MALTER DAM – INNOVATIVE EXTENSION OF SERVICE-SPILLWAY USING A NOVEL VERTICAL FLOW SEPARATOR

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ABSTRACT

The 102-year old Malter Dam (masonry gravity) at the Rote Weisseritz River in Saxony (Germany) is of great importance for flood control of the City of Dresden (Capital of Saxony) with more than 500,000 inhabitants. During a catastrophic flood in 2002 spillway and outlet works were overloaded due to exceeding of design discharge. Afterwards updated hydrologic modeling indicated that the design discharges for the dam had increased significantly. The original spillway discharge capacity was insufficient to pass the revised design flows. The dam safety against overtopping was endangered. Thus the dam owner (State Reservoir Administration of Saxony, Germany) has launched an innovative extension of service spillway to increase the discharge capacity. A design concept was developed to add a second spillway and stilling basin to the dam. To pass flow into this spillway a novel vertical flow separator as diversion structure was designed. The design and performance of this system was evaluated using a 1:25-scale physical model.

1. INTRODUCTION

1.1 Dam

Between 1908 and 1913, the Malter Dam was built on the Rote Weisseritz in Saxony (Germany) as a gravity dam made of quarry stones (height 36 m) of the Intze type with a curved axis (Figure 1). The dam, which is under monumental protection (total storage capacity 8.78 million m³), serves mainly as flood protection for the town of Freital and the state capital Dresden. It is also used for service water supply, electricity generation and local recreation.

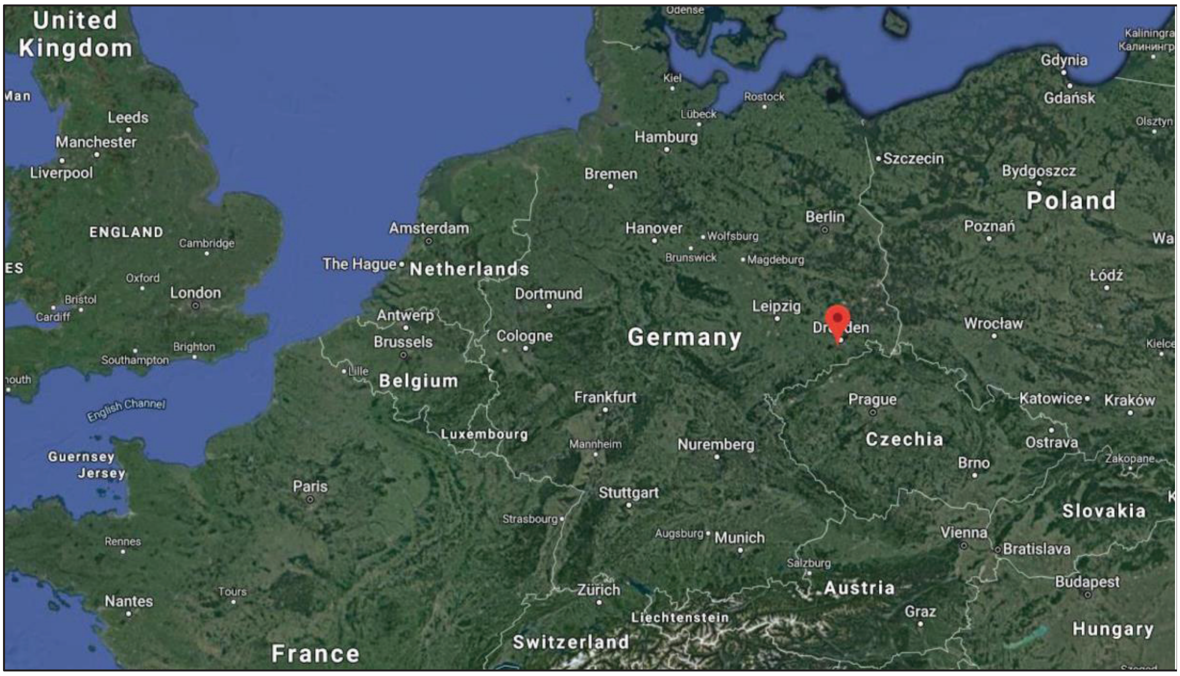

Figure 1 : Location of Malter Dam (Google Maps)

1.2 Dam outlet works

The Malter Dam has the following outlet works (Figure 2 and Table 1).

