THE WETTED RACK LENGTH OF THE TYROLEAN WEIR

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ABSTRACT

The Tyrolean Weir – a submerged weir with horizontal or inclined trash rack was developed as a water-intake from mountain torrents. For design it is important to know the wetted rack length. To find this parameter depending on specific discharge, inclination of the rack and width of the bar-gaps experiments were performed at the hydraulic laboratorium of the University of Technology, Vienna. Experimental results were compared with theoretical calculations. Examinations of waterdistribution along the rack occurred to ascertain the loss of water in case of a too short rack. It is advantageous to overdimension the rack rather than a restrained design.

Figure 1: Tyrolean Weir of the water intake Verpeil, power plant Kaunertal

Keywords: Tyrolean Weir, water-intake, model tests

INTRODUCTION

The Tyrolean Weir was developed as a water-intake from mountain torrents and is a submerged weir with horizontal or inclined trash rack (Figure 2). Due to the water-intake from the brook bed the weir has to be low in order to restrict the discharge cross section as minimal as possible. Thus the flood level remains the same as before.

Furthermore the low weir is well protected against avalanches, because it is too low to provide for a surface. As a protection against rock slide the trash rack can be equipped with a rock fall rack.

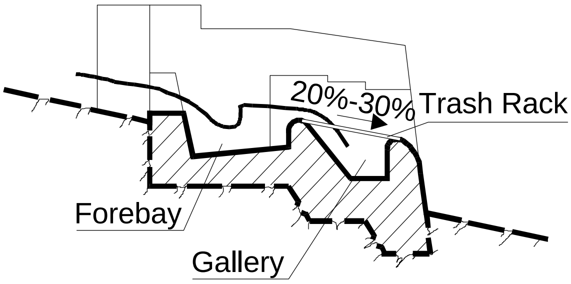

Figure 2: cross section of a Tyrolean Weir [1]

The Tyrolean Weir was developed in South Tyrol where the peasants had to take water from brooks with heavy bed load movement for irrigating their meadows on the valley terraces. The valley bottom was wet or swampy because of the hill-side water, but the meadows and fields of the graded terraces had to be irrigated. Even today the irrigation ditches can be seen in North and South Tyrol, they are called "Waale".

In order to be able to take out the water from the brook the peasants made a ditch across the brook bed and covered the ditch with tree trunks. The water could run through the gaps between the trunks into the ditch below, the coarse bed material was held back by the trunks. This was the first Tyrolean Weir. The stones held back by the trunks were washed away by the water that was not taken into the weir or the next flood took them with it.

Small stones and sand running through the gaps were dragged along by the water and were deposited in one of the even parts of the Waal. For maintenance the trash rack made of trunks and some parts of the Waal prone to sedimentation had to be cleaned from time to time. But the often kilometer-long Waal was spared from clogging with big stones and strong siltation.

When the Tyrolean Weir came into general use to take water from brooks with heavy bed load movement the ditch across the brook was exchanged for a conduit-type concrete sewer, the gallery. The trunks were exchanged for a steel coarse rack to prevent coarse sediment. To prevent sand and small stones to get into the adjacent conveyance system a settling basin is built. Through this basin the water becomes free of solids and the adjacent conveyance system does not have to be cleaned permanently from sedimentation. The sediment collected in the settling basin is continuously or intermittently flushed back into the stream for further transport by the next flood. The amount of the intake with a Tyrolean Weir is dependent on the size of the horizontal or inclined coarse rack, the size of the clearances between the bars of the rack, the inclination of the rack and the shape of the bars. Based on observations it is known that a major part of the water-intake runs through the bars of the rack, but a minor part which is not to be neglected runs along the back of the bar and depending on the inclination and the shape of the bar – rounded or plane – the water runs into the weir channel below after a more or less long distance. A too short rack does not take in the total amount of water, but the water running along the back of the bars runs off.

HYDRAULIC OF THE BED RACK

In order to calculate the discharge through the bed rack the course of the water level and the water distribution along the rack has to be determined. Referring to the ratio of energy along the rack two hypotheses exist:

- constant energy level (corresponding to a horizontal energy line)
- constant energy head (corresponding to an energy line parallel to the bars of the rack)

Both hypotheses illustrate the possible limits of the inclined rack, in-between lies the actual course of energy. The results are the same in a horizontal rack.

