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'GOING DOWNTOWN' IN SINGAPORE

Singapore's Downtown Line Stage 3 (DTL3) is expected to be completed in 2017, after which it will have a 21 km long route with 16 stations. Robbins TBMs have played an important role in the project.

For three of the DTL 3 contracts (C925, C927 and C937) logistics are said to be quite complex. Each contract includes the construction of shafts, parallel tunnels and station sites.

Contract C925, with two 800 m long parallel tunnels running between Tampines and Tampines East station sites, was awarded to Korean contractor GS Engineering & Construction Corporation. The company selected a 6.6 m diameter Earth Pressure Balance (EPB) TBM to bore the parallel tunnels. As such, the machine had to be designed for quick removal from dead end tunnel - past segment rings that made the tunnel smaller in diameter - so that it could be launched on a second tunnel drive. Ground conditions based on tests included clays, sand, gravel and sandstone conglomerate.

Contract C937, comprising two 780 m tunnels driven between River Valley station and Bencoolen stations and two 560 m long tunnels between River Valley station and Upper Cross Street, was also awarded to GS Engineering & Construction. For this contract the company chose two 6.6 m diameter EPBs to bore each of the 780 m long tunnels and one identical machine to excavate both parallel 560 m tunnels. Sections of the C937 contract made contact with the Fort Canning Boulder Bed, consisting of relatively strong and large rock boulders in a stiff clay matrix. Other ground types include clays, mudstone, siltstone and sandstone.

Parallel 1.4 km lines on the C927 contract running between Bedok Park and Bedok Reservoir Stations were awarded to Italian contractor CMC di Ravenna. The company opted for two EPB TBMs for the tunnels, which pass below a canal, foundations for a pedestrian bridge and a national park. Based on core samples ground conditions included clays, sand and sandstone conglomerate.



Above: The first of the five Robbins EPBs broke through at the C927 site in October 2013 after achieving advance rates up to 15 m per day.

Left: The C925 location is located just metres away from high rise condominiums, a school and a busy roadway.

Map: Singapore's Downtown Line Stage 3 (DTL 3) is a 21 km long route with 16 new stations.



Mixed ground conditions ranging from clay to mudstone, sandstone and boulder fields dictated the use of mixed ground EPBs on many of the tunnels.

Of all the jobsites, GS Engineering's C925 site may be one of the smallest, according to Robbins. "It's very close to condominiums. We were limited to filling the mucking box during days, and we have noise barriers up. There were noise metres on tops of the condos, and our ambient noise readings were only allowed to average 65 dB, which is a little bit more than ambient noise," said Andy Birch, Robbins' field service site manager. The site was additionally near a main road and a school, and though the narrow jobsite was quite long, about 1.5 km, there is very little area for storage. A station box directly abuts the back of the C925 tunnel with STEC machines operating at that site, making space a premium.

Assembly of the Robbins machine at the jobsite was also a challenge. "We had to place cranes on the surface and do load calculations to get the machine down into the shaft for assembly. We had to build the TBM on an access between two tunnels, then push it over on jacks to get it into the right alignment for launch," explained Mr Birch.

CMC di Ravenna's C927 jobsite using two EPBs was similarly cramped. "We had a small shaft available for the

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two TBMs, 20 x 20 m. Both machines bored in the same direction, for twin drives, and passed under foundations for an overhead pedestrian bridge. These tunnels are predominantly under a national park (Bedok Park), and also go under a large 9.5 m wide canal that is 3.5 m deep for about 400 m of the tunnel,” said Chris Knight-Hassell, project manager for CMC.

At all of the sites very little muck could be stored on location due to lack of space; instead it was immediately loaded into trucks. The material was then designated for landfill to build up the shoreline of Singapore.

‘Unique conditions’

At C925, the specialised mixed ground Robbins EPB machine was launched from the small shaft site in December 2013, and quickly began ramping up excavation pace using a muck pump for muck removal in old alluvium. “It’s the first time a muck pump has been used here. We’ve gotten good advance rates, the fastest advance rates in Singapore, in fact,” claimed Mr Birch. “We started our actual excavation at one ring a day, then very quickly moved to two, and then by the time



Above: Assembly of GS Engineering’s C925 EPB took place in a cradle that had to be jacked into place for the tunnel alignment.



Left: A Robbins EPB is assembled at shaft bottom on CMC di Ravenna’s C927 contract.



