Sylvenstein reservoir
Dam rehabilitation

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Introduction
Apart from the river Isar, Sylvenstein reservoir - named after a natural gorge section in the upper Isar Valley - also dams up its tributaries, the rivers Dürrach and Walchen. This created a fjord-like lake which is embedded into the mountain landscape in such an astonishingly natural way that one could mistake it for a relic from the Ice Age.

Sylvenstein reservoir’s 42 m long and 180 m high dam rests on foundations in the form of a 100 m deep erosion gully in the main dolomite filled with river till which has been sealed with multi-row grout curtains with clay/cement during construction in the 1950s. The slim central sealing core consists of an artificial compound soil cement (gravel, fine sand, addition of Schluffmit bentonite) with adjacent moraine gravel filters on the air and water sides. Together with the pitched/green slopes, the support structure made from river gravel characterises the dam’s surface.

Since its start-up in 1959, the dam serves as a flood protection measure. Being Bavaria’s oldest water reservoir and the most important one in terms of flood protection, it has done its job very well for more than half a century and has proven its protective effect during large flood water discharges, especially for the city of Bad Tölz and the state capital Munich.

In dry periods, it raises the river Isar discharge which has been narrowed by drainage of water. Water from the reservoir is being used for environmentally friendly power. Furthermore, it has developed into a popular destination for recreation seekers and tourists. Being the oldest state-operated water reservoir in Bavaria, it has been technically adapted from 1994 to 2001 with the construction of a second flood relief spillway and the expansion of the flood control area by 20 million cubic metres through raising the dam by 3 m.

Planned dam rehabilitation measures
Detailed surveying of the sealing core and the measuring system in recent years has prompted the water resources management authority which operates the barrage to carry out essential rehabilitation measures on the dam and its subsoil. The current upgrading measures are being performed between 2011 and 2015 and are divided in three core areas.

The barrage is located in a valuable area of unspoilt nature, the dam itself in an FFH zone. In order not to overly alter the dam’s exterior appearance, solutions involving measures on the dam’s inside have been pursued. Besides the safety of the dam structure in the construction phase and in its final state, ensuring unabated flood protection for downstream riparians was of paramount importance. If possible, storage of water in the reservoir should remain possible during the construction period.

In the last two years, numerous variants were intensively examined and the following measures were selected as the optimum solution.

1. Slurry wall
Installation of a slurry wall up to 70 m deep and approx. 1 m thick in the sealing core. This wall reaches down up to 25 m deep into the former Isar valley floor below the dam. The slurry wall was constructed in 2012 by means of a milling machine and grabber.

2. Seepage water tunnel
In order to build the seepage water tunnel, an access tunnel has first to be blasted into the rock at Sylvenstein face in 2013. From there, a tunnel drilling machine is used to drill the horizontal underground tunnel through the dam into the opposite Hennenköpfli rock face. Subsequently, the tunnel drilling machine will be retrieved through a previously blasted, 40 m long vertical target shaft. After that, the seepage water tunnel will be finished on the inside.

3. Drainage piles
In 2014, so-called drainage piles of approx. 40 m depth are supposed to be installed behind the slurry wall for the purpose of collecting potential seepage water. A drainage pipe inside these piles ensures the collection of water which is being guided into and measured at the lowest point in the seepage water tunnel.
The drainage piles were sunken from the dam in 2014 and finished in such a way as to allow the measurement of seepage water. This task was awarded to Porr Deutschland GmbH, Foundation engineering department, now Stump Spezialtiefbau GmbH. The work could be commenced on schedule in July 2014 and finished successfully well within the contractual period by the end of November 2014.

A total of 54 drainage piles of 2.8 m length and 900 mm diameter were sunken on to a depth of 42.5 m. The bore holes were executed as wells and connected to the seepage water measurement device by means of horizontal drilling from the seepage water tunnel (d=2.4 m). The drainage piles 01 to 05 are located directly on top of the tunnel axis, above the gradient Hennenköpfl rock slope. In the area of the embankment, the bore holes (d=900 mm) were sunken with integration in the rock. In the rock material, bore holes (d=300 mm) without pipes ending at the seepage water tunnel’s crown were executed by means of the down-the-hole hammer drilling method. For this purpose, the tunnel walls (d=2400 mm) of concrete quality C50/60 were to be drilled through at their respective ridge.

Executing the bore holes as wells included a sump pipe (d=500 mm) including a hopper and “Dr. Traub sleeve”, stainless steel continuous slot screens as well as filter and solid pipes made from PE. This ensures their function as monitoring wells for seepage water accruing behind the new sealing wall and the old dam sealing.

A BG36 drilling rig including piping device as well as a LH853 cable excavator, also fitted with a piping device functioning as a lifting apparatus, were used. The d=900 mm drill pipes were sunken in an oscillatory manner onto the final drilled depth of 42.5 m by means of the drilling rig with an auger drill mounted in front.

The d=300 mm rock bores with a drilling length of 25 m were carried out by means of the down-the-hole hammer drilling method. Tunnel finishing work was performed using the LH853 lifting apparatus including piping device for pulling the drill pipes during gravelling using filter gravel.

In order to adhere to the drilling tolerance of 1%, all wells had to be examined and documented by means of verticality measurement after sinking. These measurements were used for the drilling points in the seepage water tunnel in order to install the drainage lines from the wells to the tunnel.

Drilling work was performed using the MR700 basement drilling rig from inside the tunnel. For this purpose, additional sealing systems had to be installed at the joints to collect potential seepage water.
Aerial shot in direction of Sylvenstein reservoir: in the foreground, one can see the outlets for the regulation of the water level
Image: PORR AG

Building site with BG 36 drilling rig for drilling work and LH853 cable excavator for well removal and dismantling of piping d=880mm
Image: PORR AG

BG36 drilling rig with automated rotary table and drilling auger during drilling work on the dam body
Image: PORR AG

Execution of horizontal drilling using basement drilling rig in the tunnel with a diameter of 2.4 m. Installation of the drainage pipe inside the temporary piping (d=178 mm)
Image: PORR AG

Seepage water tunnel with drainage well in the area of the tunnel top during horizontal drilling between tunnel and well
Image: PORR AG

Completed drainage line with sealing using a packer system for the collection of seepage water from the drainage well
Image: PORR AG

With the revitalisation of the construction site and the reconstruction of the main road B 307 crossing the dam including an additional longitudinal parking strip, the construction scheme should be completed in mid-2015.

Summary
Sylvenstein reservoir was built in the 1950s using the technological and financial resources available at the time. The 1980s saw the first rehabilitation efforts on the dam's core and essential parts of the dam structure were upgraded in the 1990s. Among others, the centennial floods of 1999 and 2005 could be handled thanks to these.
measures, for instance through raising the dam by 3 m.

Now, it is time to use current engineering possibilities to create a system that is prepared for the tougher challenges projected for the future – also in the wake of climate change. Even in times of tight public budgets, the Free State of Bavaria has therefore decided to undertake the project “rehabilitation of Sylvenstein reservoir bank.”

With the successful processing and the constructive collaboration between the client and its project management and the involved planning offices, a unique building has been rehabilitated.