PARSHALL FLUME CALIBRATION FOR FREE FLOW

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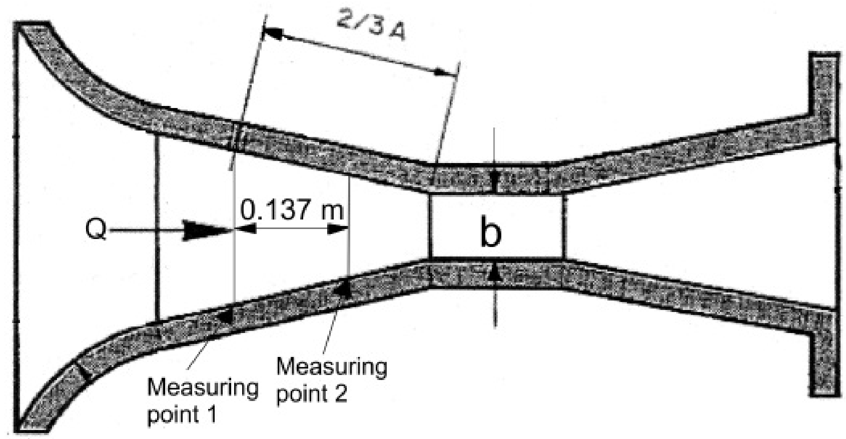
Summary: *For a b=0.0254m wide Parshall flume, the literature provides the dependence of flowrate and water depth in the throat within the flowrate range of Qmin-Qmax – discharge curve. The calibration of discharge curve by transposing measuring point 1 to measuring point 2, error values were obtained, which are lower than the ones recommended by the standards of this country and the relevant literature. A new discharge curve was set for flowrate below Qmin at measuring point 2 and at water temperature of 16 to 17°C.*

Keywords: *Calibration, Parshall flume, free flow, viscosity of water*

1. INTRODUCTION

Within the Stormwater Drainage Systems as Part of Urban and Traffic Infrastructure Project, a structure was procured for flow measuring from the experimental catchment area on the territory of the Faculty of Civil Engineering in Subotica - a Parshall flume manufactured by INDAS from Novi Sad.



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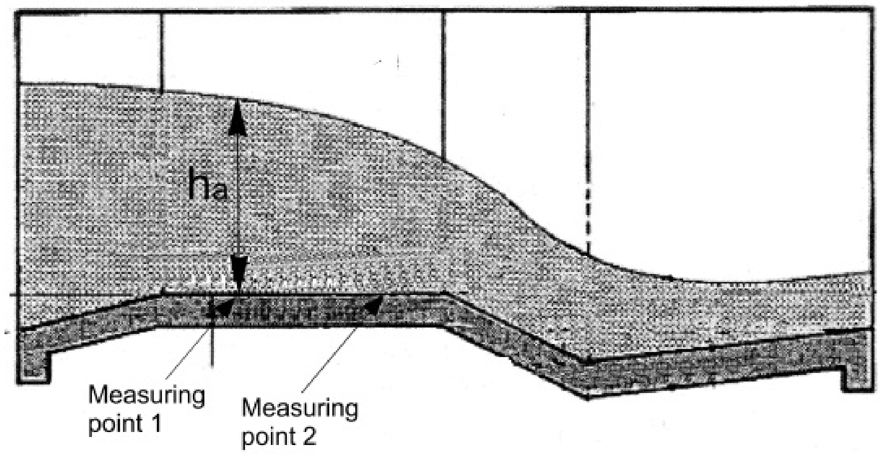

Figure 1: Parshall flume with measuring points 1 and 2

For free flow and for the known value of throat width b at flowrate ranges of Q_{min} to Q_{max}, the scientific literature indicates the relationship between the measured depth h_a and flowrate Q [1]:

$$Q = Ch_a^n \tag{1}$$

where C and n are coefficients given for the contraction of width b. For this dependence, h_a is measured in measuring point 1. In relation to original measurements, equation (1) can provide differences up to 5% [2], and up to ±3% [3] respectively.

Analysing the accuracy of equation (1), it has been established that around Q_{min} flowrate decrease weakens the defined relationship between Q and h_a [4]. Measurements were made for throat width of b=0.076, 0.152, 0.305 and 0.610 m. The authors assume that changes in relations were resulted by the influence of the viscosity of water.