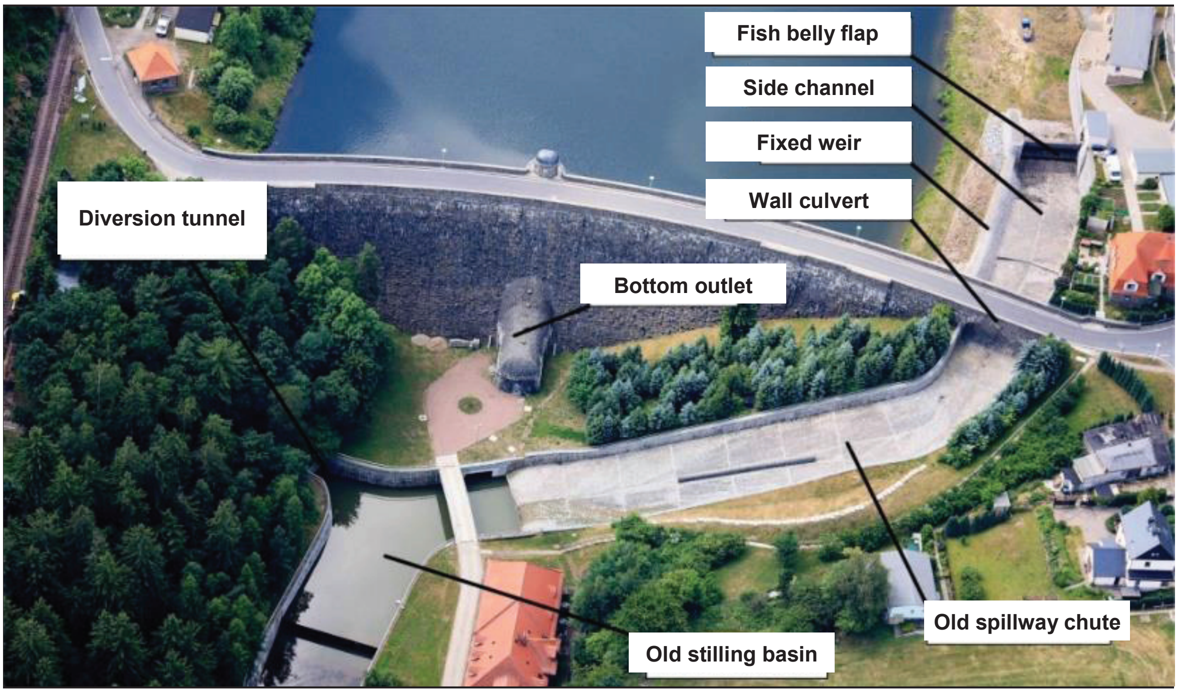

Figure 2 : Malter Dam – Outlet works (Schmidt 2015 modified)

Table 1 : Spillway and outlet capacity

Service spillway:	
Crest fixed weir:	333.00 m a.s.l.
Crest flap weir:	330.40 m a.s.l. (lowered fish belly flap)
Hydraulic capacity:	156 m³/s at full storage level = 333.50 m ü. NN (125.6 m³/s at lowered fish belly flap + 30.7 m³/s over fixed weir)
Bottom outlets:	
No. / Diameter:	# 1 and # 2 with plunger valves each DN 1200 / DN 1000
Hydraulic capacity:	2 x 7.95 = 15.9 m³/s at 326.50 m a.s.l. (normal operating level)
Operating outlets:	
No. / Diameter:	Diversion tunnel with 3 piping lines each DN 1.000
Hydraulic capacity:	Until 2018 3 x 2 butterfly valves: 3 x 6.3 = 18.9 m³/s at 326.50 m a.s.l. Since 2018 3 x 2 slide valves: 3 x 13.3 = 39.9 m³/s at 326.50 m a.s.l.

2. SPILLWAY

2.1 History

The spillway system was designed as a side channel spillway at left abutment. It originally consisted of a side channel with a gated weir and a fixed overflow weir. The cascade consisted of rock bottom and a stilling basin with end sill.

The spillway was repaired and partially rebuilt in 1967/69. The damaged cascade base was replaced by a continuous paved base. The deepest point of the cross section in the current line was built in the area that had previously been washed out the most.

