| PROJECTS |

CONTROLLED MICROTUNNELLING

In a complex hydropower project in Switzerland, the construction of a penstock for the KW Rufi power plant pushed the boundaries of microtunnelling capabilities. Using a Herrenknecht MTBM equipped with a Jackcontrol® Hydraulic Joint and a VMT SLS-Microtunnelling LT system, an s-curve tunnel alignment with a tight radius and large joint deviation angles was successfully excavated.

In the canton of Glarus, Switzerland, hydropower has long been a source of electricity production. While hydropower production is no less popular today, many of the hydropower plants built along a 34 km stretch of the Linth River in the early 20th Century are ageing and in need of renewal.

The KW Rufi Project will construct a completely new power plant designed to use water resources more efficiently by tapping unused water sources, as well as supporting the efficiency of a power plant downstream.

Jackcontrol AG was assigned the design and construction management of the project, which pushed the limits of curved microtunnelling in challenging conditions during the installation the plant's penstock by making the best use of technologies available in the current market. A penstock is a pipeline that intakes water from the source – usually a dam or weir – and delivers it to hydro turbines and sewerage systems.

DIFFICULT CONDITIONS

Like other hydropower plants, KW Rufi uses the natural gradient of an alpine river; however, it had a number of conditions that required careful planning and execution.

The weir at the water intake needed to be designed to allow fish migration, and a grit chamber was required after the intake to reduce the amount of suspended sand and gravel in the water to prevent excessive abrasion to the turbine. The penstock was required to deliver water to a power house, which would then be directed to the headrace of a downstream power plant.

The terrain and infrastructure in the area prohibited an open-cut penstock design and the depth of the penstock at the power house, as well as high groundwater table and permeability meant that closed shield mechanical microtunnelling was the most suitable method available.

The geology of the area included sediment deposits from alpine creeks and gravel from the Linth River. The materials in these areas comprised abrasive and highly permeable sandy gravel with cobbles and boulders with inlays of small-grained flood sediments.

THE PATHWAY

To cope with the maximum discharge of the plant, an internal diameter of 3,200 mm was chosen for the penstock, which could be accomplished using a microtunnel boring machine (MTBM) to install reinforced concrete pipes.

In order to avoid disturbances to a nearby rail line and sewer, as well as to avoid a shallow overburden at the railway underpass that lays between the power house and grit chamber, the crossing was designed to run under the tracks on the left side of the underpass for hydraulic optimisation.

From the drive shaft located in the power house, the microtunnel started straight and horizontal for 15.2 m, before curving left for 182.9 m with a radius of 500 m, followed by a short vertical curve to bring the tunnel to a 0.5 per cent inclination and a right-hand curve with a radius of 300 m. After crossing the sewer and railway, an upward curve leading to a small spatial radius of just 280.4 m returned the MTBM closer to ground level.

JOINTS

The tight 280.4 m radius, combined with the 150 inch (3,800 mm) outside diameter of the pipes, with lengths of 3 and 4 m, resulted in the need for a joint that could manage the large joint deviation angles that this created, while sustaining reasonable high jacking forces without damaging the pipes.

A Jackcontrol package, comprising a Jackcontol Hydraulic Joint and real-time monitoring of jacking forces, was added to the standard joint design. Compared with traditional joint design, the fluid filled hydraulic joint replaces the wooden packer to allow large joint deviation angles without stress concentration on the inside of the curve by acting as a pressure transmission ring.

The accompanying real-time monitoring system provides documentation about the structural integrity of the pipeline, using the hydraulic joint as a pressure sensor to determine the actual jacking force and the maximum admissible jacking force on the actual driven alignment.

NAVIGATION

A VMT SLS-Microtunnelling LT system was used to manage the navigation of the complex drive alignment.

The machine setup consisted of a laser target mounted in the MTBM, a laser total station on a self levelling base, a distance measuring wheel and several prisms with some inclinometers. This system continuously records the position of the machine and gives the operator steering directions to keep on the proper alignment.

Before the line of sight is blocked the laser total station and, later on, the prisms are moved into the tunnel to provide an indirect line of sight to the MTBM. The total station and prisms move along a line of known points in the tunnel, with control measurements take to calibrate the system every 75 to 120 m, to continuously calculate the actual position of the machine.

THE DRIVE

Contractor K-Boringen selected a Herrenknecht AVND3000 MTBM with a cutting wheel, using disc cutters and cutting knives, that was adapted to the geology of the drive. The crushing chambers were also reduced to a smaller size so that the excavated material could be pumped out.

There were some collapses on the first portion of the drive through the shallow overburden, but these were anticipated and therefore not of great consequence. The arch channel crossing was able to be completed at a depth of 0.6 m, without damaging the channel and with a limited amount of bentonite slurry entering the channel.

Despite some issues in the section before the railway crossing, including the groundwater table rising to 0.9 m above the tunnel and issues with the MTBM's crushing chambers leading to a 7-week delay, the crossing was able to be completed successfully. Works took place during a nightly shut down, and were completed within two nights.

After careful calculations that took the capabilities of the hydraulic joint, the depth of the receiving pit was reduced to avoid the need for extensive dewatering systems. The minimum possible radius was determined and, with a tight radius of 259 m, the MTBM was brought approximately 1.0 m closer to the surface than initially planned.

Construction of the KW Rufi penstock has shown that, when using the appropriate technologies with an MTBM, the alignment of microtunnels is no longer limited to 'straight only' shaft locations. The combined experience of the designer, contractor, surveyor and MTBM manufacturer, along with the use of current technologies, proved the capabilities of modern microtunnelling on this trailblazing Trenchless Technology project.

A: The MTBM breaks through at the receiving pit.
B: The curve alignment of the penstock.
C: The pipe equipped with the hydraulic joint.
D: The MTBM in the drive shaft.