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Rome Metro – Where Engineering Meets Art

Page 08

Monitoring activity

Are projects making the most of the recent advances in monitoring technology?

Page 14

Ahead of the curve in Bangkok

Tight radius TBMs are enabling a challenging cable tunnel project in Bangkok.

Page 32

Box-Jacking through rock in Doha

Experts discuss design schemes, construction sequences and the challenges they faced.

Ahead of the curve in Bangkok

In one of downtown Bangkok's busiest and most exclusive areas, two Terratec tight radius TBMs are enabling a highly challenging cable tunnel project for the Bangkok Metropolitan Electricity Authority. Amanda Foley reports.

The downtown area of Phloen Chit Road and Chidlom is to Bangkok what Orchard Road is to Singapore and Knightsbridge is to London. Shaped by high rise offices, upscale apartments, international embassies, expensive shopping malls and luxury hotels, the exclusive area represents the modern face of Bangkok. It is here, in the heart of the city's affluent retail district, that contractor Italian-Thai Development PCL (ITD) is currently operating two Terratec 'tight radius' Earth Pressure Balance Machines (EPBMs) on Bangkok Metropolitan Electricity Authority's (MEA) challenging Chidlom Outgoing Cable Tunnel Project.

Designed to accommodate a new high-voltage cable system, the Chidlom tunnel is one of a series of tunnelling projects currently being undertaken by the MEA to answer the growing demand for electricity in central business districts that are experiencing continued commercial growth and to improve the attractiveness of downtown Bangkok in preparation for its designation as an ASEAN 'Smart City' metropolis. The MEA projects will also improve the reliability of the power transmission system and reduce the risk of physical damage to conventional above-ground power lines as a result of accidents and storms. .

Project background

Running from a small project site in front of the MEA Head Offices and adjacent Chidlom Terminal Station, on Chidlom Road, the Outgoing Cable Tunnel project encompasses three tunnel drives – totalling 1,870m – and four shafts (see project map). The tunnels lead east to the Central Embassy 'ultra-luxury' designer mega mall, located on Phloen Chit (Rama I) Road within the former gardens of the British Embassy site, and southwards to the intersection of Sarasin Road and Lumphini Park (one of the largest public parks in Bangkok).

In order to remain within public road easements, as well as negotiate building foundations and the deep piles of the BTS Sukhumvit Skytrain that runs along Phloen Chit Road, the tunnel alignments are subject to strict constraints that require several tight radius curves (the tightest of which is just R35m) to bring them into MEA's Chidlom Terminal Station.

Traditionally, excavating tightly curved tunnels with a TBM is uncommon. However, this is one of a number of recent cable and drainage tunnel

View of the Shaft 2 site in front of the MEA Head Offices where Tunnel C curves to the left through the road intersection projects in Bangkok to adopt Terratec's tight radius TBM technology to facilitate challenging project requirements. Successful results have led to further projects that would not have been otherwise possible.

The Australian TBM manufacturer, who recently merged with its long-time Japanese partner JIM Technology (JIMT), has a well-established regional base in Thailand, having sold its first machine in the country eight years ago, to ITD, for the Metropolitan Rapid Transit (MRT) Blue Line Extension Project. Since then, Terratec has supplied nine machines to Thai projects in recent years. Several of these have featured an extreme X-type articulation system that can accommodate minimum radius curves of 30m.

This made the TBM selection on the Chidlom Outgoing Cable Tunnel fairly straightforward for ITD, who purchased a new 4.27m diameter tight radius EPBM (the S69 machine) from Terratec when it was awarded the construction contract in 2017, as well as a refurbished 3.2m diameter EPBM (the S48B machine) – that had been used by another contractor on a previous tight radius cable tunnel for MEA – for the two shorter drives on the project.