CALCULATION OF THE WETTED RACK LENGTH ACCORDING TO FRANK

The course of the water level over the rack can be seen as elliptic arch according to Frank which proceeds from a constant energy level over the rack.

The major half-axis of the ellipse corresponds to the wetted screen length L, the minor half-axis corresponds to the flow-depth h_0 which sets in at the assumed beginning of the rack, at the level of the weir crest, with the angle of inclination α when the energy level gets to its minimum (Figure 3).

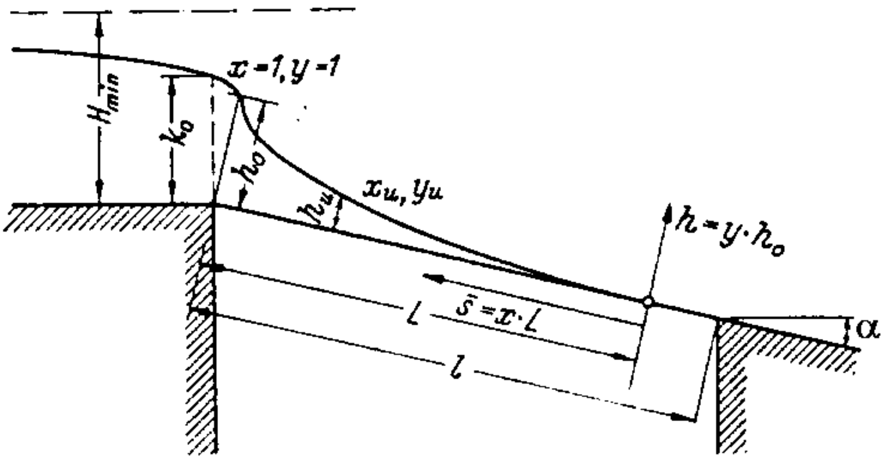

Figure 3: water level of the Tyrolean Weir as elliptic arch [5]

According to the coordinate axis shown in Figure 3 this ellipse is

$$\bar{s} = \sqrt{2 \cdot \frac{L^2}{h_0} \cdot h - \frac{L^2}{h_0^2} \cdot h^2} \qquad (1)$$

which leads to the wetted rack length L given by

$$L = \frac{0,846}{\mu \cdot m \cdot \cos^{1/2}\alpha \cdot \sqrt{c}} \cdot \sqrt[3]{q_0^2} \qquad (2)$$

μ is the discharge coefficient of the rack which is dependent on the shape of the cross section of the bar, m is the ratio of construction and c is a reducing factor dependent on the inclination of the rack.

CALCULATION OF THE WETTED RACK LENGTH ACCORDING TO KUNTZMANN AND BOUVARD

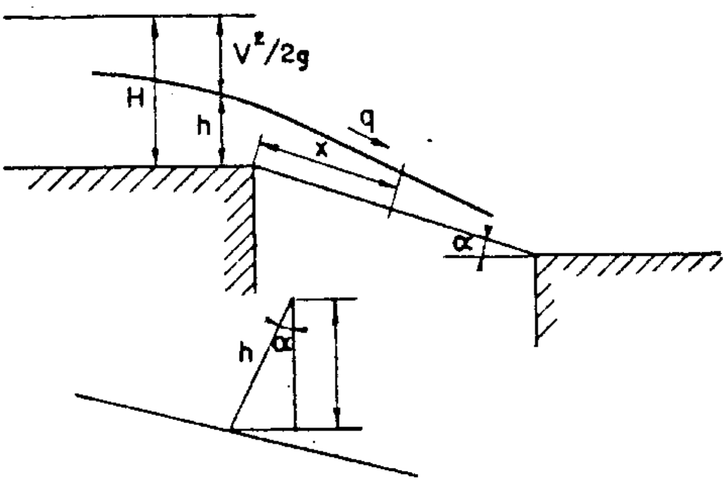

Figure 4: hydraulic of a bed rack according to Bouvard [9]

According to Kuntzmann and Bouvard who as well assume a constant energy level, the wetted length of the rack may be calculated by a different equation of first classification and sixth degree.

$$\left(\frac{dq}{dx}\right)^6 - 2g\cdot m^2\cdot\left(\frac{dq}{dx}\right)^4\cdot\left(H + x\cdot\sin\alpha\right) + 4g^2\cdot q^2\cdot m^6\cdot\cos^2\alpha = 0 \tag{3}$$

With this equation the wetted length of the rack L cannot be directly calculated, thus Kuntzmann and Bouvard give design charts in Ref. [9] which calculate the length with variable ξ. The curves of the charts show the result of the integration of remodeled equation (3).