A cutterhead is lowered within a small opening of the shaft at CMC di Ravenna’s C927 jobsite.

we reached rings 50-60, were getting up to four rings per day - the first time that has been done here in a 24 hour period.”

While the 30 m deep tunnel did not pass near existing utilities or building foundations, settlement still had to be kept to a minimum and ground conditioning was a big factor in that. “The operators knew about continued conditioning in front of the head, and that the material had to be kept at a certain consistency,” said Mr Birch. “We injected foam and monitored the earth pressure sensors continuously. It was imperative that we maintained about 1.6 bar on the top two pressure sensors, the middle at about 1.8, and the bottom sensors around 2.0 bar.” GS Engineering verified the effect of the machines with surface settlement monitoring.

Steady progress was made using the 6.6 m diameter Robbins EPB and it finished its first 800 m drive in April 2014. The result was within five months of its start in early December 2013 and within its 180 m/month programme average. To facilitate in-tunnel disassembly of the machine so it could start its second drive, Robbins designed each of the major components in such a way that disassembly was possible and each component could be easily transported along the tunnel and readily reassembled in the new shield. The process took about 16 weeks.

Its second blind-hole finish was scheduled for late January 2015, when it would again be disassembled, and the shield could be abandoned with the components withdrawn through its completed tunnel.

The TBMs at site C927 for CMC were launched in October 2012 and June 2013, respectively. A soil mix block 10 m in length (length of shield) x 20 m wide was added around the docking area for the TBMs. Excavation began in tough conditions from the outset. “Old alluvium is renowned in Singapore to be particularly abrasive. We use foams and polymers. I’ve worked for 16 years in Singapore, and

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this ground was particularly abrasive, with regular interventions every week to change out carbide bits and scrapers. This was generally done every 100 to 150 m,” said Mr Knight-Hassell.

Ground was particularly challenging around the area of the canal, where it was sandy and already prone to natural settlement. “When we were going through this area with the first machine, we did experience some settlement, which we then mitigated during the second machine pass,” added Mr Knight-Hassell.

The first of the CMC machines broke through in October 2013, after having achieved up to 15 m per day. The TBM exited into a 20 m wide receiving shaft, abutting the 200 m long main station structure. CMC applied ground treatment to allow the TBM to sit at the diaphragm wall, so that crews could hand excavate to meet the TBM head, allowing the TBM to move forward onto the cradle. The second machine followed suit in May 2014.

The three EPBs at GS Engineering’s C937 contract were launched between March and October 2013. Sections of tunnel are located in the Fort Canning Boulder Bed, though as of February 2014 the TBMs were only beginning to touch the outer edges of the formation. Located between 0.5 and 20 m below the surface, the boulders consist of sandstone with quartzite and felsites, and are thought to have been deposited between ½ and 1 million years ago in a series of landslides and mudslides. Boulder sizes have a minimum of about 0.5 m and a maximum of 3 m in diameter.

The implications of the boulder field on TBM tunnelling have historically been complex, explained Robbins. Since the boulder bed has relatively strong boulders located in a clay matrix, the cutting action of the disc cutters on the TBM cutterheads is hindered. Before the pressure required to chip the boulders into fragments is reached, the boulder moves in the clay matrix. When these boulders move, they can bang against other parts of the cutterhead, such as scrapers and bits, and damage them as well. In addition, the boulders and clay matrix have different hardnesses, so that the cutters are exposed to many shock loads in a short time. This reduces the life of the cutter and creates more



The completed tunnels will run just 4 m below the bed of the Singapore River, and just 5 m away from active Central Expressway Tunnels.

interventions to replace the cutters. Boring through this boulder field has historically been a slow ordeal as the TBM must go slow enough to avoid moving the boulders, but still push hard enough to break the boulders. If the boulders will not break, divers must go in front of the cutterhead to manually break up the boulders before the machine can advance.

The Robbins machines at C937 advanced at rates of up to 33 rings per day. One of the contract’s three machines completed its first 783 m long drive on 24 March 2014, and the second machine completed the parallel tunnel on 4 May. The third machine on the contract finished the first 570 m long tunnel towards Chinatown and rather than breaking through into the neighbouring Chinatown station contract, the TBM holed into the station box diaphragm wall and had to be dismantled and withdrawn back through its completed drive, similar to the C925 disassembly process. It was then re-launched on a second drive in June 2014 and finished later the same year. ■

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