USE OF WATER POWER– SMALL WATER POWER PLANT IN LIBĚCHOV


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Summary

The designing of additional construction of water power stations on waterway drop structures on the Lower Elbe River necessarily involves serious conceptual issues to be solved. It is also the case of the small water power plant in Liběchov, which should be erected on the waterway drop structure in Dolní Beřkovice. The small water power plant being prepared is situated below the right-bank weir sluice and logway; its design is atypical (in the Czech Republic) – it is designed as a submerged water power station. The complicated flow in the vicinity of the hydraulic structure was the original reason why research inolving hydrotechnical modelling was commenced in the laboratories of the Faculty of Civil Engineering, Czech Technical University in Prague.

1 Introduction

Maximum exploitation of water power as a clean and sustainable source of electrical energy represents one of the principal trends in the future development of water management. For now, the hydro-power potential of the Czech Republic can be further exploited under acceptable economic conditions even though the required technical solutions are very non-traditional in a number of cases.

The non-traditional solutions also include the technical design of the water power plant with a weir (the power station in Liběchov) below the Dolní Beřkovice hydraulic structure on the Elbe River. The unconventional nature of the scheme in this case also ensues from the fact that the relatively complex and technically innovative project involves a private investor.

In accordance with the conceptual proposal of the investor, the whole hydraulic structure in Liběchov is placed close below the right weir sluice of the three-sluice weir in Dolní Beřkovice. The distance between the sector of the Beřkovice weir and the gate of the power station in Liběchov is only 105 km, and so both the water structures are in close contact.

Due to numerous uncertainties particularly related to the operation of the newly designed hydraulic structure during floods and in conditions of the sediment-carrying water course, the investor decided to collect more detailed data on the future performance of the water structure in a research done on a small physical model in the lab. The entire exploration of hydrotechnical aspects of fish migration (fishway) was secured by the staff of the Department of Hydrotechnics of the Faculty of Civil Engineering, Czech Technical University in Prague supported by the staff of the Department of Hydraulics and Hydrology.

2 Small Water Power Plant in Liběchov

The small water power plant to be erected is designed below the right-bank weir sluice and logway of the water structure in Dolní Beřkovice. The weir structure is currently composed of three sluices of sector weirs.

The inlet into the water power plant will be a pool, the right wall of which will be made by the newly built bank reinforcement with a drive and a fishway, while the left wall will be composed of a newly erected interconnecting wall continuing the pier of today's sector weir. The bottom of the inlet pool will be modified sloping towards the inlet into the flushing opening.

The impounding facility is designed as a shutter weir with two sluices 24.5 m and 34.0 m wide, respectively. The structure will be mounted onto the ceiling of the machine room of the small water power plant.

The new structure of the water power station will be made by inlets into the trash racks, intakes in the turbines, the machine room and outlets from the turbines. Access to the machine room of the water power plant will be provided from the right bank of the bank facility adjacent to the right wall of the pool.

The water power station outlet will be made by a sloping bottom bounded by a sill at the end. The outlet sides will be composed of a side wall on the left continuing the overflow body, and a modified bank wall of the outlet pool on the right. The fishway of the canal type will be erected at the right bank in accordance with the requirements of the standard TNV 752321 with stone drop structures.

The inlet into the fishway in lower water will be placed beyond the outlet from the turbines, while the inlet into the upper water will be in the new zone above the weir.

- No of turbines: 6
- Type of turbines: tubular Kaplan's horizontal PIT
- Diameter of the runner: 3100 mm
- Scope of gradients: 0.5 m – 2.54 m
- Scope of discharges: 14 m^3s^{-1} – 52.5 m^3s^{-1}
- Installed capacity: 6×400 kW = 2400 kW
- Stop log: gate
- No of gates: 2 (24.5 m, 34.5 m)
- Size of trash racks: 52.5×15.5 m
- Distance between trash racks: 40 mm

3 Sediments in Small Water Power Plant in Liběchov: Analysis

The suspended load comprises all solid particles of mineral, as well as organic matters that float in water. If it settles, it is called sediments.

Transport of suspended load over weir bodies, navigation locks, logways and fishways does not cause any serious complications. The suspended load moves forward, passing over the weir and may silt the weir area. If it passes through the hydraulic perimeter of the water power station, complications occur and their consequences are very bad. Suspended load may silt inlets into turbines, draft tubes and other facilities, thus causing unplanned shutdowns of electric power generation. In order to reduce transport of suspended load over turbine runners, a sedimentation space before the inlet into the power station was designed. The space is 5.5 m wide, 80 m long and 0.5 m – 1 m deep below the bottom (see **Fig. 1**).