The standards of this country: Water flow measurement in open channels, weirs and measuring facilities comprise also the Rectangular broad crested weirs (SRP U.C5.090 from 1994.) [5] and the Water flow rate calculation methods by defining depth at the outlet section of rectangular channels with free cascade (SRP U.C5.092 from 1994.) [6] – and these are in accordance with the ISO 3846: 1989 and ISO 3847:1977 standards. Parshall flumes are not covered by any of these standards. The SRP U.C5.092 Standard provides the approximate domain of 2 to 5% for water flow measurement accuracy for rectangular throats.

The international standard, ISO 9826:1992, gives instructions on defining the inaccuracy of flow measurements in Parshall flumes without indicating the value limits of permitted errors [1]. Of the indicated throats with b=0.0254-15.24 m width, standard throats are b=0.152-2.4 m wide.

Recommendations for the calibration of flow measuring devices in open channels are given in Flow Measurement Methods in Open Channels issued in Quebec in 2007 [3]. The minimum time of water intake is 90 s for volumetric calibration. The recommendation is applicable to b=0.0254-15.24 m wide Parshall flumes as well.

Within the above mentioned project, a b=0.0254 m wide Parshall flume was procured. At measuring depths of h_a=0.019-0.184 m, at measuring point no. 1 (Figure 1), and at water flows of 0.00013-0.00438 m^3/s, equation (1) becomes [3]:

$$Q = 0.0604 h_a^{1.55} \left(\frac{m^3}{s} \right) \tag{2}$$

The aim of this paper is to present the calibration of equation (2) at flowrates of 0.00013-0.003 m^3/s, by extending the range to 0-0.00013 m^3/s, expected at the Faculty of Civil Engineering catchment point.

2. INSTALATION AND METHODS

In the Hydraulic Lab of the Faculty of Civil Engineering in Subotica, a b=0.0254 wide Parshall flume was built at the downstream end of a 20 cm wide channel (Figure 2).

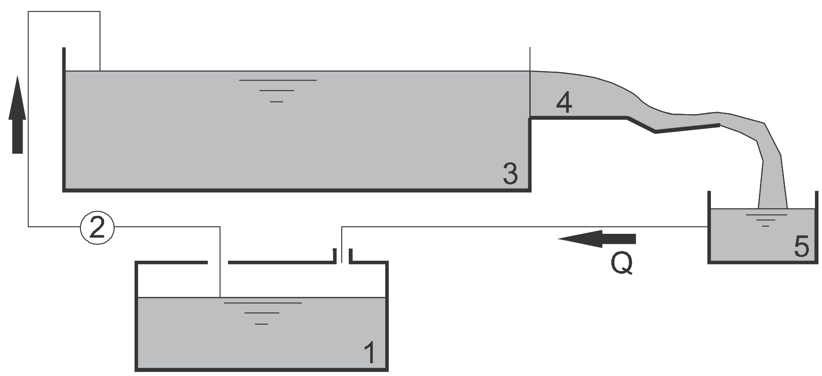

Figure 2: Laboratory Structure Scheme – 1. Reservoir, 2. Pump, 3. A 20 cm wide channel, 4. Parshall flume, 5. Collector tank

From the reservoir of 10 m^3 in volume, built in the backyard of the Faculty of Civil Engineering, the water was pumped to a 20 cm wide channel. The stilled water from this channel was led via a free flow Parshall flume to a collector tank, then further transported to a catch tank.
The measurement results for steady flowrate Q were:

- water depth h_a at measuring point and
- water volume at the downstream end of the Parshall flume, caught within 90 seconds.

Water depth was measured by point gauge of 0.1 mm accuracy. Water volume was defined by measuring the weight and temperature of the water. Water weights of 2.4-11.2 kg were measured by weighing scale of 5 g accuracy, water weights of 26.2-102.6 kg by scales of 10 g accuracy, and weights of 138.8-261.3 kg by scale of 100 g accuracy. Flowrate measurement errors were calculated by using the following equation [7]:

$$G(\%) = \frac{Q_i - Q_m}{Q_m} 100 \tag{3}$$

where: Q_i flowrate are calculated as a function, while Q_m is the measured value of flowrate.

