RAISING OF MAXIMUM STORAGE LEVEL OF HPP VILA VIÇOSA BY MOUNTING A FLAP GATE TO THE SPILLWAY-CREST

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Abstract The weir of the Hydro Power Plant Vila Viçosa in Portugal was raised by 2 meters by subsequent installation of a flap gate on the crest of the spillway. (Lifting of maximum storage water level from 209,5 to 211,5 m.) Thus the short-time water storage basin was increased from 12.400 m³ to 29.700 m³. The job had to be done by keeping the original spillway-crest profile and with a minimum of work on the concrete structure.

1. History

Due to the change of the legal situation in Portugal it has been possible since 1988 for private investors to erect and operate small Hydro Power Plants up to 10 MW.
The same year the Portuguese power generating company HIDROCENTRAIS REUNIDAS SA was founded. This company decided in the year 1990 to erect small Hydro Power Plants in the North of Portugal. Because of the high quantity of rainfall this area is suitable in an excellent way for the use of hydropower to produce electric energy.
Two Hydro Power Plants were erected near the villages of Vila Viçosa and Ermida. They were put into operation in April respectively May 1993.
The total produced energy is fed into the Portuguese main supply network (Electricidade de Portugal). The necessary aerial lines (for 15 kV respectively 60 kV) to connect to the existing distribution centre were erected.

2. Power Plant

GENERAL

Vila Viçosa is situated near Castelo de Paiva at the Rio Ardena, an affluent of the Rio Paiva, which eventually flows into the main river Douro.
At the weir site the river has an area of precipitation of 53 km². The specific mean annual run-off amounts to 32,26 l/s,km².
The bypass reach amounts to 1.900 m, the gross head to 123,4 m. A slope of approximately 6,5% results.