In 1977, the gate weir was replaced by a fish-belly flap. The floods and test discharges via the fish-belly flap that occurred in the following years showed that the existing hydraulic capacity of the spillway was not designed for the then current design discharge.

In 1983, a model test (scale 1:20) was therefore carried out to determine the actual capacity of the spillway and to derive the changes required to control the then current design discharge (Q = 112 m³/s). As a result, baffles were installed to improve the discharge conditions in spillway chute and stilling basin.

2.2 Flood 2002 – course and consequences

During the extreme flood in 2002, the then valid BHQ2 (HQ 10,000 = 166 m³/s) was exceeded, resulting in a significant hydraulic overload of the outlet works. The spillway (capacity Q = 156 m³/s) was loaded with 228 m³/s (Figure 3, Figure 4). This resulted in massive water leakage from the spillway chute (with erosion of the downstream slope on the left) and from the stilling basin (with flooding of the downstream dam toe area and the bottom outlet gallery).

The peak values and discharge amplitudes of the BHQ1 (HQ 1,000 = 289 m³/s) and BHQ2 (393 m³/s), which were newly determined with the subsequently updated rainfall runoff model, increased so much that the flood safety of the dam structure could no longer be proven.

Figure 3 : Side channel during flood 2002 (LTV)

Figure 4 : Stilling basin during flood 2002 (LTV)

3. PLANNING AND APPROVAL

3.1 Preliminary investigations

The operator (State Reservoir Administration of Saxony, Germany) has commissioned several plans for the safe passage of extreme floods. In order to find a hydraulically optimal and economical measure under the given boundary conditions, a total of 35 alternatives (individual construction measures) were combined in 24 variants and compared hydraulically, technically and economically in an evaluation matrix (target tree method).

In the result it was determined that the reconstruction of spillway is necessary. In the extended preliminary planning, advantages and disadvantages and finally the preferred variant were determined (Figure 5).

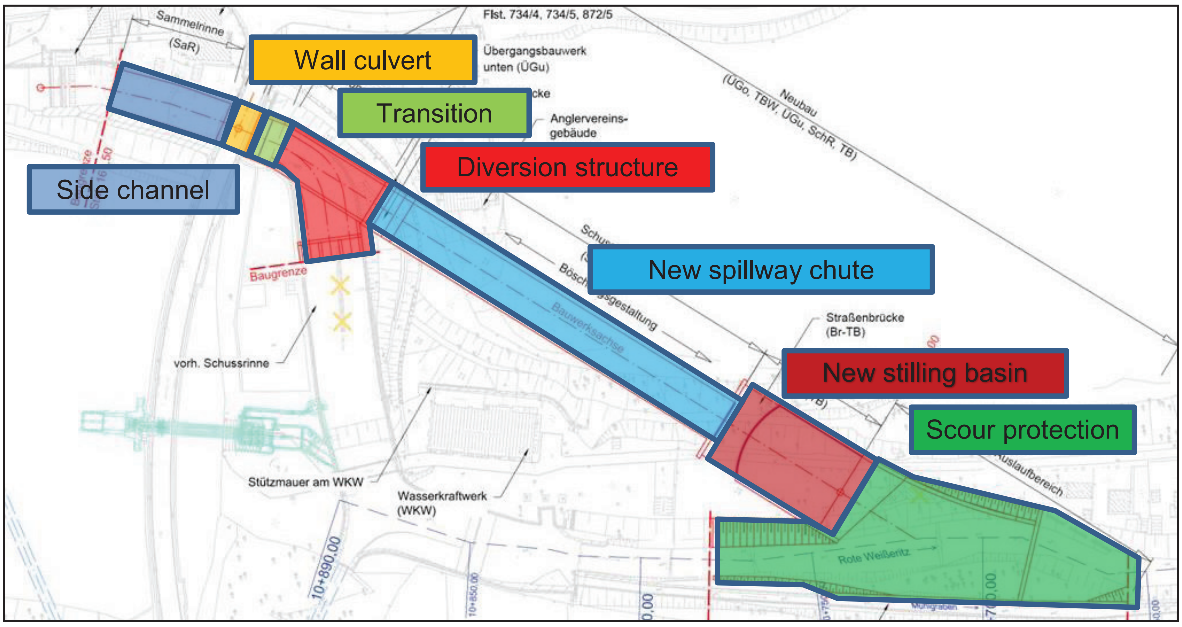

Figure 5 : Spillway design (ARGE LHP-SI Talsperre Malter 2015)

3.2 Preferred variant and design details

The preferred variant includes an additional new spillway chute with new stilling basin. It was adapted and optimized within the framework of the preliminary design.