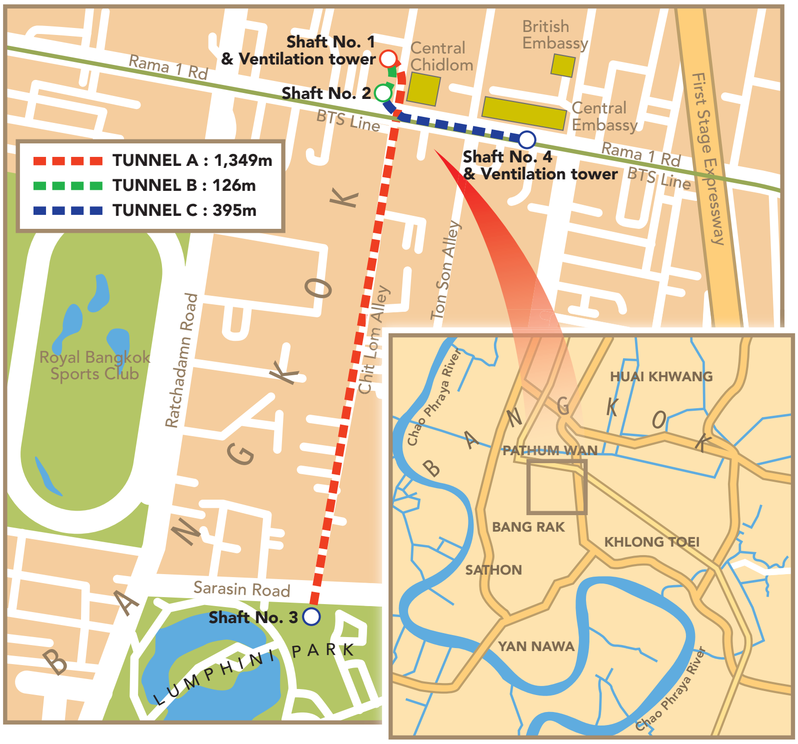
"We have worked closely with Terratec on several projects in the past and were keen to work with them again," explains ITD's Project Manager, Supak Khunviriya. "They have experience from similar projects in Bangkok, so there was a close collaboration from the tender stage. The TBMs are designed to achieve a high level of performance in difficult circumstances and we have trust in Terratec's team, who have assisted us throughout the tunnelling operations."

Site set-up

Due to heavy traffic and the physical limitations of this densely built up area, shaft locations, site set-up and logistics during the launch and operation of the TBMs has been extremely challenging for ITD. The project has two (very small) operational shaft sites and two (extremely small) reception shaft sites, all in very sensitive locations. Added to this is the inability to halt traffic on any of the surrounding roads and a five-hour day-time curfew on heavy vehicles accessing the sites.

Shaft 2 is a 9m diameter, 26m deep, octagonal diaphragm wall shaft located directly in front of the MEA's Head Office building that is being used to stage two short, 3.2m diameter, TBM drives (Tunnels B and C) using the S48B EPB machine. Shaft 3 is a 10m diameter, 20m deep, caisson shaft located within a small site on the edge of Lumphini Park, next to Sarasin Road, that is being used to service the project's main 1,349m-long, 4.27m diameter, S69 TBM drive (Tunnel A) northwards to Shaft 1. The sites both have a footprint of about 15m x 60m, serviced by gantry cranes, and with just about enough space to store 10 rings of tunnel lining segments and muck boxes that can hold about five rings of excavated material.

Shaft 4 is a 6m diameter, 20m deep, circular reception shaft site for Tunnel C, which is located in a small area under the BTS Sukhumvit Skytrain viaduct, directly in front of the Central Embassy luxury mall complex. Last, but not least, is Shaft 1, which will receive both TBMs on their final drives.



The Chidlom Cable tunnel map

This remarkably narrow 6.6m wide x 27.6m long x 38m deep diaphragm wall reception box has been sandwiched into a small side-alley on the far side of the Chidlom Terminal Station with just a metre clearance either side to the foundations of the neighbouring buildings. It can only be accessed from the main road via the use of steel decking over the shaft, requiring equipment and materials to be hoisted in and out, before replacing the cover and manoeuvring trucks onto the decking for loading.

Shaft construction

ITD mobilised on site and began preparing for shaft construction in mid-2017. It took about six months to complete the eight-sided Shaft 2: "With about three months for the diaphragm walls and about two months for excavation," says Khunviriya. The access restrictions added to the challenge, with equipment having to be brought on and off the site at night in order to free up space to conduct other operations. "This area is very congested and there is a curfew on the large 10-wheel trucks we use from 10am to 3pm. Sometimes we use smaller six-wheel trucks, which are not included in the curfew, but most of our transportation operations are done at night."

Shaft 3, on the edge of Lumphini Park, also posed challenges. "The project was slow to start, because the park authority didn't want construction in this area and it took some time to get the necessary permissions," says Khunviriya. "Thankfully, we have direct access to the site from Sarasin Road with a separate gate and there is a large temporary fence around the area, so it does not disturb the rest of the park." Ground water inflows during shaft excavation were also an issue, due to the presence of water-bearing sands in this area, and ultimately required both pre-grouting and rounds of supplemental grouting around the shaft to seal the water out. With this in mind, additional chemical grouting was also

View of the Shaft 1 site with and without its steel decking cover

added to the planned TBM break-out grout block, which performed well.

