a set of integrated features tailored to a specific project's geology. The main components of DGS allow for ground investigation ahead of the TBM, increased monitoring, and methods to keep a machine shield from becoming stuck.

Some of the system's main components include customized cutterhead drives, high torque and multi-speed gearboxes to allow a machine to advance at high torque and low RPM through fault zones, mixed face conditions and more. We have similarly revamped our shield design--the Continuous Advance Shield is ideal for blocky rock and squeezing ground where the risk of a machine becoming stuck could result in significant delays. Short shields combined with a stepped or tapered design keep the machine moving, as does bentonite injected through radial ports. Should the machine become stuck there are strategies including added thrust and hydraulic shield breakout using pressurized hydraulic lubricants to free the machine.

The DGS can be fully customized for a particular project, and the features do not stop there. From sealable muck chambers that hold back high water pressures to cutterhead inspection cameras, the DGS is all about painting the full picture of the ground around your TBM and providing assurances in the case of an event. We are now capable of measuring convergence in the case of squeezing ground using external sensors so measures can be taken as early as possible, and improved probing and grouting capabilities give contractors a way to detect and treat the ground ahead of the machine. Multiple drills including a forepole drill can be installed on the TBM to allow for further ground consolidation abilities.

> "The [DGS] system is an assurance that the machine will be able to handle expected and unexpected conditions, and if conditions are known the system can be made all the more accurate."
>
> - LOK HOME, PRESIDENT

Of course, the overall goal of DGS is to avoid making these modifications in the tunnel—a process that can cause significant downtime. The system is an assurance that the machine will be able to handle expected and unexpected conditions, and if conditions are known the system can be made all the more accurate. Contractors and owners must strive to provide accurate geological reports so that DGS can be at its most effective.

Owners and contractors should give full consideration to building in these features when difficult conditions are a possibility. With these features, we are confident that a shielded machine can keep advancing, whether the concern is high cover mountainous tunneling with squeezing and rock bursting, water inflows, fault zones, mixed face conditions, or all of the above.

HIGH-ALTITUDE HARD ROCK

ALTO MAIPO ON THE MOVE

At 2,500 m (1.5 mi) above sea level, the Alto Maipo jobsite is a high-altitude marvel that required a feat of logistics to bring a TBM to it. Located about 90 km (56 mi) from Santiago, Chile, the jobsite sits in the Andes Mountains along 20 km (12 mi) of steep, unpaved roads. A 4.13 m (13.5 ft) diameter Robbins Main Beam TBM began excavating the first of two hydroelectric tunnels in mid-2015.

The TBM is boring the tunnels, known as Alfalal II and El Volcan, for a total excavation length of 10 km (6.2 mi). The tunnels will connect up with two underground powerhouses--the Alfafal II and Las Lajas plants--located in caverns. Together the power stations are capable of generating 531 MW of electricity.

As of 2016 the TBM has bored more than 700 m (2,300 ft) in heavily fractured rock for the Hochtief/CMC JV. The ground conditions have slowed progress, but the adaptable TBM is capable of handling the challenges. “We started using the McNally system due to fractured rock we encountered. In my opinion, I find the McNally system very efficient. It increases the workers’ safety, and prevents the TBM from being damaged by the falling rock,” said Enrico Brandoni, TBM Manager for Hochtief-CMC. The system allows crews to install steel slats as the TBM advances, consolidating fractured rock in the tunnel crown. In other sections the crew is also installing rock bolts and wire mesh as well as a layer of shotcrete.

Despite the challenges, Brandoni is confident that the TBM will persevere: “Robbins has a long history in designing and manufacturing TBMs. TBMs are much more efficient than drill & blast, and the anticipated geology of the rock is suitable.”

Above all, Brandoni is proud of the local crew and the progress achieved. “Up to now, this is only the third TBM used in Chile, so our greatest achievement has been creating an effective TBM team of local miners who previously only had experience in drill & blast.”

The adaptable 4.13 m (13.5 ft) diameter Main Beam is boring through fractured hard rock high in the Andes Mountains of Chile.

The crew of Foraction, Inc. and Robbins gathers around the Double Shield TBM to celebrate the tunnel completion.

Workers climb through the cutterhead of the Robbins TBM to mark the breakthrough in November 2015 at a large ceremony.

