REINFORCEMENT OF THE SYLVENSTEIN DAM

Dipl.-Ing. Heiko Nöll & Dipl.-Ing. Stefan Raab

CDM Consult GmbH, Deutschland, Lazarettstraße 4, 80636 München

Bayerisches Landesamt für Umwelt, Deutschland , Lazarettstraße 67, 80636 München

email: heiko.noell@cdmsmith.com, stefan.raab@lfu.bayern.de

Abstract

After a 50-year period of operation the Sylvenstein Dam is to be re-inforced with an additional slurry wall in the dam and a new monitoring system for percolating water. The planned measures can also be understood as a precaution against the consequences of a possible climate change. Due to the dimension and rapid succession of recent flood events in the years 1999, 2002 and 2005, increased operational demands on the dam structures in the alpine area related to climate change are expected in the future. This paper describes the planned construction project that is already being implemented, in more detail

Introduction

Since the 1999 flood, over 1 billion Euros have been invested in the construction of protective infrastructure related to the Flood Action Program 2020 of the federal state of Bavaria. In addition, the good focus is on safety and the condition of the existing flood control reservoirs.

The Sylvenstein Reservoir is Bavaria's oldest and most important water storage structure. Since 1959; it has demonstrated its protective function for downstream areas, particularly for the City of Munich, in times of large floodwater discharge.

Figure 1: Aerial view of the Sylvenstein Dam

Detailed studies on the sealing core and on the existing leachate monitoring system have prompted the Wasserwirtschaftsverwaltung (Water Management Authority), the operator of the dam, to carry out reinforcement measures. CDM Consult GmbH was commissioned with the design in 2008.

The essential data for the Sylvenstein Reservoir are:

Table 1: General Data

Catchment Area	1.138 km²
Total Retaining Capacity	124,30 Mio. m³
Ordinary Flood Volume	53,30 Mio. m³
Extreme Flood Volume	26,00 Mio. m³

The previous highest storage output took place on 22.05.1999 (Whitsun flood) with 360 m³ / s.Table 2: Floodwater inflows

HQ_1	HQ_5	HQ_{10}	HQ_{50}	HQ_{100}	HQ_{200}	HQ_{1000}
210 m³/s	400 m³/s	500 m³/s	750 m³/s	950 m³/s	1000 m³/s	1400 m³/s

The flood protection for Bad Tölz was raised from 450 m³ / s to 650 m³ / s.

Detailed Investigations of the Dam

The original 42 m high and 180 m long dam built on a 100 m deep gully in the main dolomite is in filled with sediments. . This underground was sealed using numerous clay injections during the construction in the 1950s. The narrow sealing core consists of an artificial earth-concrete, comprising gravel, fine sand, silt and concrete. The sealing

core is symmetrical covered with a gravel filter on the water and the air side. In 1972, injections were performed in the dam core (east abutment), along the entire length of the core and the underground to about 60 m in depth (approximately 2,000 m grouting with clay cement mixtures). These measures were implemented in order to seal cracks in the core. However, with the compression a part of the air-side filter was also impaired.
Test drillings and precise investigations of the measurement system have provided evidence of increasing permeability in some areas at the foundation level of the dam. With these critical considerations and the newly implemented DIN 19700 in mind, it appeared to be reasonable to incorporate an additional sealing to the dam's core and substrate based on state-of- the-art techniques. In addition, a completely renewed measurement system for percolating water was designed.

Since the reservoir is located in a designated valuable natural area, with dam itself in a FFH area, appropriate alternatives and solution for dam rehabilitation in the dam interior were examined.

In 2008, after CDM Consult GmbH was commissioned with the design of the reinforcement. A detailed investigation and a preliminary design were completed in 2009. The approval for the proposed measures was then granted in the spring of 2011.