3. RESULTS

For measuring points 1 and 2, shown in Figure 1, all flowrates were measured five times each. During measurements, water temperatures varied between 16 and 17 ^{o}C.

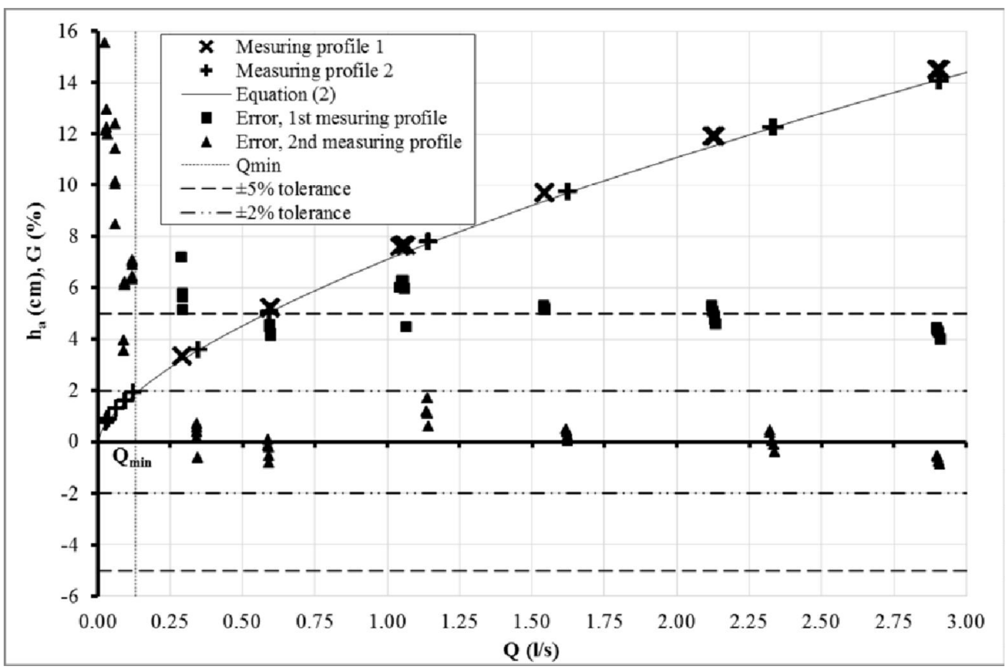

Figure 3: Equation (2), measured results and their errors for measuring points 1 and 2

The errors for each measurement were determined by using equation (3).

4. DISCUSSION

For measuring point 1 (Figure 1) measurements were made for flowrate exceeding Q_{min}=0.13*10^{-3} m^3/s. Measured flowrates were compared with flowrates calculated by using equation (2). Flowrate errors (from 4 to 7.2%) do not meet either the values recommended by scientific literature (up to 5% and ±3% respectively) or domestic standards (2 to 5%).

By using the same methodology, for flowrates over Q_{min}, the errors (-0.8 to 1.7%) remained within the permitted limits when the measuring point was transposed to point 2, which was at 0.137 m downstream from measuring point 1 (Figure 1).

For measuring point 2 flowrates below Q_{min} were tested as well. Measured flowrates were compared with flowrates calculated by using equation (2). Flowrate errors were between 3.6 and 15.6%.

Based on measurement results, the following equation was defined instead of equation (2):

$$Q = 208.88h_a^4 - 15.197h_a^3 + 0.5402h_a^2 + 0.0002h_a + 0.0000001 \quad (4)$$