Shaft 1 took just over a year to build, hampered by the limited access to the alley alongside the Terminal Station building. The 27m long by 6.6m wide shaft has 22 diaphragm wall panels that are each about 1.2m in thickness and extend to a depth of 47m. The shaft has been mined using a compact excavator and is serviced by a 60t gantry crane, which sits on tracks in the one metre clearance either side of the shaft. "The problem has been the shallow foundations of the buildings on either side, which are about 20m deep," says Khunviriya. "This excavation is twice that depth, so movement of the shaft was a concern. We initially used a lot of temporary steel bracing, about nine layers, but once we reached a depth of about 15m we decided to switch to casting concrete in order to provide more support."

TBM drives

With tunnelling commencing at Shaft 2 on Tunnel C last September, focus switched to TBM logistics and the transportation and delivery of the oversized TBM parts for assembly within the shaft. Terratec, who would be assisting ITD in the operation and maintenance of the TBMs, had been working closely with ITD from day one in order to coordinate the complex overnight TBM deliveries into the city and this paid off with everything going smoothly.

The geology along the project is typical for Bangkok, generally comprising stiff to very stiff clay, with lenses of sand and a groundwater head of about 2 bars. The TBMs therefore feature classic soft ground open spoke cutterhead designs, with knife bits to assist break-in and break-out of the concrete shaft eyes. In addition to their unique articulation design, the TBMs also have back-up systems that are tailored to accommodate tight radius curve requirements, including slightly shorter gantry lengths and a mucking system that can convey spoil from the TBM's screw to a transfer pipe using air pressure.

Unfortunately, there was little time for ITD to get familiar with these systems on the Chidlom project before it commenced: "We started out straight into the 35m radius curve with the S48B machine, going under the road and around the corner of the Central Chidlom department store," explains Khunviriya. "This is an old building, so the foundation piles extend down about 20m. The tunnel is at exactly the same level, so we had to be very careful not to cause any settlement. We also had to negotiate the BTS Skytrain foundations on the other side, giving us a window with about 1m either side of the machine."

ITD had an array of monitoring equipment in place to check any tunnelling induced settlement, including

Transition between traditional lining rings and the short steel sets used in the Tunnel C tight radius curve

Above: The S48B machine, showing its full articulation capacity

Right: S69 TBM assembly in Shaft 3

deep extensometers, inclinometers and settlement points at the centre line of the tunnel, but thankfully zero movement was recorded. Khunviriya credits much of this to the experience of Terratec's field service team, whose experienced TBM operators steered the TBM throughout the curve.

"We have two Terratec operators on the project, as well as an electrician and a mechanic, says Khunviriya. "But they all switched to the S69 machine on the Tunnel A drive when it began in early February. By then we had completed the curve on Tunnel C and had entered the straight section towards Shaft 4."

Progress through the curve did go slowly, with the TBM advancing just one or two rings per day in a single work shift. However, this is said to have been largely due to the limitations of the site and the extreme sensitivity of the surrounding structures, particularly the BTS foundation piles. Once the curve was passed, advance rates increased rapidly and the Tunnel C drive was completed in the first week of May, when it broke through into Shaft 4.

As they progress, the machines install two types of linings. For the majority of the alignment a traditionally reinforced Universal tapered precast concrete ring, consisting of four segments plus key, is used. However, during the course of the sharp tight radius curves a shorter (300mm wide) steel ring set is adopted – simply requiring an adaptor on the TBM's segment erector to be installed to adjust the catching point. All of the segments are manufactured at ITD's fabrication complex, which is located about 100km from the city.

Future challenges

With Tunnel C now complete and the S69 TBM well underway on Tunnel A, having excavated 191 of its scheduled 1102 rings and due to breakthrough at Shaft 1 this September, ITD is now looking ahead to the final curved drives that will bring both TBMs into Shaft 1 to make the final connection with the Chidlom Terminal station. "For the final [80m radius] curves and TBM breakthroughs, we will perform a large jet grouted block, about 10m long," says Khunviriya. "It's all in a layer of wet sand, so we need to control the water for careful breakthrough, and also it's a very difficult and small space to work in."

The two machines will enter the end of the narrow shaft at different heights, complicated due to the location of an existing 2.6m diameter cable tunnel built 10-years ago that crosses the shaft at a depth of 17m. "The S69 machine excavating Tunnel A will breakthrough first, at a depth of 33m," explains Khunviriya. "Once we have disassembled that machine and lifted all the parts out, then a platform will need to be installed at a depth of 24m to receive the smaller S48B machine when it completes Tunnel B. But the shaft is very deep, and narrow, and we are still considering how best to perform the TBM disassembly in such a difficult small space."

It will take a long time to disassemble the TBMs, as they will each need to be cut into parts and the elements lifted individually via the gantry crane to the surface; the shaft decking then has to be replaced before a truck can be brought onto the platform and the part lowered; then the process will be repeated for the next element.

In the meantime, the continued successful application of these tight radius TBMs could open up new possibilities for a number of utility providers and water agencies around the world that face similar alignment challenges.