DOUBLE SHIELD DOES IT RIGHT

MONTREAL BREAKTHROUGH

In a large November 2015 ceremony attended by the mayor of Montreal, Quebec, Canada, and representatives from local media outlets, the Rosemont Reservoir tunnel construction came to a close. The challenging project gave good cause for celebration as crew members crowded around the cutterhead of the 3.0 m (9.8 ft) diameter Double Shield TBM that had emerged into an exit shaft.

Local contractor Foraction, Inc. headed the 4.0 km (2.5 mi) tunnel bore with a TBM launch in December 2014. Roger Lepinay, Equipment Manager for Foraction, Inc., praised the Robbins disc cutter wear: “I was impressed by the cutters, it was a nice surprise. They were quite long-lasting compared to other cutters I have used.”

Lepinay characterized the ground as “almost ideal”, with a few difficult sections. “Below Montreal there is mostly thinly bedded limestone, with some shale and intrusive igneous rocks, mainly dykes and sills,” said project geologist Brigitte Gagné for company Exp Service Inc. While the limestone averaged 100 to 150 MPa UCS, rock in the intrusives ranged from 100 to 300 MPa. The dykes and sills were as small as a few centimeters wide and as large as 8 to 10 m (26 to 33 ft) wide. The contractor was able to successfully navigate these sections despite the varying rock strengths. Even with geologic challenges including water inflows and over-break in small sections, the contractor was able to achieve advance rates of up to 38 m (125 ft) per day in two shifts of 9.5 hours each. Much of the ground was self-supporting, though the contractor installed rock bolts every 2.5 m (8.2 ft) into portions of the tunnel crown, while mesh and steel sheets were added in unstable rock.

With the breakthrough, an important phase of the Rosemont Reservoir project is complete. The reservoir itself was built in 1960 to increase water supply to the city and a geotechnical study for the tunnel was carried out in 1977. However, other major infrastructure projects took priority and the project was placed on hold. By 2010, the population of the city had increased dramatically and problems with the existing reservoirs put the project back on the fast track. The large reservoir that sat idle for decades will now be used to improve much of the city’s water supply.

With tunneling complete, the contractor has installed carrier pipe, consisting of 2.13 m (84 in) I.D. pre-stressed concrete cylinder pipe. There will be several more work stages to be carried out before the Rosemont Reservoir is finally reconnected to the water main network in 2019.

INSIGHTS FROM THE FIELD

CROSSOVER TBM PROVES ITSELF BELOW MEXICO CITY

The 8.7 m (28.5 ft) Crossover XRE has bored through fault zones and andesite rock, achieving up to 185.1 m (607 ft) in one week.

To the west of Mexico City, a key component in a massive wastewater overhaul is underway. A 5.8 km (3.6 mi) tunnel project, known as Túnel Emisor Poniente (TEP) II, will supplement an existing wastewater line built in the 1970s and is part of a solution to a big problem in the area. The Valley of Mexico consists of a drained clay lake bed interspersed with volcanic rock and boulders. Chronic groundwater depletion has resulted in soils that sink as much as 20 cm (8 in) per year. All that sinking has caused the city's wastewater tunnels to lose their slope, creating a recipe for widespread flooding each year during the rainy season.

The scheme is a hefty undertaking: "This deep drainage tunnel will serve to prevent recurrent flooding in Valle Dorado, and will benefit the cities of Cuautital Izcalli, Tlalnepantla, and Atizapan de Zaragoza, which altogether have a total population of 2.1 million inhabitants," explained Enrique del Castillo of contractor Aldesem.

The tunnel path travels below a mountain with cover as high as 170 m (560 ft), through fault zones and below valleys, ending in a section with cover as low as 20 m (65 ft). Much of the tunnel consists of andesite rock with bands of tuff, and softer material in fault zones as well as an 874 m (2,870 ft) long section in soft ground at the end of the tunnel.

It was this complex geology that prompted the contractor, a consortium of Aldesem/Proacon/Recsa, to choose a Crossover TBM. "The geological profile of the project goes through six different lithologies, among them hard rock such as dacite. To get the best operation in both areas required use of dual mode technology such as the Crossover TBM," said del Castillo. The 8.7 m (28.5 ft) diameter Robbins XRE (Crossover between Rock/EPB) is a design that allows for the TBM to effectively bore in both hard rock and mixed ground.