The hydraulic loading of the old spillway chute as well as the new spillway chute takes place behind the dam crest bridge through a new type of diversion structure with a vertical flow separation.

In the case of spillway operation the outflow is first discharged into the old spillway chute in the transition channel via an opening in the bottom of the diversion structure (see Figure 6). Due to the optimal dimensioning of this opening, its hydraulic capacity corresponds to the capacity of the old stilling basin, taking into account the inflows from the bottom outlet and diversion tunnel, thus excluding the possibility of overloading the old stilling basin. If the flood discharge exceeds the capacity of the opening, the opening is overflowed and the remaining discharge is led via the diversion structure into the new spillway chute.

This solution also incorporates the demand of the monument protection authorities for future use of the old spillway chute including the old stilling basin.

In the following, design details of the individual elements of the new spillway are explained.

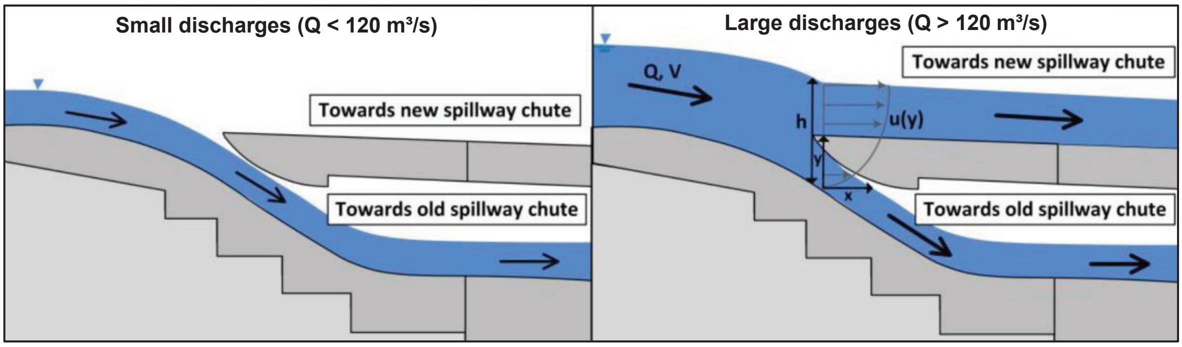

Figure 6 : Diversion structure – Operating principle (Schmidt 2015 modified)

3.2.1 *Side channel inlet and fixed overflow weir*

The existing side channel (L / W approx. 50 m / approx. 12 m) is limited on the long sides by the boundary wall and the fixed weir. The fish bellied flap is located at the front of the side channel.

To increase the hydraulic capacity, the bottom is deepened by approx. 1.5 m with a bottom slope of 3.5 % to prevent backwater (see Figure 12). The bottom is designed as a 1 m thick reinforced concrete slab. In order to prevent a possible uplift of the base plate, a permanent drainage concrete layer of at least 20 cm thickness is planned as foundation.

3.2.2 *Wall culvert*

The wall culvert (L / W approx. 7 m / approx. 12 m) connects the upstream and downstream dam sides and enables water to flow through the dam. On the upstream side it currently has a height of approx. 5.9 m. In its current state, it is not possible to prevent the culvert inlet from submerging in case of high discharges.

The demolition and the construction of the underpinnings are similar to those at the side channel. The transverse slope of the base is distorted to approximately the middle of the wall, so that a horizontal base is created. From the middle of the wall, the rounding off for the division of the outflow of the two flow routes already begins. To be able to properly connect the reinforced concrete structure adjoining the wall culvert, the so-called transition structure at the top to the dam, two wall connection bodies must be constructed vertically on the dam.