With the angle of inclination α and the ratio of construction m the wetted length of the rack L may be calculated by

$$L = \xi\cdot\sqrt[3]{\frac{q^2}{g}} \tag{4}$$

CALCULATION OF THE WETTED RACK LENGTH ACCORDING TO NOSEDA

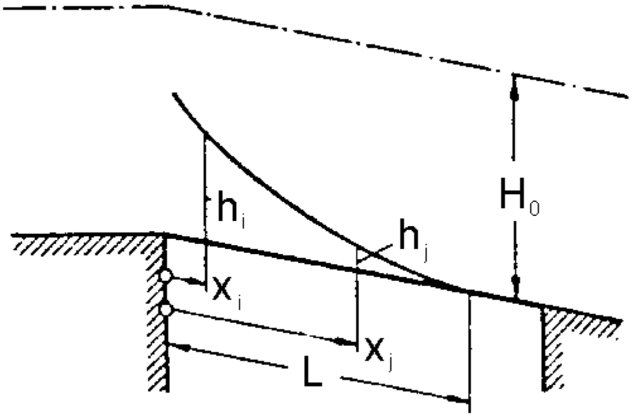

Figure 5: schematic layout for determining the wetted rack length according to Noseda [10]

Noseda's [10] equation is based on a constant energy head with total water-intake by the bed rack and calculates the wetted rack length directly

$$L = 1{,}185 \cdot \frac{H_0}{\mu \cdot m} \tag{5}$$

But this equation neglects the inclination of the rack and thus it is only valid for horizontal racks.

MODEL TESTING

INTRUDUCTION

The model of a Tyrolean Weir was built to a scale of 1:10 in the hydraulic laboratorium of the University of Technology, Vienna and operated according to Froudian principles. It was designed with a bed rack of 5.0 m width and its bars had a circular cross section with 10.0 cm diameter in original dimensions.

The wetted rack length was calculated for five different rack inflows at four different inclinations of the rack ranging from 0% to 30%. Corresponding to original sizes the specific discharges turned out as follows:

$$q_{1,N} = 0{,}25 m^3 / s \cdot lfm$$
$$q_{2,N} = 0{,}50 m^3 / s \cdot lfm$$
$$q_{3,N} = 1{,}00 m^3 / s \cdot lfm$$
$$q_{4,N} = 1{,}50 m^3 / s \cdot lfm$$
$$q_{5,N} = 2{,}00 m^3 / s \cdot lfm$$

The width between the bars was 10.0 cm and 15.0 cm. In order to make the comparison of the testing results easier and more exact the lengths of the rack bars measured from the weir crest were projected on a horizontal.

MEASURING OF THE WETTED RACK LENGTH

For calculating the wetted rack length two different lengths were determined on the rack bar.

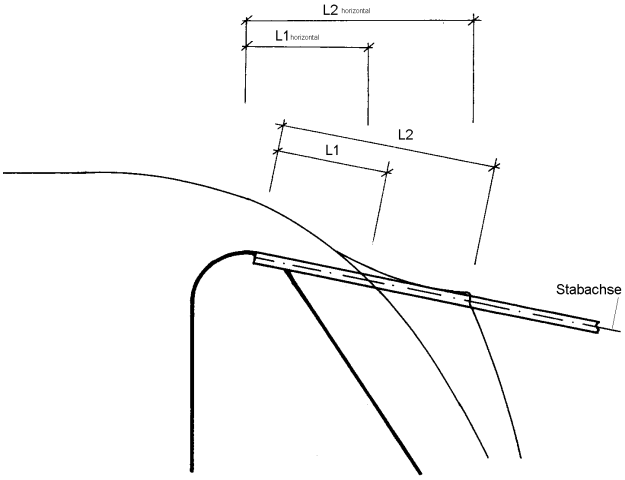

Figure 6: wetted rack length and shape of the nappe at the testings

The major part of the discharge flew through the rack bars. At the point where the surface of this nappe crossed the axis of the rack bar the length L1 was read (Figure 6). This point was found out by using a peak gage.