Dam Reinforcement Concept

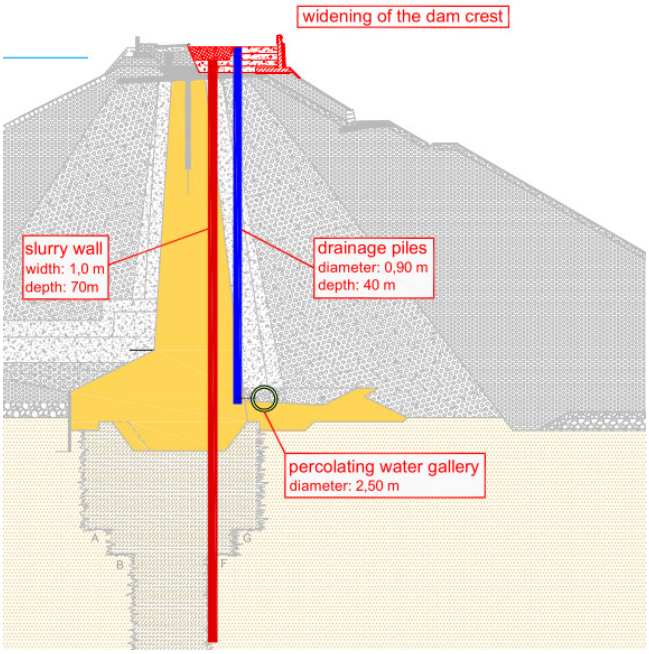

Figure 2: Cross-section with planned construction measures

Feasibility studies were carried out to determine the most appropriate sealing method. CDM compared all slurry wall variations with different positions on the dam axis and core. Also a double slurry wall with a transverse bulkhead was evaluated as an option for future monitoring. Boring pile walls were not considered to be an option due to the lack of accuracy during perpendicular production. Other options, using injections were also identified do not deliver the desired improvements in the core; impairments in the dam cross sections also cannot be eliminated.

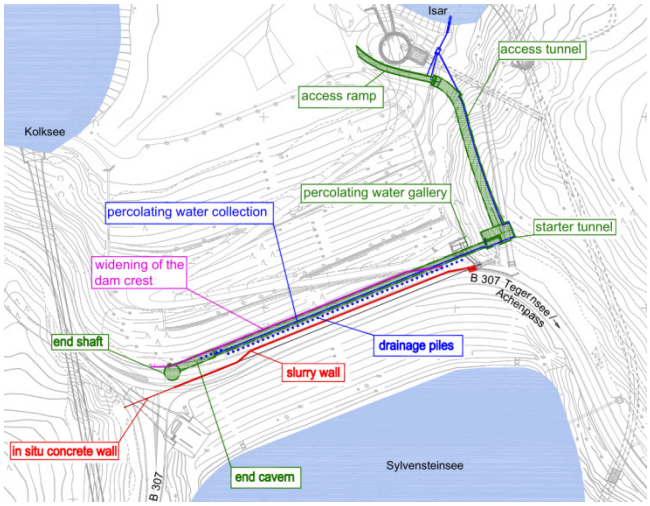

Figure 3: Site plan with planned construction measures

The solution chosen for the additional inner sealing is a two-phase slurry wall, which will be positioned slightly offset from the middle of the dam towards the air side in order to preserve the existing core as far as possible. The appropriate depth for the slurry wall was determined through a number of exploration drillings to a maximum depth of 140 m as well as finite element calculations. The chosen depth for the slurry wall is about 70 m with a thickness of 1 m.