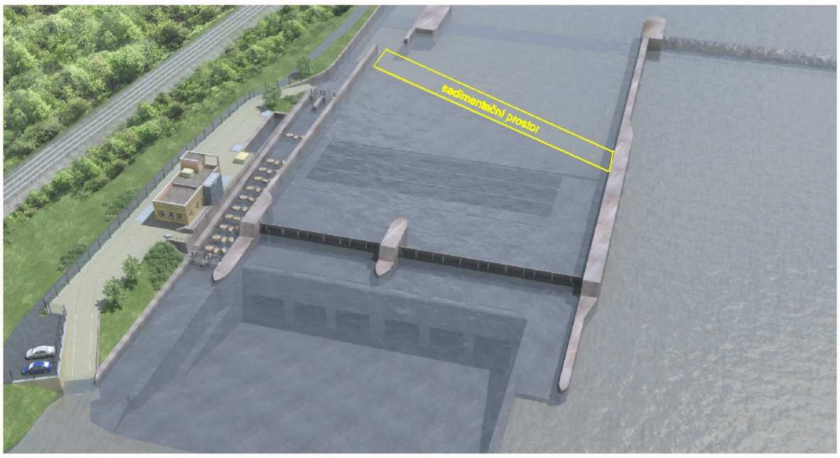

Fig. 1 Projection of the designed power plant with marked sedimentation space.

4 Research Based on Hydrotechnical Modelling

The hydrotechnical model of the small power plant in Liběchov was designed in order to get answers to the questions below which sum up the basic problems outlined above:

- what are the hydraulic characteristics of the right sluice and logway of the hydraulic structure in Dolní Beřkovice,
- what are the hydraulic characteristics of the small water power plant in Liběchov (to be solved in the second stage of the research project),
- optimization of the placement and size of the settlement area before the inlet into the power station (2 alternatives),
- optimization of the placement and size of the opening for flushing the settled sediments (7 alternatives),
- optimization of the handling of the weir gate, logway gate and flushing opening gate (7 alternatives),
- optimization of the design of the inlet into the turbines (to be solved in the second research project stage),
- optimization of the design of the draft tube of the turbines (to be solved in the second research project stage).

5 Model Description

The hydraulic model of the small power plant in Liběchov (sector weir, shutter weir, logway, zone before the weir and flood bed) has been created in the scale of 1:45.

The hydraulic model of the small power plant in Liběchov is predominantly made of plastic materials (PVC – cured, PVC – expanded plastic, PVC – transparent) of zinc coated sheet and steel girders. The parts of the model which could not be produced from plastics, are made of zinc coated sheet. The colour design of the model is important because of the clarity of the photo documentation (photo and video).

The division of the model parts into colour groups is as follows:

- grey – the substructure, the piers, the bottom below the weir, the zone in front of the sluice and the logway of the hydraulic structure in Dolní Beřkovice,
- green – the hydrostatic sector with needles,
- brown – the gates above the small water power plant in Liběchov, the sector in the flushing canal and the gate in the flushing opening,
- ochre – the piers of the shutter weir and the piers in the fishway,
- red – the model modifications, the bottom of the zone in front of the sluice, the inlets, the substructure, the draft tubes of the small water power plant in Liběchov, the partition wall, the settlement area, the vacuum gate and the modifications in the bottom and in the logway walls,
- brown pebbles – the reinforced bottoms in front of the settlement area,
- white sand – the settled material washed away through the flushing opening,
- hard coal – the material in the bottom of the middle sluice of the hydraulic structure in Dolní Beřkovice.

The colour design of the model corresponds to the colour visualization of the designs. It particularly concerns the current state of the drawings shown in black colour and subsequent modifications (newly designed parts) presented in red. Such a representation makes the orientation in the drawing documentation, the photo documentation, as well as the lab model much easier. The colour design (the contrast of the white sand, the red settlement area and the hard coal below the middle sluice of the weir in Beřkovice) makes assessment of each test easier.

6 Program of Experiments

The program of the experiments was detailed after the completion of individual tests depending on the results of individual tests, visual observation of the tests, and the source materials from the designer and the investor. **Tab. 1** shows individual tests with corresponding details of the individual parts.

