The Snowy 2.0 project

Described as one of the civil engineering wonders of the modern world, the Snowy Mountains Hydro-electric Scheme in Australia is undergoing an expansion programme, Snowy 2.0, but challenging ground conditions meant innovative solutions have had to be incorporated to allow tunnelling work to continue

Grouting work carried out with the aid of a Comacchio MC 22 rig allowed tunnelling to continue on the Snowy 2.0 project after a shink hole developed stopping the TBM

The Snowy Mountains Hydro-electric Scheme, originally built from 1949 through 1974, stands as a testament to Australia's engineering prowess, seamlessly blending renewable energy generation with intricate infrastructure. Located in the Snowy Mountains in the state of New South Wales, it is described as one of the civil engineering wonders of the modern world, consisting of eight power stations, 16 major dams, 80km of aqueducts and 145km of interconnected tunnels.

The expansion phase of the 4100MW Snowy Mountain hydroelectric scheme is currently underway with the Snowy 2.0 project. The project involves the construction of a 2000MW underground pumped-storage hydroelectric power plant that will link two existing water reservoirs, Tantangara and Talbingo. The project features 27km of tunnels – waterways, auxiliary and access tunnels – and an underground power station measuring 22m wide, 50m high, 250m long and located beneath around 800m of solid rock.

The hydroelectric power station will generate green energy as the water passes turbines in the tunnels, sending it to the grid. The reversible turbines are designed to push water back upwards, meaning the same water will be pumped back and forth all the time, allowing for hydroelectricity on demand.

This massive hydropower project is being built for project promoter Snowy Hydro by Future Generation (FGJV), a joint venture between Webuild, its American subsidiary Lane Construction and Australian firm Clough. It is the largest renewable energy project under development in Australia (and one of the biggest pumped-storage projects in the world), and it is critical to support the country's shift away from coal and other fossil fuels towards renewable sources for the production of electricity.

One of the longest and most technically difficult sections of the project, a 15km long segment of the "headrace" tunnel linking the upper Tantangara dam to the underground power station is being built using a 2000t, 143m long and 11m diameter open-faced tunnel boring machine (TBM).

THE CHALLENGE

Early during the tunnel excavation phase, unforeseen obstacles emerged, and the TBM had to be paused: as it advanced through low-strength rock, the machine faced a sinkhole caused by a faulted and fractured zone of completely weathered rock, combined with a buried gully with substantial subterranean water flow. This led to the TBM dipping steeply, with collapsing material above reeling into the open face of the machine, creating a sinkhole to the surface. The machine became immobilised, unable to steer, and any movement risked further collapse, exacerbating the sinkhole.

To assess the situation, extensive geotechnical investigations were carried out on the headrace adit alignment, including horizontal boreholes alongside from adjacent to the adit launch, inclined boreholes from above, geophysical MASW seismic lines from above, forward investigation holes from the two drill rigs inside the TBM, thus helping finalise remediation plans.

WAGSTAFF PILING'S SOLUTION

Due to the poor and very poor rockmass conditions encountered in front of the TBM, several rounds of grouting were performed from the TBM during the excavation of the tunnel, around and in front of the shield, to improve the rock mass condition. However, for a more effective ground consolidation, a treatment campaign needed to be implemented from the surface to improve the disturbed zone of the ground matrix sufficiently and ensure the TBM can successfully restart excavating.

The contract for surface consolidation works was awarded to Wagstaff Piling, an Australian-owned and operated piling contractor with over 40 years of experience in technically advanced foundation engineering.

"Due to the challenging conditions, we decided to adopt a special grouting method, using Part A and Part B grout combinations for control of grout mobility, viscosity, and gel set times," Russell Denny, special projects manager at Wagstaff Piling, explained. "Part A typically comprises cement, bentonite, and water, and Part B comprises activator sodium silicate diluted in a bentonite and water slurry. The ability to vary the activator dose in real time allows the injected grout to be changed between high and low mobility very quickly. Grout properties can, therefore, be adjusted to suit unpredictable and/or variable downhole conditions. Textbook terms 'compaction' grouting, at the low mobility end of the range, and 'permeation' grouting at the high mobility end of the range. Real time oscillation between high and low mobility is the key to solving difficult problems with flowing groundwater, artesian pressures, voids, cavities, karstic conditions, and the like. This technique is predominantly a 'single-shot' technique, although a 'double-shot' process can be used if required."

