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Tunnels AND TUNNELLING

SUEZ CROSSING

The first breakthrough on the Ismailia Road Tunnel

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TUNNELLING IN THE JUNGLE

Snakes and hard sandstone were among the challenges facing Seli Overseas on a new 11.5km low pressure headrace tunnel for a hydroelectric project in Laos

***Above:** Breakthrough was achieved in March, three months ahead of schedule*

Video

The TBM manufacturer has released a video of this project: http://terratec.co/video/05.html

SNAKE IDENTIFICATION IS NOT typically included on a site induction for a tunnelling project, but with more than 20 different types of snakes common to the remote jungle areas of the south of the Laos People's Democratic Republic, tunnellers from Seli Overseas had to be prepared for snake bites. The nearest minor hospital was two-and-a-half

Left: ***Xe-Pian site location relative to the Laotian capital***

Project Statistics

Client: Xe-Pian Xe-Namnoy Power Company SK Engineering & Construction, Korea Western Power, Ratchaburi Electricity Generating Holding, Lao Holding State Enterprise)
Main contractor: SK Engineering & Construction (South Korea)
Operation and Maintenance: Korea Western Power
TBM tunnelling contractor: SELI Overseas
Length of TBM bore: 11.5km
TBM supplier: Terratec
Construction scope: Xe-Pian Dam, Xe-Namnoy Dam, 3 no. saddle dams, transfer conduit, headrace tunnel, shaft, penstock, powerhouse, M&E work.
Construction period: 60 months
Contract type: Build Operate Transfer (BOT)

hours away by car, and the closest major hospital, over the western border in Thailand, around five hours away. "Scientists say that the most dangerous snakes in the world are in Laos. The most common is the viper. Then there is the cobra, which is very dangerous and many others," says Dario Vizzino project director for tunnel contractor Seli Overseas. "You have to use the right anti venom for specific snake. Some venoms make the blood coagulate, others affect neural pathways in the brain and stop respiration," he says.

A full range of anti-venoms were therefore stored at the jobsite and the contractor also hired an Italian doctor to support the 260-strong team in case of any incidents. "The last bite was only two days ago, a local guy here. We inject the anti-venom and put him in the emergency car and went as fast as possible to hospital," he says.

RECORD PROGRESS

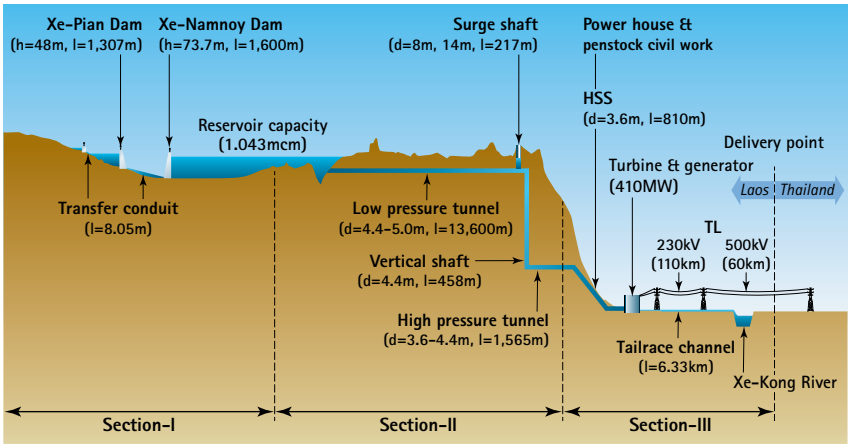
The remote nature of the site is often a feature of hydropower projects and the 410MW Xe-Pian Xe-Namnoy Hydroelectric Power Project is no exception. Located in the far south of Laos, the site is in an isolated area of national park on the Bolaven Plateau, 80km from the town of Pakse on the Mekong River and involves construction of a new reservoir, associated dams, a low-pressure tunnel, vertical drop shaft, high pressure tunnel, power house, turbine and generator and tailrace channel.

The main contractor for the scheme is South Korea's SK Engineering and Construction, which in turn employed Seli Overseas to deliver the 11.5km TBM driven element of the 13.7km low pressure tunnel. For the TBM, Seli turned to Australia's Terratec who supplied a 5.74m diameter double shield machine to grind through the mudstones, sandstones and siltstones. "We finished excavation in March, three months early," says Vizzino explaining that a range of factors contributed to the speedy progress from the quality of the workforce to the performance of the TBM and the efficiency of the mucking out system. A decision to separate the pea gravel injection from the excavation was also critical in enabling the TBM to continue unimpeded. "We decided to disconnect this activity from the TBM work because at the beginning we had some problems with the pea gravel mix design with the client. The TBM had already started the excavation when we started with the grouting. So, our experience told us to disconnect these two activities."

The pea gravel, which is often used to back fill the annulus in hard rock tunnelling, was supplied by the main contractor SK E&C, with Seli Overseas responsible for its application. The gravel itself was expected to be smooth pebbles of 6mm to 12mm but instead the aggregate was irregular and angular with stones from 4mm up to 20mm. This made it highly abrasive causing massive wear to the double pump application system and leading to major losses of time as the pipes were replaced. In addition, the mix was sticky and clogged the pipes, requiring huge amounts of pressure to unblock. "We explained to the client that if you inject this type of pea gravel, the pressure of 6 bar needed to apply it was too much for the structure of the segments so they began to find another solution," says Vizzino.

When the alternative pea gravel arrived, it was perfect. "It was the best we had ever used. It flowed like water," says Vizzino. This enabled the team to apply it as designed at the planned

Below: ***Layout of project components, divided into three sections***



injection points at 10pm, 2pm and at the crown rather than having to also inject at 04pm, 08pm and at invert because of the poor viscosity of the original material.