The Crossover machine was launched in August 2015, and advance rates picked up quickly. Project records were set in January 2016 after the machine achieved a best day of 42.8 m (140 ft) and a best week of 185.1 m (607 ft). By mid-March the machine had bored through the first of the contact zones, a 30 m wide section of fractured and blocky rock. While the excavation through the contact zone was slow going, progress picked up again in the more competent rock. By late March, the machine had reached a milestone when it broke through into an intermediate shaft. The machine will undergo some maintenance before continuing on to bore the final 3.2 km (2.0 mi) of tunnel.

NORTH AMERICA'S NEW WAVE OF TBMs

It's no secret that North America--and the United States in particular--is experiencing a tunneling boom. Robbins is playing a role in that growth with two high-profile U.S. projects slated to start up in 2017.

New York City's Rondout West Bypass Tunnel will use a 6.6 m (21.6 ft) diameter Robbins Single Shield TBM to excavate a 4.0 km (2.5 mi) long tunnel below the Hudson River in the first quarter of next year. Ground conditions are expected to consist of shale with possible zones of intense water inflow up to 30 bar. The machine, for the Shea/Kiewit JV, will be designed to passively hold the potentially high water pressure using a cutterhead drive sealing system and backfill grouting through the tailskin. The machine is equipped with high thrust to get through challenging ground and sophisticated drilling and pre-grouting equipment for detection. Water-powered, high-pressure down-the-hole hammers can accurately drill 60 to 100 m (200 to 330 ft) ahead of the TBM, while blow-out preventers enable drilling at high pressures up to 20 bar. This is an example of a customized DGS system for expected geological difficulties (see page 2, Difficult Ground, for more info).

THE CROSSOVER TBM FOR THE AKRON OHIO CANAL INTERCEPTOR TUNNEL WILL BE THE FIRST USED IN THE U.S.

Rondout is not the only customized TBM being developed. Robbins will also supply a 9.26 m (30.4 ft) diameter Crossover TBM to the Kenny/Obayashi JV for the Akron Ohio Canal Interceptor Tunnel (OCIT). The large machine marks the first time that a Crossover TBM has been supplied in the U.S. The Crossover XRE (a cross between a hard rock shielded TBM and an EPB) will be ideally suited for the anticipated mixed ground conditions. The rebuilt XRE TBM was originally used on the Mexico City Metro Line 12, and is scheduled to be launched in the first quarter of 2017.

The OCIT comprises 1.9 km (6,240 ft) of 8.2 m (27 ft) tunnel that will be lined with a one-pass precast segmental liner. The tunnel will convey dry weather sanitary flow by gravity to the Little Cuyahoga Interceptor (LCI) sewer and will be capable of storing up to 95 million liters (25 million gallons) of combined sanitary and storm flows during wet weather events. The new tunnel is the largest component of the City of Akron's USD $1.4 billion mandated program to control overflows into the Cuyahoga and Little Cuyahoga rivers.

The mixed ground EPB made its final breakthrough on January 27, 2016.

At the Chennai Metro, Robbins India crews mapped ground ahead of the machine in order to successfully navigate changing ground conditions.

CHENNAI CHALLENGE OVERCOME

CREWS TRIUMPH OVER MIXED GROUND, BRUTALLY HARD GRANITE, AND MORE

On January 27, 2016, a Robbins mixed ground EPB broke through at Chennai Metro, finishing up a challenging second drive that saw the full gamut of difficult conditions. The 1,027 m (3,370 ft) long second drive for the machine was part of Lot UAA-01 on Line 1 of the city's metro, consisting of two parallel 1.0 km (0.6 mi) tunnels running from the Washermanpet area towards Chennai International Airport. Contractor Afcons Infrastructure Ltd. reflected on the breakthrough: "We are really proud of our executing team, who have maintained a high standard of quality. We didn't record any water leakage or settlement at the surface, and we have demonstrated a high standard of safety in the tunnel during construction," said Mr. Gopal Dey, Sr. Manager for Afcons.

The 6.65 m (21.8 ft) diameter Robbins EPB was designed to excavate granite, sand, silt, and clay with boulders up to 300 mm (12 inches) in diameter. The specialized design utilized a combination of 17-inch diameter disc cutters as well as soft ground tools.

The TBM was launched on its initial drive in January 2012 from a 28 m (92 ft) deep starting pit. Challenges began nearly from the outset. The TBM bored into mixed face conditions that contained varying strengths of granite, from weathered to hard granite of 150 MPa (21,700 psi) UCS. The unexpectedly hard rock caused high cutter consumption rates and slowed advance.