A CAPABLE COMACCHIO RIG

Wagstaff Piling could rely on a Comacchio MC 22 duplex drilling rig, that was designed according to the client's specifications through the collaboration of the longstanding Australian dealer Drilltechniques.

"The MC 22 rig's features include advanced mast articulation capabilities, allowing it to perform the multiple inclinations required for the project," explained Christopher Logan, Director of Sales and Operations at Drilltechniques. "Moreover, we spec'd out the machine to include a heavy-duty double-head system, comprising a 2400daNm lower head and 900daNm upper head, combined to a triple clamp with the patented Comacchio casing extractor".

Drilling was performed with a down-the-hole hammer using 152mm diameter outer casing rotating left and inner rods rotating to the right with interchangeable drill bits. The drill holes extended from 45m to 60m at varying sub-horizontal angles in a canopy above and around the TBM's cutting head under the sink hole, and in front of the cutting face to reach the sound rock head forwards of the TBM location. Following air flush drilling to the toe level, the inner drill rods with the DTH were extracted leaving the outer casing in place.

Mixing of all grout components, testing of grout parameters and pressure grouting would then be conducted via the end of the casing, as the casing was slowly withdrawn.

The seamless handling of casings and drill rods was made possible through the Comacchio excavator-mounted CPH grab.

GROUTING CHALLENGES

Maintaining precise borehole inclinations was critical to ensure effective grout penetration and consolidation of the fractured rock mass. However, this was only one of the challenges the drill crew had to face during the eight months of continuous operation.

Winter conditions posed significant operational challenges, particularly related to freezing slurry lines and temperature-induced variations in grout viscosity and set times. The slurry plant was designed with a recycling capability to prevent freezing and maintain continuous operation.

As the project progressed, a 24-hour shift system was adopted to expedite the process and align with TBM excavation schedules, which required precise coordination with the client and its TBM activities.

Due to the project's location in the heart of the Kosciuszko National Park, strict environmental control measures were enforced to minimise the impact of drilling and grouting operations. The use of an internal diverter mounted on the Comacchio MC 22 and the implementation of comprehensive measures for waste containment and disposal ensured that all environmental requirements were met.

"A series of 152mm diameter holes in the improvement zone would be drilled and grouted, with the variation of the grouting properties analysed, including delivery pressures, flow rates and volumes," Denny explained. "A general target sequence was developed involving primary holes followed by secondary infill holes. However, as early works commenced the sequence was soon re-developed in response to the observations of the early grouting performance. Primary holes generally provided a baseline of the performance, and later holes indicated considerable ground improvement. Comparison of flows, back pressure, volumes, and connectivity to the TBM itself led to necessary viscosity adjustments and hole sequencing adjustments."

A total of 128 boreholes were executed, with approximately 6000m drilled and over 2000cu.m of grout injected.

SUCCESSFUL STABILISATION

Detailed monitoring of the surface area was carried out through a lidar survey to verify the effectiveness of the consolidations over time, highlighting the progressive reduction of the connection between the underground excavation of the TBM and the subsidence effect on the sinkhole on the surface until its stabilisation.

Ongoing injection eventually led to sufficient improvement in front of the TBM to allow thrust on the face to reinstate the ability to steer the machine A sufficient stabilised canopy had been provided above the machine to drive ahead without unstable ground reeling into the machine. Now with stability at the face, the machine could be converted to closed face slurry mode. Once in slurry mode, the TBM could progress into the unstable interface zone, and drive into stable rock, where normal operation was possible.

Once complete, the Snowy 2.0 hydropower project will increase the scheme's generating capacity to 6.3 from 4.1GW, and will also serve as a battery, storing up to 350GWh for use at peak times, thus providing stability to the power grid when other renewable sources like wind or solar are failing to meet demand. ▼

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