Powered up

The Angostura hydroelectric power plant, which began operations earlier this year, represented a major power project for Chile and offered plenty of construction challenges

Chile's burgeoning economy and the growth of its mining sector have increased the demand for electricity in the country.

The south-central part of Chile in particular benefits from a natural environment and climate conditions that allow for the inexpensive, sustainable hydroelectric generation of electricity.

The Angostura hydroelectric power plant is one of several major hydroelectric projects carried out in the country in the past decade.

Located approximately 600km south of Santiago, in the municipality of Santa Barbara y Quilaco, in the Biobío region, the Angostura plant is the largest hydroelectric plant built in Chile since 2004.

Developed by the Chilean utility company Colbún and opened in April 2014, the power plant has a capacity of 316MW and an average annual generation capacity of 1,542GWh.

The plant uses water resources from the Huequecura and Biobío rivers through a reservoir with minimal regulation, which allows a variation no higher than one metre in water level, thus minimising the environmental impact and enabling tourism development in the area.

The plant covers an area of 641 acres (2.6km^2) and stores some 100 million m^3 of water. It features three vertical Francis turbines, two 136MW Francis turbine-generator sets, and one 46MW Francis ecological discharge turbine, which ensures that rivers feeding the hydro scheme have the minimum water flow required for the ecosystem, provided by Alstom.

The architecture allows enough flexibility to operate both generator sets in times of higher flow, as is the case in winter, or lower flow, as in the summer. The plant also has the largest turbine hall in the country – 59m high, 177m long and 30m wide.

The Angostura hydroelectric power plant

DAM CONSTRUCTION

The project was awarded to industrial group Salini Impregilo for a total value of €250 million (US$313 million), and construction began in February 2010.

The main civil works included the construction of an earth dam approximately 1.6km long and 25m high on the left bank of the river and a roller-compacted concrete (RCC) dam, 125m long and 63m high, with a spillway incorporated along the Biobío river.

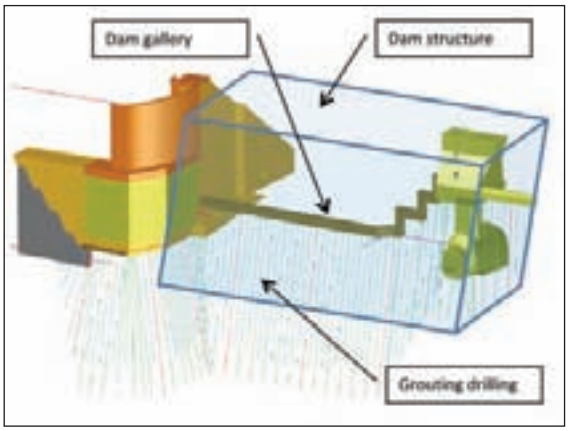
Although the bedrock formed of sedimentary rock offered good conditions for the construction of a dam, the project requirements included waterproofing the dam body by means of drilling and grouting with cement.

The drilling operations were also aimed at identifying and securing any weak or permeable zones along the dam structure.

The Chilean foundation contractor Pilotes Terratest, part of Echeverria Izquierdo Group, was in charge of the execution of all the drilling works, including injections and waterproofing, consolidation, drainage and instrumentation installation (piezometers and an inverted pendulum).

The majority of the works were carried out underground, including the diversion tunnel, ►

Working within the narrow galleries of the dam



Layout of the dam

outlet tunnel, dam, drainage gallery, headrace tunnels, discharge tunnels, turbine hall and access galleries to the turbine hall.

DRILLING TECHNOLOGY

Two different drilling techniques were used to carry out the consolidation and waterproofing works involved in the project: rotary-percussive drilling and core drilling.

The main challenge was that the majority of waterproofing drilling operations had to be carried out in low-roofed tunnels and galleries, 2.4m wide and 2.5m high.

The Comacchio MC 3 D unit working in low-overhead conditions inside the galleries

In order to meet this requirement, Pilotest Terratest chose a Comacchio MC 3 D drill rig (formerly the MC 235) with a separate power pack. Due to its compact size (1.15m wide with a 2.3m-long mast and 2,500daN feed/pull-up), the rig could be successfully operated inside the small galleries incorporated into the dam structure.

"The drill rig features a variable-width undercarriage that is 750-1,150mm wide, thus allowing for operation even in very confined spaces," explains Comacchio's sales manager, Flavio Durigan.

"The machine is equipped with an electric power pack, avoiding emissions and reducing noise levels, thus providing a safe work environment for all workers. The power pack is also mounted on an undercarriage with adjustable width from 1 to 1.5m, fitting the limited space inside the galleries. The rubber track undercarriages of both drill rig and power pack ensured that no damage was caused to the concrete floor of the galleries."

WATERPROOFING

Waterproofing of the bedrock was done by drilling 64mm holes and then grouting with cement for a total of 7,018 drilling metres. Part of the drilling took place in cramped galleries, with very limited free space to operate on above the drill rig. Drill tubes as short as 1m had to be used, making straight drilling particularly difficult.

"The drilling needed for waterproofing of the bedrock was performed using an innovative technique," says Alberto Mukden, production manager at Pilotes Terratest.

"For the first time we implemented a rotary-percussive drilling system with a hydraulically driven DTH hammer developed by Wassara. The advantage of this system is that no compressed air is required, thus there is no harmful noise in the working place, the hydraulic power pumped to the hammer has practically no loss, and it allows for a better control of borehole deviation.

"The allowed borehole deviation was set to 2% at full length (up to 60m). We are proud to say that this requirement was met by far, despite the extremely low headroom. Also, the use of water-powered drilling offered a considerable reduction in noise level, resulting in a healthy, dust-free and comfortable drilling environment for all the people working inside the galleries.

"The other major advantage of this system is the great productivity: we managed to improve the production ratios up to 20%, as compared with traditional systems using compressed air."

The project took 22 months to complete, working both day and night shifts. Since its launch, the hydroelectric plant has become an essential contributor to Chile's Central Interconnection System (a power grid that spans from Taltal to Chiloe and serves 92% of the population), generating about 3.3% of the system's demand for last June.

Dam drilling

The extensive drilling operations included:

- 4,665m rotary-percussive drainage drilling; 100mm drilling diameter
- 1,429m with 15m length 'upwards' and 2,336m with 45m average length 'downwards' drilling
- 1,484m rotary-percussive drilling for consolidation works; 64mm drilling diameter
- 7,018m rotary-percussive drilling for waterproofing; 64mm drilling diameter
- 853m diamond drilling; HQ3 system
- 712m rotary-percussive drilling for the installation of piezometers