New Spillway at the Esch-sur-Sûre Dam in Luxembourg

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1 Introduction

The Esch-sur-Sûre arch dam, designed by the French engineer Coyne, was built between 1956 and 1957 on the river Sûre, 1.2 km upstream of the small town Esch-sur-Sûre in the north west of Luxembourg. It’s maximum height is 50 m and the crest is 170 m long between the two massive buttresses which constitute the abutments of the arch. The design of the dam was particularly bold (Figure 1) with the purpose to minimize the volume of concrete. Thus, the thickness of the arch is only 1.50 m at the crest and 4.50 m at the base. The crest, which is constituted of prefabricated elements anchored to the dam, includes two road lanes.

The small dams located downstream of the Esch-sur-Sûre Dam provide a sound regulation of the river discharge and an appropriate control of the water level at the town of Esch-sur-Sûre in normal conditions. The dam foundation is mainly constituted of hard and sound Schist and Quartzitic Sandstone of Devonian age.

The drainage area at Esch-sur-Sûre amounts to approx. 428 km$^2$, two thirds of which are in Belgium. The dam impounds a reservoir of approx. 59 million m$^3$ (total storage capacity), which is mainly used for drinking water, flood protection, flow regulation during the dry season, power generation and for touristic and recreational activities.

The reservoir is approx. 19 km long and its surface is 3.50 km$^2$. The dams of Pont Misère and Bavigne, located at the reservoir tail, allow the upstream water level to be maintained above a minimum level to preserve the site (environmental and touristic aspects). The powerhouse, located at the toe of the dam, is equipped with two 5 MW Francis units with a total discharge capacity of 25 m$^3$/s. The average annual energy generation is approx. 16 GWh/year.

Currently, floods are evacuated downstream of the dam through the two bottom outlets located at the central cantilever (Figure 1), noting that the dam is not equipped with a surface spillway. The bottom outlets are controlled by two 3.50 m wide and 2.75 m high radial gates with a total capacity of 450 m$^3$/s. The current discharge capacity of the dam is not sufficient to meet the updated flood safety requirements, in particular if we consider the possibility that one or both gates could fail to open during the flood due to power failure, gate jamming or human error.

The flood control volume between el. 320.0 m a.s.l. (N.W.L.) and 322.0 m a.s.l. (M.W.L.) amounts to approx. 7 Mm$^3$. During winter, the normal water level is lowered by 3 m in order to increase the flood control capacity by 9 million m$^3$ and to improve the dam safety. Hence, 35% of the reservoir capacity is reserved for flood mitigation during the winter months. The hydrologic regime of the River Sûre shows regularly decreasing discharge during the summer and very high values during the winter. The largest floods occur mainly in January and they are characterized by large incoming volumes, peak discharges and long durations. Three significant floods, with return periods of up to 50 years, were observed during the period 1990 to 1995.

Current reservoir operations during flooding have been established in order to meet dam safety requirements and to protect the town of Esch-sur-Sûre against dam overtopping. Therefore, the flood discharge evacuated downstream of the dam is limited to 95 m$^3$/s as long as possible. This value corresponds to the maximum capacity of the river Sûre at the town of Esch-sur-Sûre. However, if the reservoir level reaches el. 320.0 m a.s.l. the outflow has to be increased significantly up to the total capacity of the bottom outlets (450 m$^3$/s) in order to avoid the overtopping of the dam.

2 New spillway at the Esch-sur-Sûre dam

2.1 Foreword

The floods observed over the period 1990 to 1995 justified the review of the hydrological data of the River Sûre at the dam site and a reassessment of dam safety. This analysis carried out in 1995, led to the conclusion that both the volume and the peak...
discharge of floods associated with different return periods has significantly increased. The main consequences are that the current discharge capacity of the dam is insufficient to cope with current safety standards and that the town of Esch-sur-Sûre is threatened by frequent flooding.

Based on these conclusions, the Administration des Ponts et Chaussées appointed Lombardi Engineering Ltd to carry out prefeasibility and feasibility studies for a new surface spillway at the dam and for a flood relief tunnel bypassing the town of Esch-sur-Sûre (Figure 2) [11]. In fact, although the dam rehabilitation project provides a better flood routing effect and therefore a reduction in the flow, it is still insufficient to ensure adequate flood protection of the town. In this configuration, the new spillway will safely evacuate flood discharges through a tunnel passing under the left abutment of the dam, while the 142 m long flood relief tunnel, bypassing the town of Esch-sur-Sûre, will increase the global capacity of the river across the meander.

### 2.2 Main project features

The spillway is constituted of two 37.5 m long labyrinth weirs located on the left abutment close to the dam. The labyrinth optimized geometry allows to minimize the volume of excavation and therefore to reduce the visual impact of the project. The crest of the weirs is situated at el. 320.70 m a.s.l., that is to say 70 cm above the current N.W.L. The spillway, designed to evacuate the 10 000 year return period flood of 650 m$^3$/s considering a single bottom outlet in operation (250 m$^3$/s) and the reservoir at the M.W.L. (323.00 m a.s.l.), will be equipped with a debris boom to keep the floating debris off its crest. The spilled water is discharged downstream of the dam through a gallery passing under the abutment. The junction of the two labyrinth weirs is located at the top of the inclined shaft. Both the headrace and the tailrace tunnels have the same dimensions (BxH = 6.15 m x 6.40 m) and are lined with concrete to ensure good flow conditions and to avoid erosion damage. The circular inclined shaft, which has an internal diameter of 6.15 m, is also lined with concrete. The asymmetrical flip bucket has been designed to ensure good flow restitution conditions to the river in all operation conditions.

The increase in the total discharge capacity will allow the maximum water level to be raised by 1 m up to el. 323.0 m a.s.l. in order to increase the flood protection capacity by approx. 3.5 m$^3$/s. Both the new spillway and the rise of the maximum water level will lead to a reduction of the peak outflow discharges during severe floods, thus contributing to flood protection of the towns downstream of the dam.

The design of the new spillway meets the following requirements:

1. guarantee the operational safety of the spillway;
2. avoid any loss of agriculture surfaces;
3. avoid the loss of power generation capacity and drinking water;
4. limit visible structures (mitigation of environmental impacts).

### 2.3 Physical model investigation

The hydraulic behavior of the new spillway was tested at the Laboratory of Hydraulic Constructions of the University of Liège using a physical model downscaled at 1:26.19 (Froude similarity). Physical investigations aimed to validate the discharge capacity of the design, to assess the flow characteristics inside the galleries and the shaft under any operational conditions and to improve the ski jump design regarding scouring risks in the downstream natural river bed.

**Characteristics of the physical model**

The model represented a part of both the upstream reservoir and the downstream natural river, linked together by the complementary spillway structure. The projected geometry of the galleries and the shaft were built with very slight geometric simplifications, using mainly plastic transparent materials. In particular, the complex transition from rectangular to circular section was manufactured using the stereolithography (rapid prototyping method). This technique provides quick and accurate representation of any complex 3D shape.

Downstream of the ski jump, the natural river bed was modeled with movable gran-
The construction of a new spillway at the Esch-sur-Sûre Dam will increase significantly its discharge capacity in compliance with current flood safety requirements. It will also help to protect the towns downstream against flooding by reducing the peak outflow with respect to the current situation. Although the dam rehabilitation project allows an increase in the flood routing effect and therefore a reduction of the outflow, it is still insufficient to ensure adequate flood protection to the town of Esch-sur-Sûre, which is located 1.2 km downstream of the dam. The project also includes the construction of a flood relief tunnel bypassing the town, which will increase the global capacity of the river reach at the vicinity of the town.

### Literature


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