TITLE UNDERSEA MICROTUNNELS FOR MINING INDUSTRY IN CHILE

Author: Bernard THERON

1. ABSTRACT

In 2014, Bessac was awarded a contract by Mining Company BHP Billiton for the construction of 3 undersea microtunnels for the new desalination plant of the Escondida copper mine in Chile.

The Project includes one 530-meters long 2-meters diameter seawater intakes and one-360 meters long 2-meters diameter outlet. The microtunnels are excavated in diorite and gabbro rocky formations. Two brands new microtunneling machines run in parallel for this project.

The reinforced concrete pipes are manufactured next to the jobsite, in an existing precast plant, under the supervision of Bessac.

At the end of each drive, the microtunneling machines are retrieved at 30 meters deep in the wet, in 6 meters diameter shafts dug below the sea bed.

Besides the difficult geology and the logistical challenges related to the off-shore constraints, Bessac had to strictly comply with the QSE expectations of the Mining Industry, which go far beyond the traditional construction standards.

2. DESCRIPTION OF ESCONDIDA WATER SUPPLY PROJECT

The Escondida Water Supply (EWS) project is contributing to BHP Billiton's base metal mining efforts in the Atacama region, north of Chile. This massive project includes the following elements:

- A new collection of sea water and brine discharge located in Puerto Coloso.
- A new desalination plant seawater of 2,500 L / s, located in Puerto Coloso.
- A new transport system including pumping stations and pipelines to transport water product to the dam at the mine.
- A new dam on the mine site.
- New high power lines and electrical substations.

Works covered by our contract correspond to Marine Works related to the desalination plant.

2.1 Marine Works Project

The Marine Works project is located in Puerto Coloso, south of Antofagasta, Chile. This portion of the EWS Project provides for conveyance of water to a desalination plant for use in mining processes and diffusion of concentrated brine into the Pacific Ocean. It includes the following components:

- Intake/outfall structure – an approximately 35m by 13m, 32m deep, rectangular shaft that serves as an intermediate point between the Pacific Ocean and the inland processes including the Sea Water Pump Station. The intake/outfall structure has two intake chambers, one outfall chamber, and an overflow structure.
- Sea water pump station – an approximately 44m by 21m, 17m deep, provides pumping facilities to transfer seawater from the intake/outfall structure to a desalination plant.
- Outfall tunnel: one approximately 360m long, 2.0m finished ID circular pipeline connecting the intake/outfall structure to the Pacific Ocean through a diffuser on the seabed. The outfall tunnel conveys the concentrated brine from the intake/outfall structure into the Pacific Ocean.
- Intake tunnels: two approximately 530m long, 2.0m finished ID circular pipelines connecting the intake/outfall structure to the Pacific Ocean through intake structures in the sea floor. The intake tunnels convey the seawater from the Pacific Ocean to the intake/outfall structure and the sea water pump station and ultimately the desalination plant.
- Marine shafts: three approximately 15m deep, 7.0m ID circular shape marine shafts excavated prior to the intake and outfall tunnels for a wet MTBM retrieval.
- Connection tunnels between the intake/outfall structure shaft and sea water pump station: two approximately 15m long, 2.0m finished ID circular pipelines, constructed by drill & blast, connecting the intake chambers of the intake/outfall structure to the sea water pump station.

Bessac scope of work is the construction of the intakes and outfall submarine tunnels.

2.2 Intakes and Outfall submarines tunnels

The tunnels are excavated utilizing two pressurized hard-rock slurry MTBMs with pipe jacking methods adapted to handle the geological conditions.

The three tunnels are straight in plan. In profile, they are divided in three different sections:

- Section 1 = at launching, a 6% slope,
- Section 2 = a 500 meters radius curve in the vertical plan,
- Section 3 = horizontal up to the recovery shaft.

The recovery shafts are 36 meters deep for the intakes and 28 meters deep for the outfall, below the mean sea level.

To complete the work within the deadlines imposed by the project, it has been necessary to use two MTBMs, running in parallel, to excavate the three tunnels.

Figure 1. Overall view of the project

3. DESCRIPTION OF THE TECHNICAL CHALLENGES

3.1 Remote location

The remote location of the construction site in relation to the Bessac company facilities represents one of the challenges of this project.
The project is located in Puerto Coloso, about fifteen kilometers from Antofagasta, the main town close to the Atacama Desert, in northern Chile. Thus, the site is more than 10 000 km of our premises in France and almost 1500 km of the Chilean capital, Santiago.