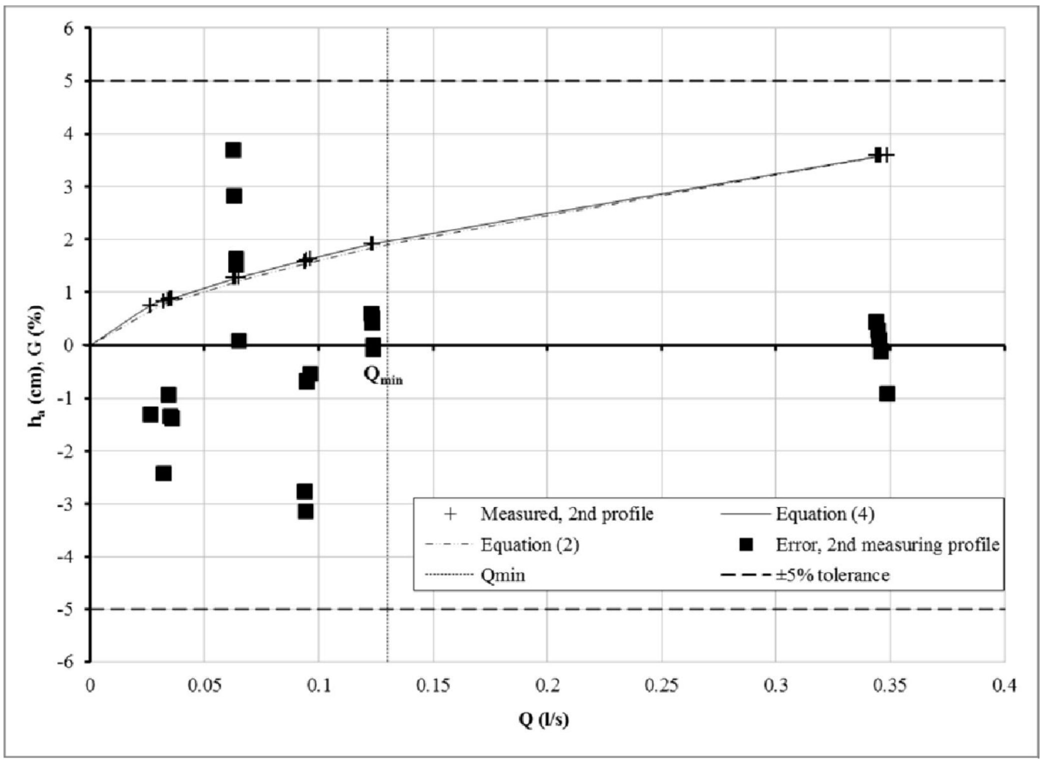

Figure 4: Equation (4), measured results and their errors for measuring point 2 at flowrates below Q_{min}

Measured flowrates were compared with flowrates calculated by using equation (4). Flowrate errors were between -3.1 and +3.7%.

Dependence depicted by equation (4) relates to flowrates below Q_{min}, at water temperature of 16-17 °C.

At a depth of h_a, for Q_{min}, equation (4) provides 6% less flowrate than equation (2).

5. CONCLUSION

For a b=0.0254 m wide Parshall flume, the discharge curve given by equation (2) provides less errors than recommended by the standard of this country and by the scientific literature for the following conditions:

- measuring point 1 should be transposed to measuring point 2, and
- flowrates should exceed $Q_{min}=0.13*10^{-3}$ m^3/s.

The discharge curve given by equation (4) provides less errors than recommended by the standard of this country and recommended by the scientific literature for the following conditions:

- the measuring point is point number 2,
- the temperature of the water is between 16 to 17 ^oC,
- flowrate is below Q_{min}.

With regard to the temperature of the water during summer periods, further testings of the indicated catchment point within the Faculty of Civil Engineering are recommended at water temperatures exceeding 17 ^oC. Having regard to the compliance of equation (2) and (4) at Q_{min}, the number discharges around Q_{min} should be increased when calibrating the throat.

ACKNOWLEDGEMENT

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КАЛИБРАЦИЈА ПАРШАЛОВОГ СУЖЕЊА ЗА НЕПОТОПЉЕНО ТЕЧЕЊЕ

Резиме: *За Паршалово сужење ширине b=0.0254m стручна литература даје зависност протицаја и дубине воде у сужењу за дијапазон протицаја Qmin-Qmax – криву протицаја. Калибрисањем криве протицаја добијене су мање грешке од препоручених стандардом ове земље и препорука стручне литературе премештањем мерног места 1 у мерно место 2. За протицаје мање од Qmin у мерном месту 2 и при температурама воде од 16 до 17*^{o}*C утврђена је нова крива протицаја.*

Кључне речи: *Калибрација, Паршалово сужење, непотопљене течење, вискозност воде*