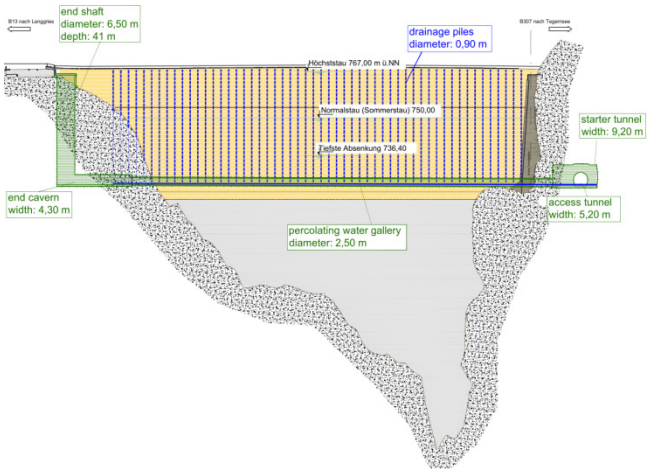

Figure 4: Longitudinal Section of Dam

The reestablishment of a comprehensive measurement system was another important part of the planning commission. The proposed percolating water collection will allow for a sectoral monitoring over the entire length of dam. The measurement system consists of air-side arranged draining piles and a walkable percolating water gallery, which is approximately located at the dam's foundation

level. The draining piles are at a distance of 2.8 meters and are each connected individually to the percolating water gallery. Permanent leakage monitoring is then ensured.

The Permanent leakage consisting of the elements access tunnel, starter tunnel, percolating water gallery and end cavern with end shaft will make possible the collecting, measuring and leading away of the percolating water collected in the drainage piles. In addition the percolating water gallery will be available later as a low-level work room where holes can be drilled into the ground below. It is also possible to install a monitoring system for the groundwater flows below.

To allow for the construction of the percolating water gallery it will be necessary to construct an 86 m long access tunnel into the rock next to the Sylvenstein dam at a depth of approx. 43 m below the dam crown. The tunnel will be constructed of DN 2500 reinforced concrete pipes which will be pushed from the start tunnel into the Sylvenstein cliff. To advance the approx. 170 m long percolating water gallery a tunnel boring machine will be used which will be equipped with a largely closed cutter head for cutting through rock and mantle rock. In order to support heading face and to remove the drill cuts a drilling fluid (cement suspension) will be used..

At the changeover between gallery and start tunnel a permanent steel safety bulkhead, capable of withstanding the hydrostatic pressure will be installed. On the Hennenköpfl side a 43 m deep shaft will be drilled to recover the tunnel boring machine. This shaft will also serve as an emergency exit and will be accessible from the air side.

Scheduling and costs

Following completion of the feasibility study in 2009 and the preparation of the basic design in 2010, the approval plan was submitted at the end of 2010. Since the design did not affect the use or development of the water body, a water rights application was not carried out.

The gross total costs for planning and execution are estimated to be approx. 25 million €. An EU grant, which may be possible, has been applied for.

The entire construction project is divided into five construction phases (CS 1 - CS 5). The first CS, preparatory measures / dam crest widening was completed in late 2011. In 2012, the slurry wall will be constructed as CS 2. In CS 3 the gallery will be constructed in 2013 in part by means of blasting drivage in the rock and in part with a tunnel boring machine in the dam. The construction of the leachate collection system / draining piles is presumed to be completed in2014 in CS 4. The final measures and the restoration of the dam crest are planned for 2015 as the final CS 5.

Measures completed in 2011

In 2011 the following preparatory measures were completed in advance of the actual improvement measures for the dam:

- Widening of the dam crest
- Cantilever retaining wall
- Training walls
- Construction of the top structure of the end shaft
- Construction of the Scour lake bridge
- Construction of the dam bypass bridge

Widening of the dam crest

For operational reasons and expected traffic it is envisaged that the dam crest is widened not just temporarily to aid construction work but for a permanent feature of the dam. The related increased cost / amount of work is relatively low. The permanent dam crest is widened by approx. 4 m and will be secured by a cantilever retaining wall.

Figure 5: Widening of the dam crest; view looking towards the Sylvenstein cliff

To the left the cantilever retaining wall and to the right the training wall can be seen.

Cantilever retaining wall

The retaining wall is constructed to a height of up to ≥ 1 m above the future level of the road. This height is the same as the height of the existing bank wall on the reservoir side.

Figure 6: Finished cantilever retaining wall on the air side

The existing measuring systems are led through the bottom slab of the cantilever retaining wall. In addition block-outs with a diameter of 900 mm and a distance apart of 2.8 m are provided for the drainage piles.