Figure 2. Location of the project

Equipment importation

The main equipment and materials are not available locally and have to be imported, mostly by over the sea.
For example, the 220 tons of reinforcement steel for the jacking pipes, mainly due to the epoxy coating requirement, are imported from the USA. The specific equipment for the excavation of the tunnels, composed by the MTBMS and the slurry treatment plants, are imported from Great Britain and Germany. The molds and ancillaries for the jacking pipe precast plant are imported from Germany.
It is not less than 40 containers that crossed the Atlantic Ocean for an approximately two months journey.

Production of jacking pipes

Concrete jacking pipes are the main components of the tunnels. As in every jacking project, it is a key component for the success of the excavation.
Two options are considered: import pipes from Europe / USA or produce them locally.
We choose the second one. We set up a jacking pipe precast plant in a local concrete batching / precast plant. As previously stated, we import the molds and ancillaries from a reliable German manufacturer in order to be able to produce high standard concrete jacking pipes, meeting client requirements. In addition, European specialists have been contracted to supervise the pipe production. They bring their know-how and train local operators.
They also ensure the Quality Control during the whole production of these 500 pipes.

Figure 3. Jacking pipe precast

Training local operators

The project also requires adjustment to the local culture and work habits. The staff in charge of management of the construction site and MTBM operators are expatriates who have technical experience of this kind of project in other parts of the world. The other positions are recruited and hired locally. As there are few experiences of tunnels construction with MTBM and pipe jacking method in the whole country, we set up a training process, during the project preparation stage. Bentonite manufacturing, use of a slurry treatment plant, preparation and implementation of the pipes in the launching shaft are included in the training program.
It is even more complicated as the site operates 7 days/7 and 24 hours/24. We work in four shifts of 50 operators, including 45 locally recruited for the two MTBMs.

3.2 MTBM in rock

According to the geotechnical baseline report, the ground is mainly composed of rock (gabbro and diorite) along the three tunnels.
Furthermore, additional tests have been carried out to confirm the rock resistance and abrasiveness. They conclude in strong to very strong rock (UCS= 50 to 150 MPa) and highly abrasive.
To ensure adequate excavation, we use cutting wheels with the following characteristics:

- 14" HD disk cutters to fracture the rocky ground,
- Scrapers collecting the excavated material.

We also added a hardox facing to protect the cutting wheel against wear.

The separation process is also well adapted to rocky condition with scalpers in stage 1, de-sanding / de-sitling in stage 2 and centrifuge in stage 3. The slurry treatment plant has the capacity to proceed the two MTBM in parallel.

Figure 4. MTBM #1 before shipment

Tools replacement

As in all undersea projects, due to the possible connection between the face and the sea by rock fractures, the tools replacement operation is always challenging.
Before each hyperbaric intervention, we apply high density bentonite mud with polymers to fill the rock fractures in order to lower the air losses when accessing to the excavation chamber.
We conduct tool inspection operation shortly after MTBM launching to value the wear and to predict more accurately the lifetime of the disk cutters.
Finally, the cutter lifetime is approximately 120 m^3.

3.3 Recovery shafts construction

In the recovery shafts area, the seabed is about 20m deep. From the seabed, the shafts are about 15m deep. They are in strong rocky ground.
As the Chile environmental laws prohibit the use of explosive to excavate the recovery shafts, our maritime works partner, Geocean, has excavated the shafts with a giant vessel called "Excalibur". It consists in a jack-up barge with large reverse circulation drilling facility. It drilled 7.0m ID shafts in one pass.

3.4 Sea recovery of MTBM

MTBM reception at intake shaft

Before arrival of the MTBM, the shafts are filled with sand up to 1m above the tunnel invert.

The Multicat (multipurpose vessel) supports the different operations such as Remotely Operated Vehicle (ROV) video recording, pumping soft material, diving operations, flexible installation and recovery and transportation of the MTBM. It is positioned above the shaft location.

A ROV supervises the MTBM arrivals into the shafts. It monitors the penetration of the MTBM into the shaft and advises when the cutting wheel is free.

The MTBM continues to be pushed, with the help of intermediate stations, to its final position, in the shaft. The ROV visually checks that the MTBM lays on the sand on the good position.