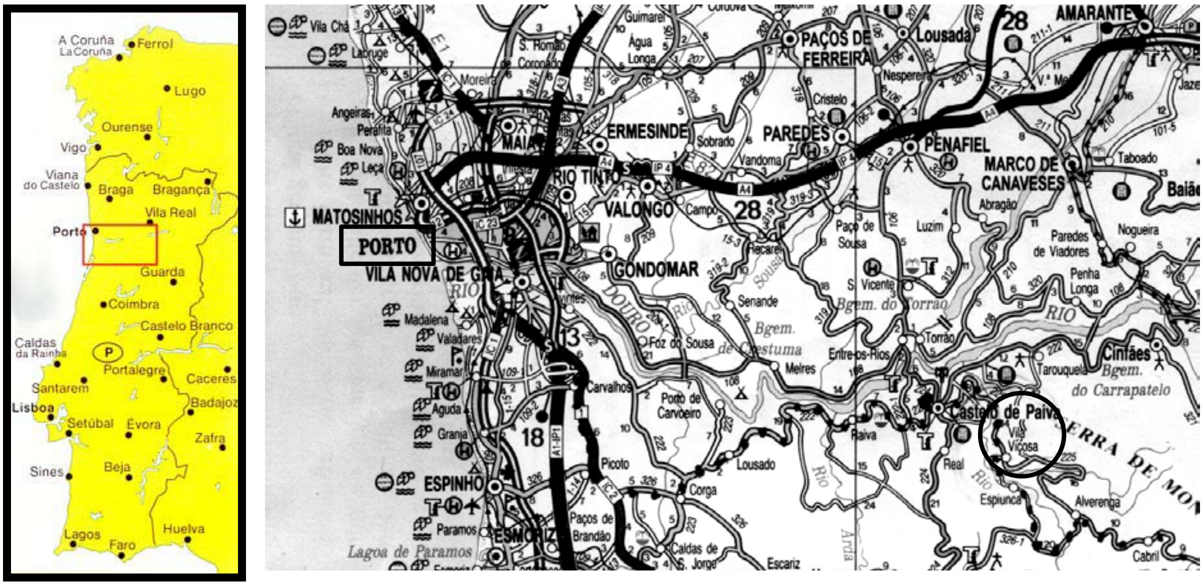


Fig. 1: Situation

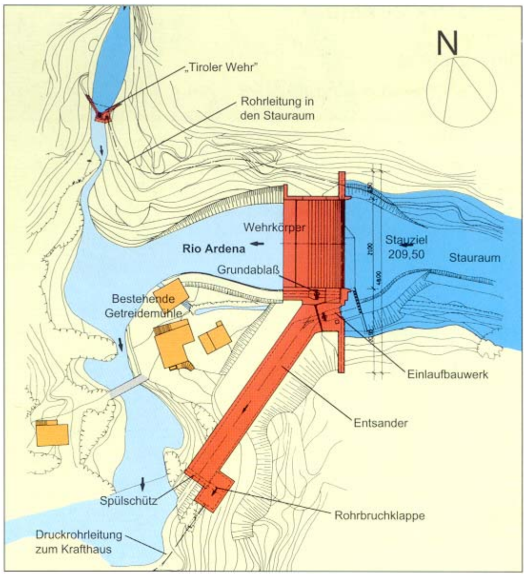


Fig. 2: Lay Out

The plant is dimensioned in such a way that the natural discharge exceeds the absorption capacity of the turbines on 45 days of the year. This amounts to a usable yearly water quantity of approximately 70% of the availability.

The size of the short-time water storage basin results from the topographical situation and enables operation of the plant in periods of high tariff. It allows the production of electric energy at peak power especially during the periods with low water supply.
The plant is equipped for fully automatic operation and is controlled by a central control station.

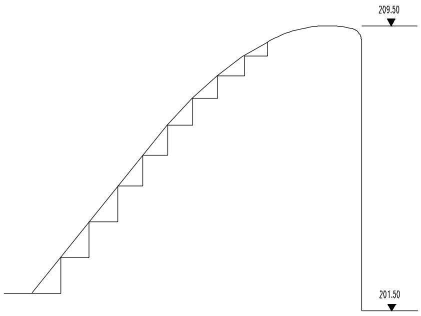
WEIR (Situation 1993)

The Rio Ardena is banked up for approximately 8 m at the weir. When lowering the normal water level by 3,5 m the usable content of the basin is 12.400 m³.
Additionally the water of a small brook is collected by a Tyrolian weir and piped to the basin.

The complete weir is 51 m in width and constructed as a gravity dam. The width of the (stepped) spillway is 21 m. The weir is equipped with a sluice gate.

As a sufficient desilting in the basin was not possible for all operating conditions an additional desilter was foreseen. Because of the extreme change of the water level during operation of the reservoir the desilter had to be pressure resistant.

The weir is designed for the 500 year high-water interval. Remarkable are the extreme high-water peaks characteristic for this area. In case of a centennial flood the discharge reaches the 180-fold of the mean annual run-off.



SECTION

STEPPED SPILLWAY

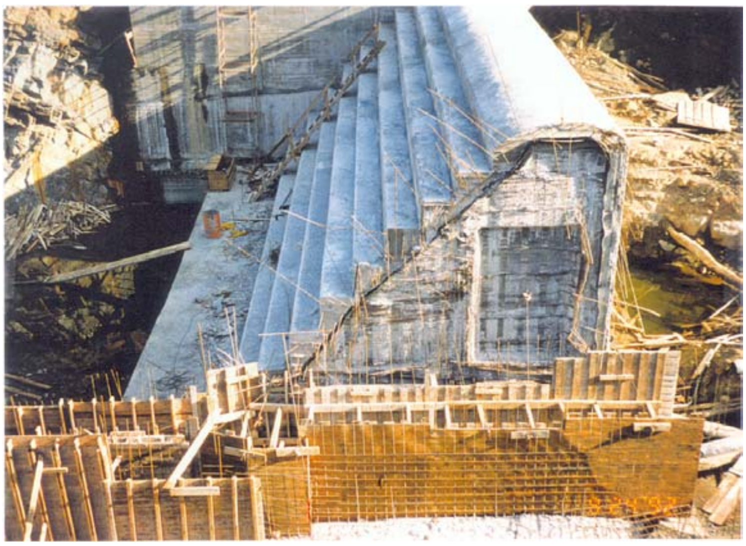


Fig. 3: Spillway: original design

PENSTOCK

The penstock was erected as an underground steel pipeline. The pipeline follows the left bank of the Rio Ardena, for positioning of the pipe considerable excavations and rock cuttings were necessary.

POWERHOUSE

In the powerhouse two Francis turbines of equal size with horizontal shaft are installed. Both engines run with a speed of 1000 r.p.m., they are directly coupled to the synchronous generators. The nominal output of the generators amounts to 1.965 kVA.
The control room is installed on the upper floor of the powerhouse.
A substation next to the powerhouse transforms the produced energy from 6 kV to the line voltage of 15 kV.