Tab. 1 List of tests

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
Opening width – 9 m; opening capacity – $Q = 92\ m^3s^{-1}$	x	x	x	x	x		
Opening width – 5 m; opening capacity – $Q = 42\ m^3s^{-1}$						x	
Opening width – 5 m; opening capacity – $Q = 26{,}5\ m^3s^{-1}$							x
Discharge only through the logway	x	x	x			x	x
Discharge over the weir and consequently over the logway, handling of the weir and the logway				x	x		

during the test							
Logway capacity	x	x	x				x
Logway capacity reduced crest of weir to the elevation 153.69 m above SL				x	x	x	
Logway is divided by a wall so that the water flow moves directly into the settlement area		x	x	x	x	x	x
Logway wall is partly pulled down, the bottom is deepened to the level of the settlement area					x	x	x
1 part: discharge over the weir 2 part: discharge over the weir discharge over the logway				x	x		

7 Test 6

Test 6 was the most successful one of the seven tests on washing away sediments. Based on the visual monitoring of the water flow and sediments transport during the test, the following facts can be deduced:

- the water flowing through the logway moved directly to the settlement area,
- the suspended load at the flushing opening and the logway, where the water flow directed by the inclined wall in the logway moved, was washed away,
- the suspended load from the entire settlement area was washed away,
- the range of washing away the suspended load was sufficient,
- a minimal deposition bed was made in the zone in front of the sluice of the small water power plant in Liběchov,
- towards the end of the test, no movement of the suspended load was visible; almost all of it had been washed away,
- the test lasted for 10 hours (recalculated to real time),
- the test result has been successful in favour of the flushing of the suspended load.

Fig. 2 documents the test results.

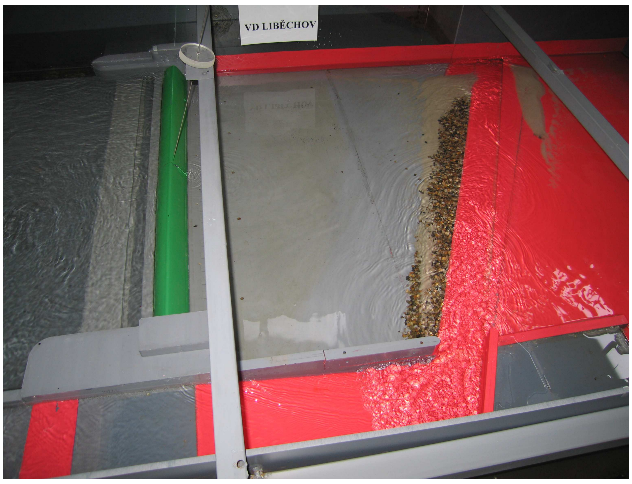

Fig. 2 Test.6 – successful washing away of the suspended load.

8 Conclusion

Based on the tests performed on the physical model, the following can be stated:

- the laboratory model in the scale of 1:45 gives a true picture of the behaviour of the hydraulic structure in Dolní Beřkovice and the small water power plant in Liběchov,
- the physical model was designed so that it could be later exploited in solving potential problems related to the small water power plant in Liběchov,
- the description of individual alternatives corresponds to the course of the project – seven tests were carried out according to the requirements of the investor, designer and representatives of the River Elbe Authority,
- the test results have been accurately documented and described in the report "Hydrotechnical Research of the Small Water Power Plant in Liběchov“,
- test 6 has shown the most successful alternative of the solution of washing away the sediments.

The nature of test 6 was uniform flow. The discharge $Q = 42\ m^3s^{-1}$, which was selected for the test, corresponds to the capacity of the flushing opening. The logway capacity $Q = 42\ m^3s^{-1}$ was achieved by removing the sill – reduction by 0.4 m to the elevation of 153.69 m above SL. The partition wall of the logway and the flood bed of the right sluice, as well as the bottom of the logway were demolished. The logway bottom was demolished up to the settlement area bottom to the elevation of 151.09 m above SL. The logway bottom was made by a chute from the elevation of 153.46 m above SL. A sloping wall was inserted in the logway to direct the flow of the water in direction to the settlement area (the wall elevation was 154.71 m above SL). The height of the flushing opening was 2 m and its width was 5 m. The calculated capacity of the flushing opening was $42\ m^3s^{-1}$. The width of the settlement area was 5.5 m and the average depth was 0.75 m. The test has shown a successful alternative of washing away sediments. Based on the results of the research based on hydrotechnical modelling of the small water power plant in Liběchov, the following can be concluded as regards the modelling of washing away sediments: settling and washing away sediments during and after the flood cannot be designed and judged clearly and simply (even ensuing from long-term experience in the field). This opinion is supported by laboratory tests (the behaviour of the movement of suspended load cannot be predicted from the desk). Even the best design idea (see tests 1, 2, and 3) can be devalued in the course of measurements as a result of an unexpected behaviour of water with suspended load. Therefore, the modelling of suspended load is an essential part of the design stage. And the use of laboratory research is an integral part of the execution project.

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