A crew of Robbins Field Service personnel and engineers assisted Afcons in remedying the problem. Robbins India provided a geologist who carried out face mapping for the whole of the first drive, in both hyperbaric and open mode conditions on a daily basis. The data not only assisted the crew in operating the TBM, but also provided a comprehensive geological record for the second drive. With the data gleaned from the geological investigation, Robbins was also able to advise Afcons on the optimal operating parameters in the difficult conditions.

Contractor Afcons was pleased with the help they received: "The Robbins Field Service team extended very good services to us, particularly in the mixed face & full face rock when they deployed their Geologist for face mapping. This helped us to understand the strata ahead of us, and based on this the TBM advance rate and operating parameters were decided," said Mr. V. Manivannan, Executive Vice President for Afcons.

> "The Robbins Field Service Team extended very good service to us, particularly in the mixed face and full face rock." -Mr. V. Manivannan, Executive Vice President, Afcons

The TBM was launched on its second tunnel in February 2015. Conditions were just as difficult as the first drive, but now the team approached it with experience: "We experienced very high water pressure in this alignment, as the water table in Chennai is just 1.5 m (5 ft) underground and the strata above the crown included silty sand, clay and weathered rock. It was very important for us to maintain the earth pressure to reduce the inflow of water," said Dey. Despite the challenges the TBM was able to complete a section below the Koovam River without any water inflows. The machine achieved up to 12.6 m (41 ft) in one day and 62 m (203 ft) in one week.

WHAT MAKES A PROJECT CHALLENGING?

THE INDUSTRY WEIGHS IN

As part of our 2016 “Focused Forward” campaign, we opted to poll the industry on a few key questions. These questions will be featured in our booths at Bauma and the World Tunnel Congress and throughout the year as part of the campaign. The question “In your opinion, what makes a project challenging?” garnered some of the most interesting and thought provoking quotes from a wide variety of respondents in the tunneling industry. Read on for some of the best.

“There is a level of uncertainty in the ground conditions. This means that sometimes the engineers do not know what can be expected. To cope with this means that machines should be designed and have additional capabilities to deal with uncertainties.” –Jamal Rostami, Penn State University

“As a geologist, TBM projects are challenging with shielded TBMs because you can’t see the rock in-situ. It makes it harder to observe or confirm the rock mass properties.” –Nichole Boultbee, Golder Associates

“PARTNERSHIP & COOPERATION ARE CRUCIAL TO THE SUCCESS OF EVERY TBM PROJECT. **MOTHER NATURE REPRESENTS A FORMIDABLE OPPONENT AND REQUIRES THE CONCERTED EFFORT OF EVERY PARTY.”**

-GARY BRIERLEY, DR. MOLE

“It can be difficult to predict what you have in front of the cutterhead. You could be faced with squeezing ground, high water ingress, or gas, and your TBM must cope with these adverse conditions. Observing the performance of a TBM excavating in a very complex geology is like watching a fascinating and exciting film. It can affect the scope of your entire career.” –Dr. Nuh Bilgin, Istanbul Technical University

“Too many TBM tunnel projects these days still suffer from inadequate site investigations, which result in missed geological risk targets. This results in great risk being placed on the contractors for TBM selection.” –Dean Brox, Consultant

“The issue that makes a TBM project challenging is the fact that very few projects are actually doing geological pre-investigations to the required level.” -Eivind Grøv, SINTEF

BORING BELOW AN ICONIC GATE IN JAIPUR

TWIN EPBs HOLD SOFT SOILS STEADY IN THE PINK CITY

Jaipur is a cultural melting pot of 6.6 million people. The city’s heart is encircled by a wall six meters high and three meters thick, with seven gated openings. Built in 1727, the walls and many of the streets were painted pink and remain so today, giving Jaipur the nickname of the “Pink City”. It is below these delicate and iconic structures that Jaipur’s first Metro, Line 1, will travel.

Chandpole gate, one of the seven, is directly above the bore path for the Line 1 extension, and serves as a historical landmark. Contractor Continental Engineering Corporation (CEC) was tapped to excavate twin tunnels 2.3 km (1.4 mi) in length. Ground conditions of silty sand above the water table meant that running sand wasn’t an issue. The contractor opted to refurbish its two 6.52 m (21.4 ft) diameter Robbins EPBs originally used on the New Delhi Metro.