Disconnection and preparation of MTBM

With the MTBM inside the recovery shaft, the connections of the MTBM, inside the tunnel, are disassembled and a bulkhead is installed in the tunnel, at the back of the MTBM. The MTBM is then air pressurized at 3.6 bars

Divers connect three hoses on the top of the MTBM. The first hose is used to pressurize the MTBM, the second one is used to actuate the hydraulic expulsion cylinders and the third one is used to retract them.

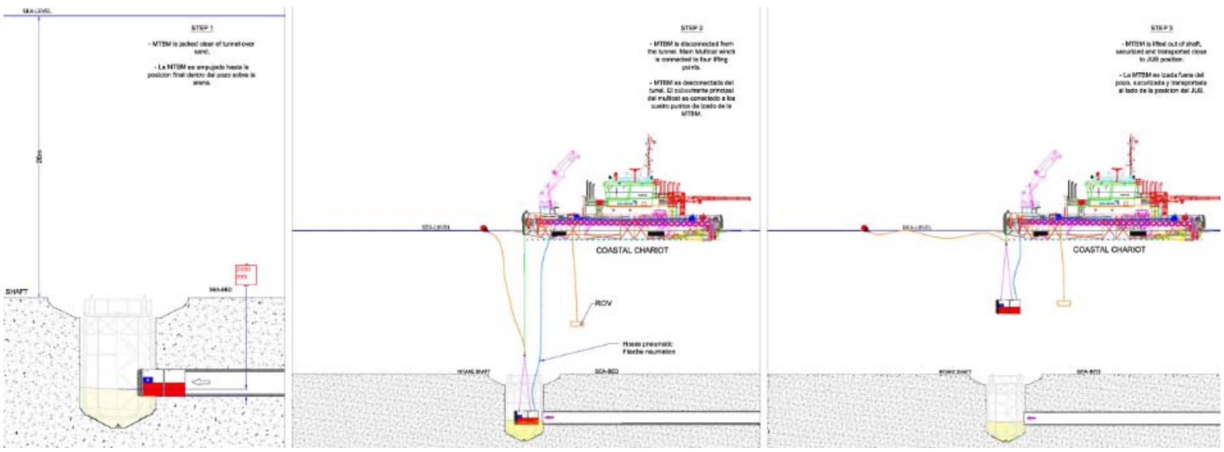

Figure 5. MTBM arrival in recovery shaft

The divers then remove the water plug to allow sea water to enter in the space between the MTBM and the bulkhead, to equalize the external and internal water pressure.

Once it is confirmed by ROV that there is no obstacle in front of the MTBM and no one inside the tunnel, we proceed to the expulsion of the MTBM from the tunnel.

After separation, we retract the expulsion cylinders, under supervision of the ROV.

Divers finally disconnect hydraulic hoses from the MTBM.

MTBM recovery

Divers install the four lifting plates on the MTBM. The Multicat winch cable is lowered and connected to the MTBM. Once the divers are in a safe position, instructions are given to the Multicat winch to begin raising the MTBM, up to 5 meters above the seabed. Then the Multicat is slowly moved to the jack-up barge location. The jack-up barge crane lift-up the MTBM and load it into the transfer vessel. It is finally transported to the harbor.