3.2.3 *Diversion and transitional structures*

The upper transitional structure (L / W approx. 7.2 m / approx. 12 m) borders on the wall culvert and divides the waterways (above: new spillway chute; below: old spillway chute). The bottom of the inlet area follows the bottom of the theoretical jet at a flow velocity of 9.0 m/s with tangential transitions. The control cross section (width = width of transition structure of approx. 12 m; height approx. 95 cm) to limit the flow in the old spillway chute is placed at the inlet of the diversion structure. Since this area is subject to high hydraulic loads, the immediate sharp-edged separation area is built with steel armouring.

In order to achieve an even flow into the old spillway chute, the outflow is divided into three open channels and the height is increased to 2.5 m to ensure ventilation and accessibility. The baffles start approx. 2 m behind the inlet opening and the end walls are designed to create a favourable flow. The guide walls initially run parallel to the upper transition structure. They are then drawn parallel to the axis of the old spillway chute, where the outlet is at the same level as the bottom of the old spillway chute.

Due to the geometric and static boundary conditions, the diversion structure is a very massive, geometrically demanding and deeply founded component (Figure 7, Figure 8).

The upper, 12 m wide channel is also continued, but is not significantly deflected and opens into the new spillway chute. The bottom is rounded off to ensure a flow-favourable transition to the new spillway chute.

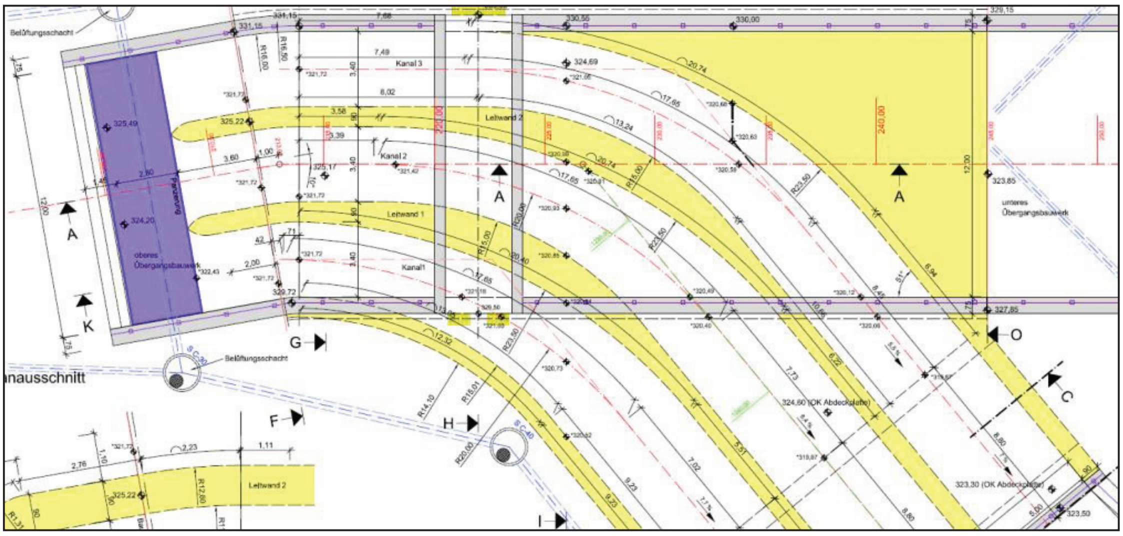

Figure 7 : Diversion structure – ground plan (ARGE LHP-SI Talsperre Malter 2015)