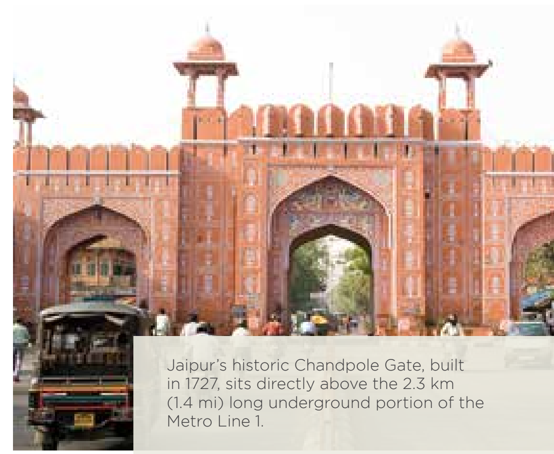
The first machine was launched in May 2015, and would serve as a test for the challenges ahead. Overburden below the gates was just 4.5 m (15 ft) between the TBM crown and foundations. Settlement below the gates had to stay below 5 mm (0.2 in).

“By far the biggest challenge to the tunneling operations was boring beneath Chandpole gate. The gate foundation is made up of stone with lime mortar joints and so was highly susceptible to damage due to any tunneling-induced ground settlement or heave,” said Jim Clark, Robbins Projects Manager India.

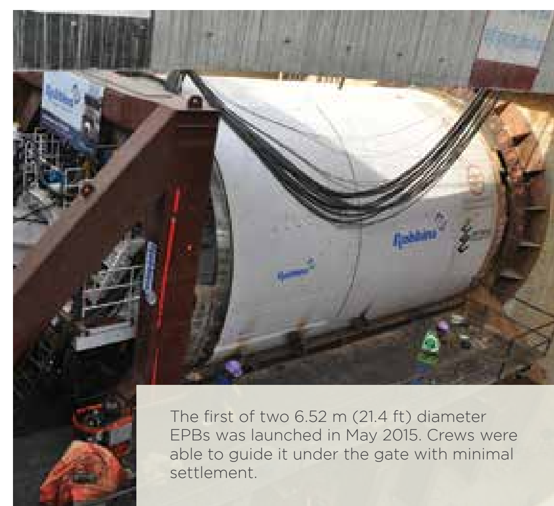
To tackle the challenge, Robbin Field Service provided training and support. “The Robbins Company provided a team of personnel including TBM operators to supervise boring beneath the gate. Basic TBM operating parameters were defined and these were then fine-tuned based on results from real time surface monitoring. Monitoring points were placed at one meter intervals above the alignment. Due to the alignment being under a road, readings were done manually by intermittently stopping traffic. By the time we reached the gate settlement was just 2 mm (.08 in),” said Clark.

That minimal settlement was accomplished through adjustments and careful strategy. Crews injected bentonite through the shields to reduce friction between the sand and the TBM. “We closed up the articulation and reverted to steering the machine traditionally, using the main thrust cylinders and copy cutters,” added Clark. The methods worked, as settlement was minimal.

As of March 2016, the first TBM was on track for a breakthrough in May and had achieved rates of up to 87 m (285 ft) per week. The second machine had achieved rates up to 107 m (351 ft) per week with a breakthrough planned later in 2016.



Jaipur’s historic Chandpole Gate, built in 1727, sits directly above the 2.3 km (1.4 mi) long underground portion of the Metro Line 1.



The first of two 6.52 m (21.4 ft) diameter EPBs was launched in May 2015. Crews were able to guide it under the gate with minimal settlement.

Below: The 23 m (74 ft) deep tunnel is the deepest and largest tunnel yet for the Hawaiian Islands. Right: The TBM was launched in spring 2015, and is now more than 82% complete with boring as of March 2016.

HAWAIIAN HEAVYWEIGHT

PROGRESS ON THE ISLAND

Main Beam TBM Nears Completion

The Hawaiian Islands, essentially the exposed seamounts in a vast chain of oceanic volcanoes, have a long and fiery history. The volcanoes laid down basaltic bedrock that can sometimes prove to be a challenging substrate for underground construction projects. That challenge is magnified for Honolulu's Kaneohe-Kailua Wastewater Conveyance & Treatment plan, which involves a deep, 4.6 km (2.8 mi) tunnel fully within the hard and often abrasive bedrock. The tunnel is the first of its size and depth to be excavated in Hawaii.

Contractor Southland/Mole selected a refurbished 3.96 m (13.0 ft) diameter Robbins Main Beam TBM to bore the tunnel. "The logistics have been our biggest challenge. Everything has to come from the mainland, as we are on an island. We also have two different jobsites we need to coordinate, one where the machine starts and the other where it's extracted at the other end," said Don Painter, Project Manager for the Southland/Mole JV.