Thanks to the quick thinking of the team the early issues around the pea gravel did not hold back the tunnel boring and according to Vizzino it also ensured that the injection team wasn't rushing to maintain pace of the TBM, allowing them to focus on the quality of application.

"The key factor on this project was quality. We concentrated on getting everything right from the beginning, working well with the TBM and Terratec, and we finished on time with very good results. It was good for everybody." So good in fact that the Seli Overseas broke its production record excavating 1,004.4m of tunnel and placing 669.5 segment rings during July 2016. Yet Vizzino says their focus was on maintaining steady progress to ensure quality was maintained.

"It was good to see a machine going into a very well run and efficient operation. It was a big relief to see the machine working so well and consistently with high production. The breakout was quite dramatic. To see a double shield breaking out in hard rock is very noisy and exciting," says Bill Brundan, site operations manager for Terratec.

Top: ***Site assembly took around four months and was carried out at the portal outside the tunnel***

Above: ***The team built a concrete cradle to hold the shield and laid a slab for the back-up gantries***

OVERCOMING CHALLENGES

Getting everything right from the beginning did require the team to overcome some considerable challenges. Progress in the first three months for example was just a fraction of the 500m/month averaged achieved over the 22 month bore as the power supply to the project was unreliable. "In first few months we were only operating between 1am and 5am in the morning as that is when we were getting most stable power from the grid as there was less usage on the surface," says Brundan.

Initially the client was not convinced of the need to invest in alternative power supply but gradually the team demonstrated the issues. "We had some stops and some blackouts but the oscillating power caused some damage to the TBM and it was clear to the client that it was a problem so they bought five generators," says Vizzino.

These Cummins 800kV engines immediately boosted progress. "We had three months of very good progress. Everything was going fine and then the rock began to change so we went from mudstone to very hard sandstone of around 200MPa," says Vizzino. This was harder than expected with sandstone along the later section of the tunnel only 80-100MPa. Despite having what Vizzino describes as a "very strong" machine, some reinforcement of the cutterhead was required to boost progress through the harder rock. "It wasn't designed for this strength of rock and we saw production begin to go down so we decided with Terratec to reinforce the TBM cutterhead. We spent all the month of January reinforcing the TBM with additional welding and steel plates. We asked Palmieri to change the type of housing and we reinforced the structure of the cutterhead with some additional steel on the bulkhead and we also added some anti wearing plate to the front of the TBM."

FULL STEAM AHEAD

Once these early issues were addressed the machine began to fly with production rates doubling as the team pushed ahead headed up by the 60t cutter head hosting 39 back loading 17 inch disc cutters. Power came from eight 250kW motors supplying a total of 2000kW and 8,000kNm of torque.

Logistically Seli Overseas opted for the lower cost option of spoil removal via train rather than conveyor, which

required design features from the TBM including a tripper conveyor that took the muck from the back-up conveyor and emptied it into the 11 muck cars. In the early stages of the project Seli Overseas used three trains and a single mobile California switch sitting at the back of the TBM. "The tripper conveyor allowed the train to go in and the pea gravel bins to be uncoupled and then the train could stay parked while the tripper conveyor moved along the whole length of the train until all the muck carts were full. So that provided a lot of efficiency in the excavation cycle," says Brundan.

As the scheme progressed and the TBM moved further along the 11.5km bore Seli invested in more trains and a second California switch at around 4km inside the tunnel. "We added another train to support excavation and that was enough to assure the cycle time. But we had two trains spare to ensure that we would never have to stop because of any train issues," says Vizzino. Maintenance activities were carried out for three to four hours each day alongside the three working shifts, which maintained 24 hour operations.

The tunnel lining was designed by Italy's Ingegneria Geotecnica with each ring consisting of four reinforced concrete hexagonal segments. Materials were provided by the main contractor and an onsite segment factory produced 24 rings per day to support construction. Each ring is 1.5m long and 250mm wide creating a tunnel with a 5m internal diameter and a 24mm annular gap. SELI Overseas opted to install this on a half stroke basis installing two segments at a time. A total of 7,636 rings were used on the project with 332 placed every month on average.

Moving the segments the 5km from the factory to the portal was achieved using trucks taking one ring at a time. Each train would then transport two segments to the TBM back up where these were then lifted onto the TBM.

Although Seli Overseas could have maintained its record breaking pace, the team opted to reduce the thrust and therefore the stress on the TBM. "We decided to reduce this a little because we could make more than 1,000m but the scope is to finish the tunnel in the right way without any problems with the TBM or the lining. The tunnel looks wonderful now. It is very straight from a topographic point of view and the quality of segments is very nice," says Vizzino.

Upon completion of the excavation in March the TBM was then disassembled and removed back through the 11.5km bored tunnel. "The TBM itself was very good condition at the end of the bore and we are now storing it on site as we are waiting to see if we can reuse it on another project."

*Right: **A strong expatriate workforce was vital for this project***

*Right: **Hydraulic arms lift the 1.5m long hexagonal segments on to the TBM***

ATTRACTING TALENT

Investment in qualified staff was another priority for Seli Overseas which invested heavily in the on-site facilities to make it a more attractive proposition for tunnellers, particularly expatriate ones. The challenging nature of the site saw Vizzino more than double his investment in experienced international tunnelling expertise with around 80 of his 260-strong team from Europe compared to the original estimate of 35.

"Experienced, well motivated and gratified workers make you save a lot of money and it is always a winning factor, this is a fact," he says. "I decided to spend money making a good camp with good facilities, very good houses, nice food, taking care first of all about creating a true team and people said that they were very happy to work here."

Fatality

Readers may be aware of a fatality on this project. A worker lost his life in a accident. However, an ongoing investigation while this article was prepared meant that it was inappropriate to publish more information at the time.