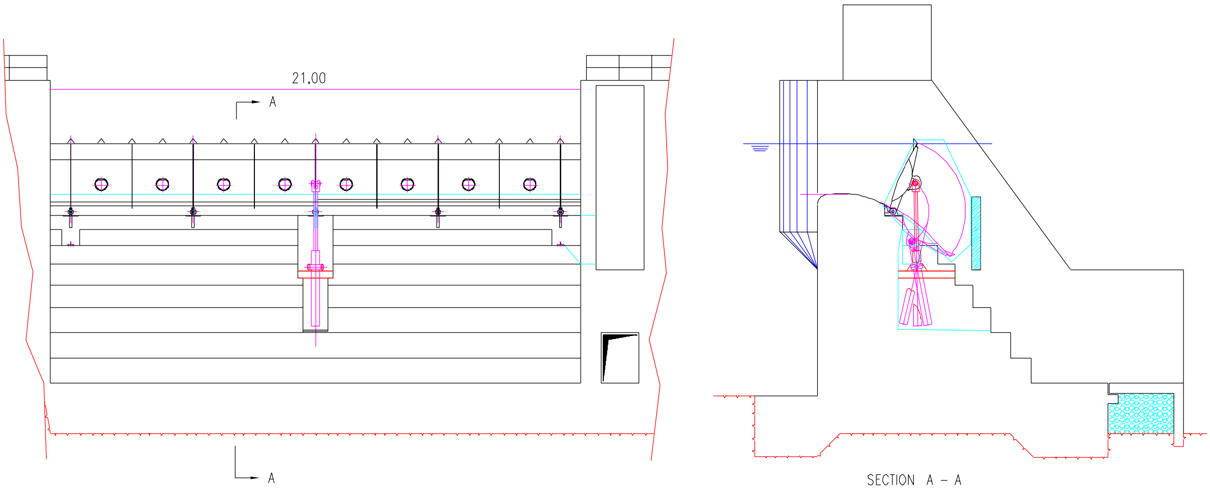


Fig. 4: Flap Gate: View from Downstream

The design of the bearing boxes made it possible to reach the necessary rotating angle of the flap gate with a minimum cutting of concrete. A slot in the bearing boxes below the level of the bearings was cut out for the bearing-bulkheads. Concrete cutting was necessary only for the slot.

Fig. 5: Bracket for Hydraulic Servo

Fig. 6: Bearing Box with Slot

The concrete of the side walls had to be removed by approximately 3 cm for the side plates. To this surface "Hat-Profiles" (stainless steel) were doweled and exactly aligned by means of lining plates. For the exact alignment of the hat-profiles the (already mounted) flap gate was used.
To these hat-profiles the stainless steel side plates were plug welded. The remaining hollow between concrete and side plates was grouted with liquid cimentalex mortar.
For aeration of the overflow in the left side wall a slot 0,35 x 2,875 m (area approximately 1,0 m²) was cut.