The machine was refurbished in Robbins' Solon, Ohio manufacturing facility and customized for harder rock conditions as well as a tight curve on the tunnel alignment with 150 m (500 ft) radius. The curve is not the only unusual aspect of the tunnel; everything from tunnel operation to pre-grouting sections ahead of the TBM for groundwater control were new for Hawaii, although not for the tunnel contractors.

The TBM was launched in spring 2015 from a starter tunnel at the bottom of the launch shaft. "Conditions wise, we are definitely probing ahead," said Painter. The machine has hit rock as hard as 137 MPa (20,000 psi) UCS, as well as water inflows. "We were probing ahead and hit a section with 1,700 liters (450 gallons) a minute. We grouted this section off right behind the cutterhead and are continuing to probe every 30 m (100 ft)." Even with the challenges the machine has excavated upwards of 49 m (160 ft) in one 12-hour shift.

The 3.96 m (13.0 ft) Main Beam TBM is boring a 23 m (74 ft) deep tunnel--the first tunnel of that size and depth ever to be built in the Hawaiian Islands.

Several more obstacles lie ahead for the TBM operation. In the area of the tunnel curve, there will be operational procedures requiring the machine to be operated using half strokes rather than a full TBM stroke. "We will get the machine around the curve as best we can, by taking wedges out of the side supports. There are several curves on this alignment, but the 150 m (500 ft) radius is the tightest. We actually started the machine in a curve of 244 m (800 ft) radius, and while it was tough to get around we were able to do it," said Painter. As of March 2016, the TBM has excavated more than 3.8 km (2.34 mi) of tunnel, or about 82% of the total tunnel length.

2016 WEBINAR SERIES

Robbins hosts three complimentary webinars annually, geared towards project owners, contractors and engineers. Attend a Robbins webinar to hear from our company executives, lead engineers, and onsite Field Service staff about the latest tunneling trends and ways to save time and money on your upcoming projects.

THE ROBBINS CROSSOVER TBM: ONE MACHINE, MANY GEOLOGIES
April 5, 2016

THE LOGISTICS OF MULTIPLE-MACHINE PROJECTS
June 2016

DIFFICULT GROUND SOLUTIONS: CARVING A PATHWAY TO SUCCESS
October 2016

Exact dates to be announced soon

Visit www.TheRobbinsCompany.com and join our LinkedIn Group, Robbins TBM, for updates and registration.

2016 TECHNICAL PAPERS & PRESENTATIONS

+ WORLD TUNNEL CONGRESS

April 22-28 | San Francisco, California, USA

Lessons Learned from EPB Tunneling in Glacially Deposited Soils in Seattle, Washington, USA
Presented by Gary Nishimura, Robbins

Use of Two Novel, Hybrid-Type Crossover TBMs for Hard Rock Conditions with Water Inflows
Poster Session by Missy Isaman, Robbins

A Novel Continuous Conveyor System and its Role in Record-Setting Rates at the Indianapolis Deep Rock Tunnel Connector
Presented by Dean Workman, Robbins & Dan Martz, J.F. Shea

Concurrent Segment Lining and TBM Design: A Coordinated Approach for Tunneling Success
Presented by Elisa Comis, Robbins and Robert Goodfellow, Aldea Services

The Next Generation of TBMs for Mining Applications
Poster Session by Dennis Ofiara, Robbins

ITAtech Special Session:
TBMs and Technology: An Integrated Solution for Tunneling in Extreme Conditions with help from Ground Investigation Systems
Presented by Lok Home, Robbins

ITACET Training Session:
Instrumentation & Monitoring
Presented by Brad Grothen, Robbins

Robbins will also give technical presentations at the following conferences:

+ CSM UNDERGROUND GROUTING & GROUND IMPROVEMENT SHORT COURSE

May 16-20 | Golden, Colorado USA

+ CSM TUNNELING SHORT COURSE

June 20-23 | Golden, Colorado, USA

+ BTS CONFERENCE

October 11-12 | London, U.K.

+ TUNNELLING ASSOCATION OF CANADA (TAC) 2016

October 16-18 | Ottawa, Ontario, Canada

SHARING OUR KNOWLEDGE
TO ENCOURAGE INNOVATION.

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The Robbins Main Beam machine at Røssåga was launched in January 2014 and overcame incredibly hard rock, water inflows, and more.