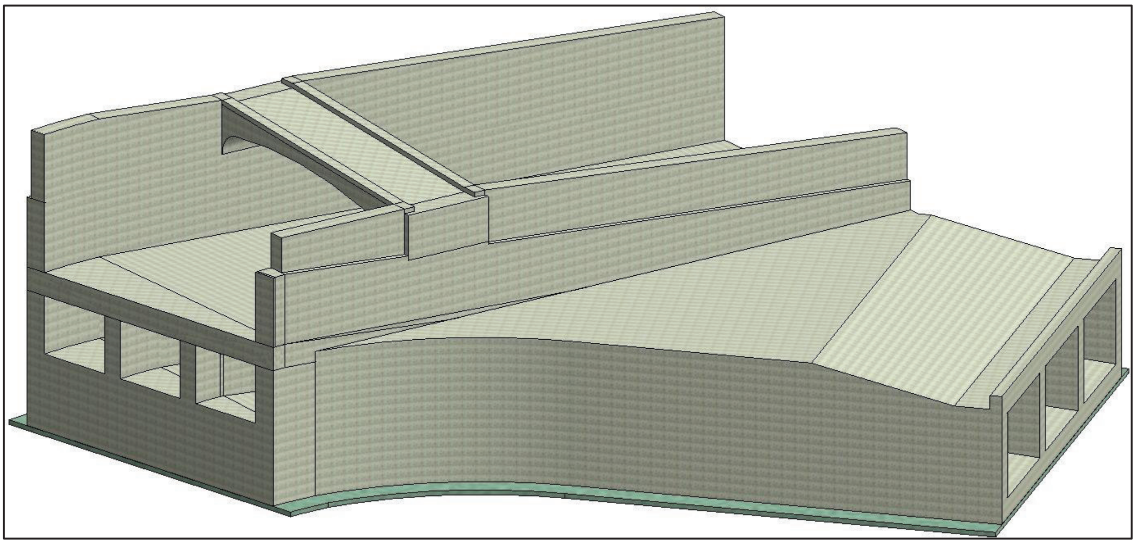

Figure 8 : 3-D-Model of diversion structure (ARGE LHP-SI Talsperre Malter)

3.2.4 *New spillway chute*

The new spillway chute (L / W approx. 110 m / approx. 12 m) is formed with a jointless reinforced concrete base, which is mounted sliding on three sides. At the end, the horizontal forces that occur are transferred into the rock via a spur.

The side walls of the spillway chute are 5 m high on the left side in the upper area and rise to approx. 9 m at the bottom. On the right side they are only 3 m high in the upper part due to the course of the terrain. The outflow of the PMF still remains in the new spillway chute. The height of the wall at the end of the spillway chute is also approx. 9 m and thus corresponds to the height of the stilling basin side wall.

The lower 15 m of the new spillway chute are covered by a bridge plate. The reinforced concrete frame construction is founded on the grown rock. The bridge width resulted from the line of the road, which already on the bridge merges into a curved area on both sides. The abutment of the bridge also forms the frontal stilling basin wall.

3.2.5 *New stilling basin*

The new spatial stilling basin (L / W approx. 25 m / approx. 18 m) and the approx. 9 m high side walls are designed as reinforced retaining walls as angle retaining wall with wall foot on both sides. The base is to be preserved in rock without any removal. The stilling basin ends with a 2 m high end sill.

3.2.6 *Scour protection*

In the course of the bed stabilization, the river bed will be redesigned in an area of about 130 m. The connections to the existing embankments will be made. To secure the river bed, the area between crossbeams 1 and 4 will be constructed as a concrete hydraulic engineering paving. The connection to the stilling basin end sill is integrated into the paving.

3.3 Model test

Due to the mutual flow influence of the individual operating facilities and the complex geometries, for which no hydraulic boundary conditions or calibration measurements were available, a hydraulic model test was carried out at the University of Siegen (Germany) for further optimisation (see also Schmidt 2015).

The hydraulic model (scale 1:25) comprised a part of the reservoir, the dam wall, the existing spillway, the planned extension of the spillway, the bottom outlets, the diversion tunnel as well as a part of the tailwater (model area L / W 19.6 m / 7.2 m) (Figure 9).

The main focus was led on the discharge distribution in the diversion structure (Figure 10), the hydraulic capacity of the new spillway chute, the dimensions and the energy dissipation of the new stilling basin as well as the effects of the planned increase of the hydraulic capacity of the diversion tunnel with simultaneous operation of the two spillways.

Figure 9 : Hydraulic model scale 1:25

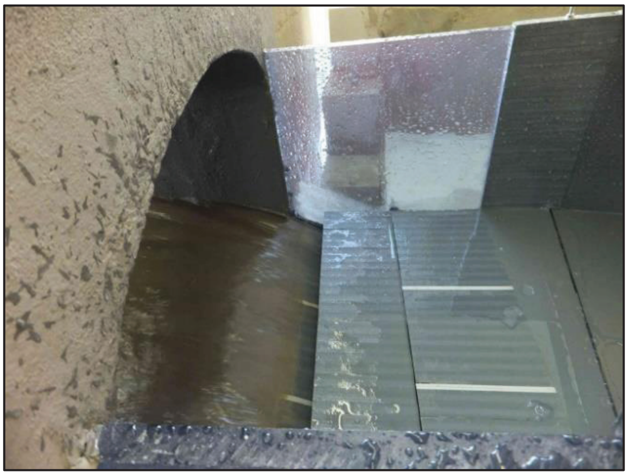

Figure 10 : Model – Diversion structure inlet

As a result, the hydraulic performance of the designed new spillway was proven and optimizations of the diversion structure and the new stilling basin were achieved (Figure 11). With the results of the model test the design planning was completed and the approval planning was prepared.