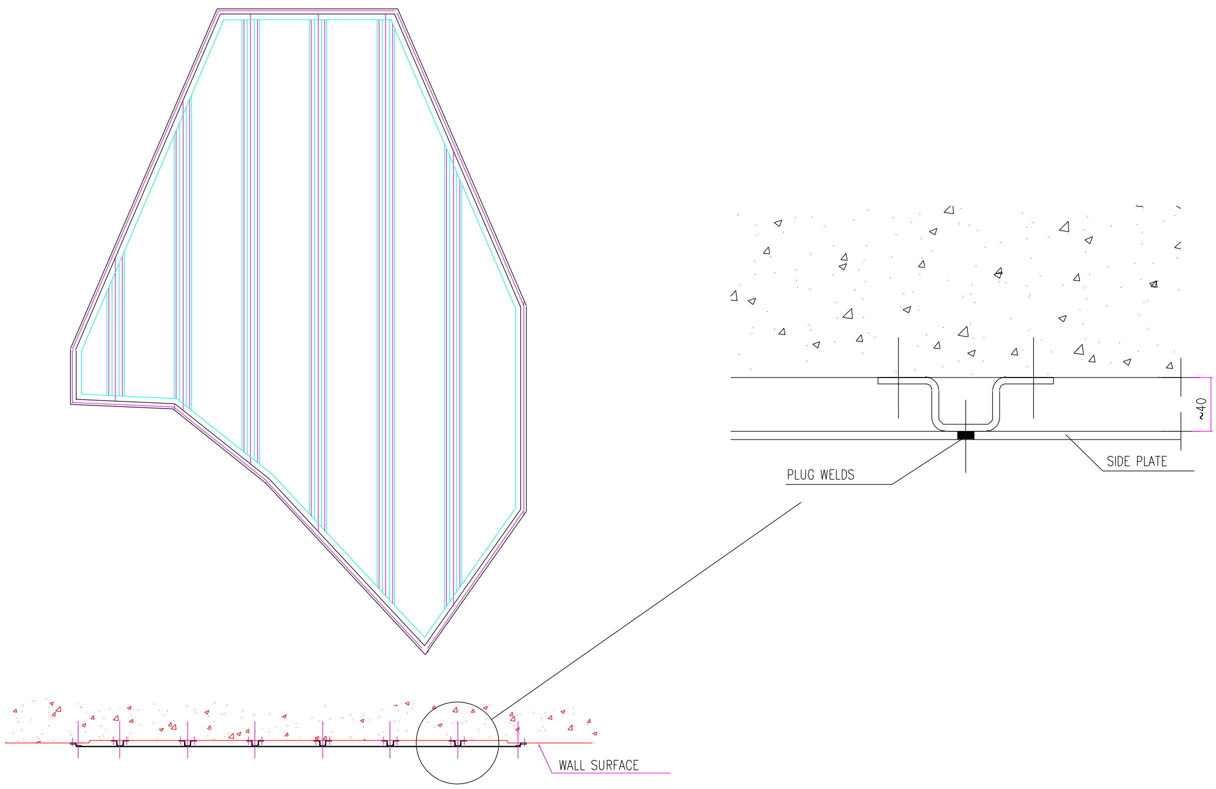


Fig. 7: Side Plates: Design, Detail Hat-Profiles

Hat-Profiles, mounted to the wall

Side Plate Aeration Aperture

Fig. 8: Side Plates: Construction

3. RAISING OF STORAGE LEVEL

After start-up of the power plant it was decided to raise the storage level, especially to increase the capacity of the short-time water storage basin.
Raising the storage water level by 2 m the usable storage capacity was increased from 12.400m³ up to 29.700 m³.
A reduction of high-water evacuation by this means was not acceptable.

4. REQUIREMENTS/ DESIGN

A flap gate as barrage was out of the question right from the beginning. Only a flap gate made it possible to keep the original profile of the spillway with the lowered flap gate.
A hydraulic servo was positioned as drive downstream in the middle of the gate. For the side seals stainless steel plates had to be mounted as sliding surface.
It was a basic requirement for the design to minimize cutting work on the concrete of the weir. An efficient aeration of the overflow had to be guaranteed as it was not possible to assess whether the overflow would be sufficiently aerated by the steps of the spillway or by the slot for the hydraulic servo.

5. CONSTRUCTION

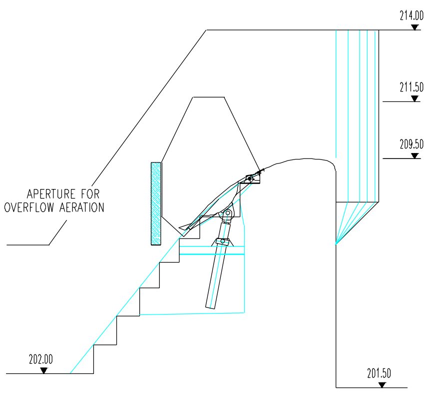


Fig. 9: Section with Flap Gate
(with Side Plate and Aeration Opening)

To keep the original overflow profile the flap gate was positioned downstream of the spillway crest so that the connection of the sill seal to the weir was also downstream of the crest. The result was a flap gate with a total height of approximately 2,5 m.
Due to the restricted space the flap gate was kept very flat and manufactured in two parts (flanged connection) for transport reasons. This solution required five bearings for static reasons.

⇐ **Fig. 10:** Flat Flap Gate

The bracket for the hydraulic servo was placed into a slot in the weir.

The following alterations on the weir were necessary for the chosen design:

- Removal of the second step of the spillway
- Excavation of the slot in the middle of the weir for the hydraulic servo and bracket
- Excavation for the flap gate bearing boxes
- Removal of concrete from the side walls for the side plates, depth 3 cm
- Excavation of the aeration slot in the left side wall

Fig. 11: Work on Spillway in Progress

6. RESULTS/ SUCCESS

By raising the maximum top water level the yearly proceeds were increased by approximately 7%. This increase is based on the better utilization of the water supply at peak power enabled by the enlarged reservoir capacity as well as by the increase of the turbine output due to the increased water head.
Return of investment was approximately within four years.

Fig. 12: IN OPERATION

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