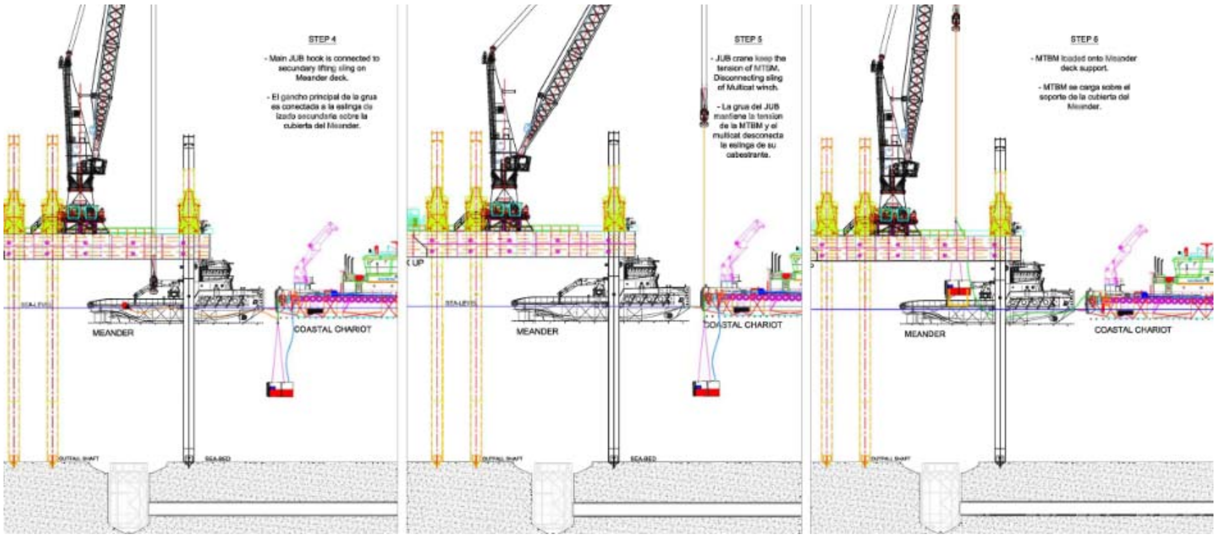

Figure 6. MTBM recovery procedure

3.5 Description of the "mining background"

The mining is rooted in the history of Chile. Saltpeter, gold and copper have now allowed the country to develop considerably during the 20th century. Today Chile is the largest producer of copper in the world.
This mining history has been marked by numerous human losses due to low safety standards.
Nowadays, attitudes have changed. Everyone is committed to "safety first" and casualties are unacceptable. Chile has enforced strict laws in the mining industry to protect people and environment.
The Escondida Water Supply project is part of BHP Billiton's development policy for their largest copper production mine in the world. As a major worldwide mining company, BHP Billiton has high internal standards.
In addition, to supervise the project, BHP Billiton contracted Bechtel Company.
Therefore, in addition to specific local laws, Bechtel and BHP company policies apply.

Safety

In this particular context, we have to conciliate the rules of Bechtel, with those of the BHP BILLITON, and those of the Chilean laws; these rules are sometimes contradictory.
Furthermore, they are well adapted to traditional mining (D&B tunnel, wells, mass extraction) but not really to TBM tunnels.
The preparation phase has been marked by meetings, presentations, workshops, to enable us, together with our customer, to adapt our working procedures and to find an agreement.

Training

Three full days of courses are required before you can enter the construction site. The main subjects are: lifting, excavation, electrical, small tools, machines, diving, working at heights, etc.

From a human resources perspective, each person is assigned a specific task and cannot perform other work, even exceptionally. It requires a larger number of operator than in a "classic" construction site.

Before performing any activity, operators have to perform a risk analysis of all the task, which shall be checked by a supervisor. This risk analysis has to be carried out every day, even if the activity is repeated, as for example the installation of a jacking pipe in the shaft.

Figure 7. Christening of the MTBM before launching

Hyperbaric works

Chilean laws do not address hyperbaric interventions. Thus, in order to achieve the hyperbaric works, we introduce for validation the French decompression tables. After several presentations with client's experts, firefighters, hospitals, we manage to get hyperbaric working procedures approved.

An emergency decompression chamber is installed on site in case of an emergency.

Structure lifetime / quality requirements

The structure is designed to have the greatest lifetime achievable.

The project is located in a very aggressive environment, due to sea water, wind, sand, etc. The requirements of contract documents are very high in term of durability.

For example, we use Super-duplex steel for parts of structure in contact of sea water and we use epoxy coated steel reinforcement for the concrete structures.

In the case of jacking pipes:

- We have to use a specific concrete formulation. As all the components are not available in Chile, we have to import part of them.
- As the specification prohibits to drill hole in the concrete, we have to integrate specifics inserts during the precast of the pipes for fixing purpose.
- We have to use Super-duplex steel for pipe collars, inter-jacking station steel components, grouting sockets, etc.
- We have to use epoxy coated reinforcement, imported form USA, for the concrete.

4. CONCLUSION

Despite the challenging conditions, the project is successful and the desalination plant will be commissioned soon.
Adverse marine conditions, high water pressure at recovery point, strong and abrasive rock, this project permits to challenge the limits of the possible of construction of sea outfall structures with MTBM and pipe jacking method.
This construction technique is in expansion worldwide as it permits to construct sea outfall, sea intakes, and landfalls without damaging the foreshore areas.

Figure 8. Construction site view