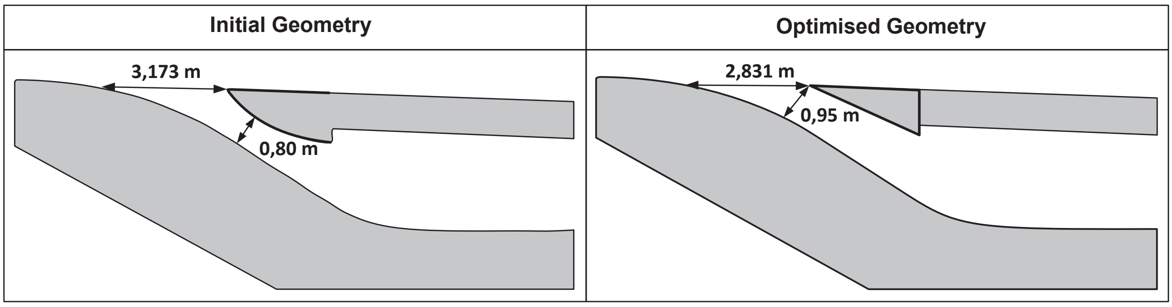

Figure 11 : Model test (Schmidt 2015 modified)

3.4 Approval procedure and detailed design

Based on the approval planning, the operator applied in 09/2015 at the Saxony State Directorate for the granting of a water law planning approval in accordance with the German Federal Water Resources Act in conjunction with the Administrative Procedure Act. In July 2018 the planning permission was granted. The detailed design was completed in 01/2019.

3.5 Flood protection during construction period

On the one hand, the flood protection during the construction period is based on a precipitation forecast dependent flood pre-release under consideration of the harmless discharge of 40 m³/s. For this reason, the hydraulic capacity of the diversion tunnel was considerably increased by replacing the valves (installation of new sliding gates in closed design) (see also Haufe 2019a). On the other hand, by lowering the operating reservoir level to 323.00 m a.s.l. during the construction period, larger floods can be intercepted without the spillway having to be activated. In addition to this, the slopes of the excavation pit are partly constructed with a reinforced shotcrete lining (see Figure 13) and a temporary safety wall is placed in the direction of the new spillway chute.

4. TENDERING PROCEDURE

Two tendering units were formed. Unit 1 (temporary site roads and building demolition) was a public tender. Unit 2 (reconstruction/new construction of new spillway and demolition of temporary site roads) was carried out as an open EU procedure.

The estimated construction costs will be about 20 million euro.

5. CONSTRUCTION

Construction period of unit 1 was between 04 - 08/2019. Unit 2 construction begin was in 08/2019. With a planned construction time of 28 months it will be finished in 12/2021.

At first extensive demolition and excavation work is carried out (see Figure 12). Then, challenging concrete work is carried out for the diversion structure, the new spillway chute and the new stilling basin.

Figure 12 : Side channel – Excavation works for bottom deepening (state 12/2019)

Figure 13 : Dam and Old spillway cute with location of diversion structure (to the right of the crane)

6. CONCLUSION

In order to restore the flood safety of Malter dam, the existing spillway and the construction of a new spillway with stilling basin as a preferred variant are being implemented as a result of an extensive variant investigation. A newly developed complex diversion structure is used to link the existing spillway system with the new spillway.

After the implementation of the construction measure, Malter dam will be fit for the hydrological challenges of the 21st century.

ACKNOWLEDGEMENTS

We acknowledge the cooperation with our client the State Reservoir Administration of Saxony (Pirna, Germany) and our JV-Partner Spiekermann (Dresden, Germany).

For the hydraulic model test we acknowledge the cooperation with the hydraulic engineering laboratory of University of Siegen (Germany).

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