A small part of the discharge ran along the rack bars. Where this part of the discharge eventually came off the bar the rack length L2 was read directly from the rack bar (Figure 6). This length is the wetted rack length expressed in theoretical calculations.

The results of the model testing were compared to calculated wetted rack lengths. The calculations were made according to above described methods of Frank, Noseda and Kuntzmann-Bouvard.

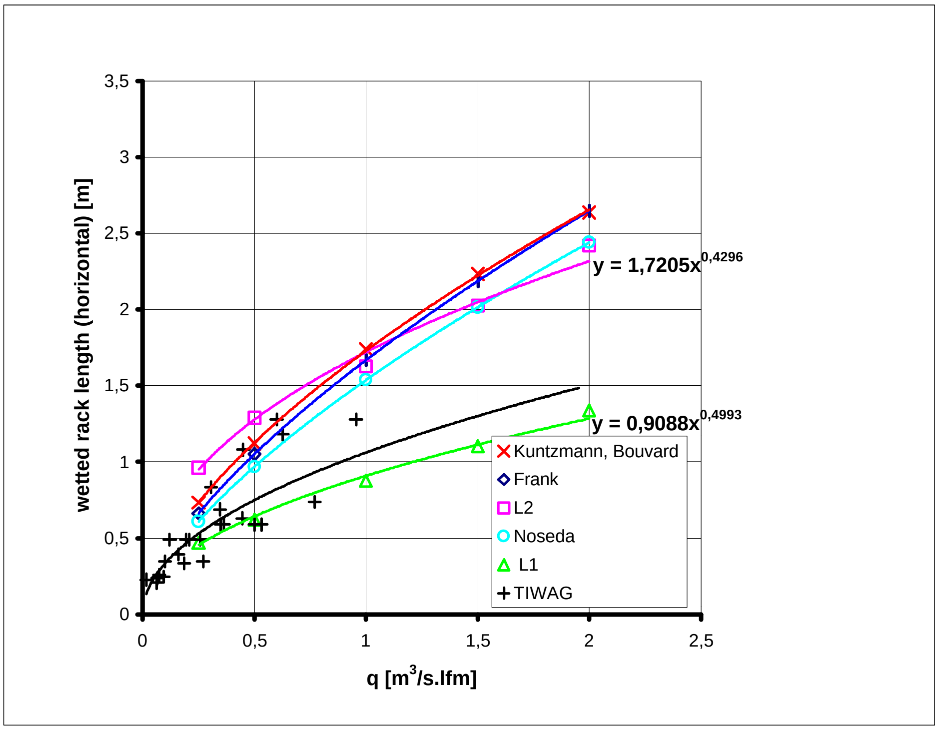

Figure 7: wetted rack length, width between the bars 15.0 cm, inclination of the rack 20%.

Figure 7 shows the comparison of the results of the testing and the calculated values for an inclination of the rack of 20% and a width between the bars of 15.0 cm. The calculated and tested values, respectively are shown as potential function whereby this function for the results is shown in the diagram. In these formulae the wetted rack length (horizontal) is expressed by variable y, the specific discharge is expressed by variable y. In addition to this, measurings of existing Tyrolean Weirs for the power plant Sellrain-Silz (Tiroler Kraftwerke AG) carried out between 1988 and 1993 are also shown in this figure.

These measures show a big scattering due to the difficulties that are faced by measuring L2 at original sites. An interpolation curve as potential function is significantly above the curve of the measured length L1.

The results of Frank and Kuntzmann-Bouvard correspond to each other. The results according to Noseda deviate more from the two other results with a stronger inclination than with a weaker inclination, because Noseda does not include the inclination of the rack in his formula.