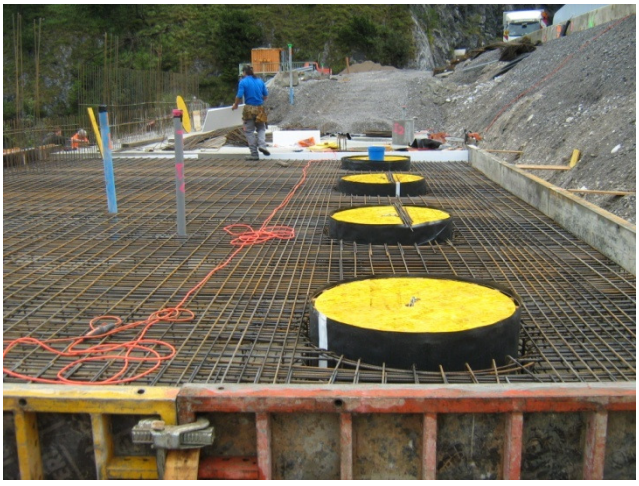

Figure 7: Construction of the bottom slab of the cantilever retaining wall with block-outs for the drainage piles

Training walls

Construction of the temporary concrete training wall, which is required for the sinking of the slurry wall planned for 2012, was also carried out in 2011 in the course of the advance measures.

Figure 8: Construction of the training wall

To be seen in the photo on the left is the formwork for the training wall. The training wall consists of 2 angle supports with a height of 2.0 m, thickness 40 cm and a length of 184 m. On the right of the photo is the bypass bridge that was erected behind the splash guard.

Construction of the top part of the end shaft

In the course of the advance measures and the erection of the cantilever retaining wall, the construction of the top structure of the end shaft was also carried out on the exposed bedrock of the Hennenköpfl.

Figure 9: Exposing of the bedrock surface on the Hennenköpfl

Figure 10: Top structure of the end shaft

Construction of the Scour lake bridge

A bridge is being constructed over the Scour Lake to allow delivery of the tunnel boring machine and the prefabricated concrete parts for the percolating water gallery.

Figure 11: View towards the newly constructed Scour lake bridge

Construction of the dam bypass bridge

To allow traffic to continue to flow during the construction of the slurry wall a bypass bridge was built on the water side of the dam next to the existing bank wall.

A steel substructure was erected on driven-in sheet wall piles and was covered with wooden planks as the road surface.

Figure 12: Construction of the bypass bridge

Figure 13: Bypass bridge with view of the Sylvenstein reservoir

Summary

Originally constructed in the 1950s with employment of the technical and financial facilities available at that time, the Sylvenstein reservoir was strengthened and modified between 1980 and 2000. Since originally erected the dam has had its height increased by 3 m and has successfully provided protection in hundred-year flood events of the past years. After this long period of operation modification of the dam structure were planned in accordance with the latest civil engineering state of the art and has been commenced since then. The State of Bavaria has decided to undertake this technically and financially demanding project in co-operation with a experienced planning office in order to ensure that the dam will meet all the present and future demands.

References

Overhoff, G. & Raab, S. (2008). *Sylvensteinspeicher – Vorbericht zur Nachrüstung des Dammes.* Bayer. Landesamt für Umwelt.

Altinger, L. (1960). *Sylvensteinspeicher mit deutscher Alpenstraße.* Sonderdruck aus Deutsche Bauzeitschrift.

List, F. & Strobl, Th. (1991, 7/8). Veränderung der Abdichtungswirkung des Kerns des Sylvensteindamms infolge Alterung. *Wasserwirtschaft*, pp. 322-327.

Bayer. Landesamt für Wasserwirtschaft bzw. Bayer. Landesamt für Umwelt (1991. 1992, 2002, 2003, 2007). *Untersuchungen am Sickerwassermesssystem des Sylvensteinspeichers*. Unveröffentlicht.

Overhoff, G. & Lang,. T. & Popp, M. (2010). Die geplante Ertüchtigung des Sylvensteinstaudamms. *15. Deutsches Talsperrensymposium. Talsperren im Wandel*, pp. 312-318.