The measured lengths L2 can directly be compared to the calculated lengths. These lengths are clearly below the calculated values with high specific discharges, they are above with low specific discharges.

Because of the risk of clogging of the rack (e.g. stones or branches) the calculated rack length has to be multiplied by a major safety factor ranging between 1.5 and 2.0. The necessary rack length calculated this way is certainly sufficient for taking in the assumed amount of water.

INTAKE ALONG THE RACK

An important question in determining the criteria for measurements of the bed rack in the Tyrolean Weir was the amount of water loss if the rack is designed too short (<L). Thus the model testing for determining the water-intake along the rack was conducted with parameters corresponding to the testing of the wetted rack length.

The intake beyond the measurement mark (space between the marks 0.5 cm to 1.0 cm) was recorded by dividing the discharge of the rack at the marking points by a plate gutter and determining the amount of water taken in by a measuring weir afterwards.

The evaluation of the testing was conducted by the means of figures (see Figure 8) which show the amount of discharge taken in by the Tyrolean Weir for a specific value of the inclination of the rack and the width between the bars. The amount of discharge is expressed in percentage of he total amount of discharge dependent on the ratio of the specific length of the testing to L2 for the specific rack inflow of the testing. The specific discharge may be determined according to length L1 expressed in section 3.2 which runs off along the rack bars when L>L1.

The discharge is generally higher in racks with small width between the bars and it grows with increasing inclination of the rack. The testing results of rack bars with circular cross sections show that between L1 and L2 up to 23% of the total amount of the inflow is taken in. In a bed rack with length L1 this may cause an unreasonable high loss of water. It is advantageous to overdimension the rack rather than a restrained design.

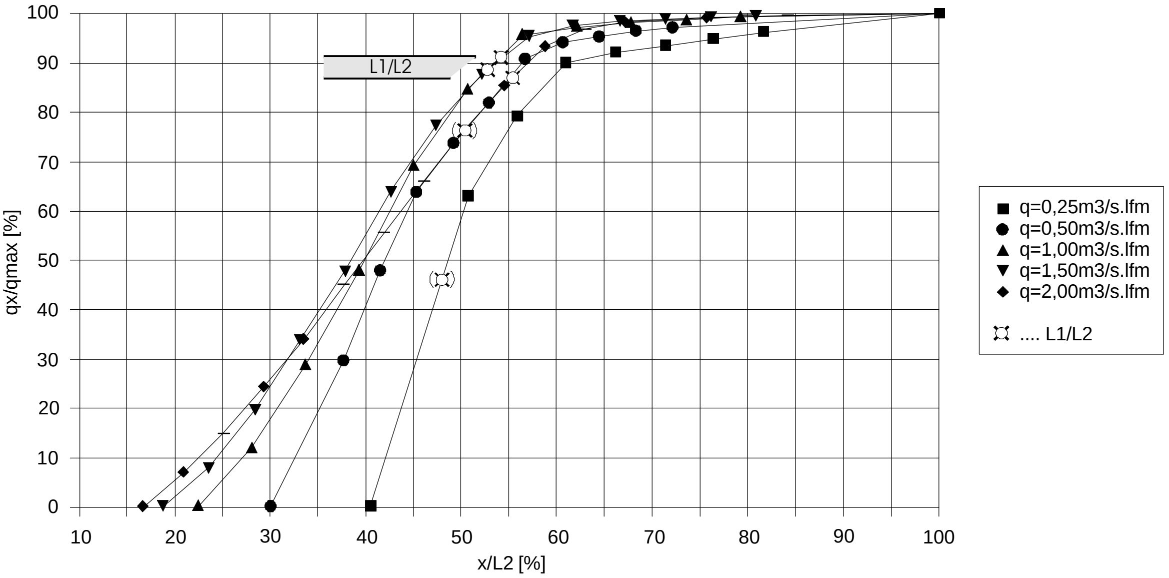

Figure 8: water-intake along the rack, width between the bars 15.0 cm, inclination of the rack 20%

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Planned testing programs regarding Tyrolean Weirs are analogue tests with plane backs of rack bars, as occurring in box-type rack bars or turned about railroad rails, as well as testing regarding the effects of clogged racks.

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