PARSHALL FLUME CALIBRATION FOR HYDROGRAPH MEASUREMENT

Ognjen Gabrić[1]
Lajos Hovány[2]
Mirjana Horvat[3]
Zoltan Horvat[4]

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Summary: *For a b=0.0254 m wide Parshall flume, literature provides the dependence of flowrate and water depth in the throat within the flowrate range of 0.13-4.38 l/s. Volumetric measurements of flow (flow range 0 – 3 l/s) and water level measurements with ultrasonic transmitter prove that hydrograph can be determined using equation (2) (within accuracy range of -5.36 to +4.99%), or with equations (4) and (5) (within accuracy range of -3.46 to +4.77%) for water temperatures of 11.5-16 °C.*

Keywords: *accuracy, calibration, Parshall flume, free flow, ultrasonic transmitter*

1. INTRODUCTION

Characteristic dimension of the Parshall flume (constructed in 1922) is the flume width, b [2].

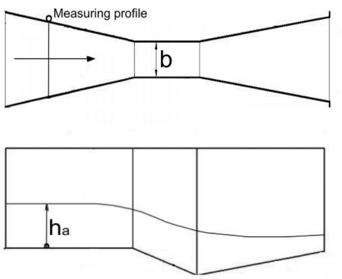

Figure 1. Parshall flume

[1]Dr Ognjen Gabrić, dipl. ing. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, e-mail: ogabric@gf.uns.ac.rs
[2]Dr Lajos Hovány, dipl. ing. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, e-mail: hovanyl@gf.uns.ac.rs
[3] Dr Mirjana Horvat, dipl. ing. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, e-mail: horvat.isic.mirjana@gmail.com
[4] Dr Zoltan Horvat, dipl. ing. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, e-mail: horvath.czoczek.zoltan@gmail.com

For declared flow ranges Q_{min}-Q_{max}, the rating curve between measured depths h_a and flows Q is given by the standards [1, 8]:

$$Q = Ch_a^n \quad (1)$$

where C and n are coefficients for the given flume size b.
Laboratory and field measurements for free and submerged flows in declared flow ranges were performed [1, 2, 3, 4, 5, 6, 7, 10]. Flows for free flow conditions were measured volumetrically (b=76 and 229 mm, b=305, 610 and 914 mm), by weighing (25, 51 and 76 mm), using weir (152, 305, 610, 1219, 1829 and 2438 mm), by current-meter (3048, 3658, 4572, 6096, 9144 and 12192 mm) and using Venturi flume (305 mm).
Parshall's original flow measurements were performed volumetrically and using the weir [1, 3]. For free flow conditions, when flow is measured volumetrically, errors were in the range of -2.4 and +7.7% (b=305, 610 and 914 mm) and -1.3% and +2.4 (b=76 and 229 mm).
In 1957 Robinson constructed and calibrated the flume size of b=25, 51 and 76 mm [4]. There are no data about calibration of those flumes in available literature.
For flow determination, float is used for water level measuring [2, 3].
For flow measurements near Q_{min}, using Venturi flume, error is increased up to 10% [5]. In order to reduce the error, instead of equation (1), new equation was proposed for the rating curve [5, 6].
The international standard, ISO 9826:1992, gives flow ranges for different flume sizes without indicating the value limits of permitted errors [8]. Parshall flumes are not covered by any standards of this country [7, 11].
Recommendations for the calibration of flow measuring devices in open channels are given in 2007. [9]. The minimum time of water intake for volumetric calibration is 90 s. The recommendation is applicable to b=25-1219 mm wide Parshall flumes as well.
Within the Stormwater Drainage Systems as Part of Urban and Traffic Infrastructure Project, a structure for flow measuring from the experimental catchment area on the territory of the Faculty of Civil Engineering in Subotica was obtained – a Parshall flume with the 25 mm flume width, manufactured by INDAS from Novi Sad [10]. This flume is designed for flow rate range of 0.00013 to 0.00438 m^3/s. Equation (1) then becomes:

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

Measuring water depth with point gauge (accuracy of 0.1 mm) and with volumetrically determination of flow (Faculty of Civil Engineering Subotica, 18-24th January 2014) under free flow conditions, flow errors in declared flow range were from +4 to +7.2%. For measurements in profile which is located 0.137 m downstream of original measuring profile, errors are reduced (-0.8 do +1.7%). For this measuring profile, flows below Q_{min} are also tested since they will appear during runoff process. Error range was from +3.6 and 15.6%. Based on measurements results (with water temperatures of 16-17 ^oC), new equation was proposed instead of equation (2). With new equation error range was between -3.1 and 3.7%. The calculated flow around Q_{min} with the new equation is 6% smaller than the flow calculated by equation (2). Since insufficient accuracy around Q_{min} and impossibility of continually measurements of water level with point gauge, new tests were performed with a purpose to initiate this flume for hydrograph measurement with ultrasonic transmitter accuracy of 1 mm. The tested flow range was 0-3 l/s.

2. INSTALATION AND METHODS

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

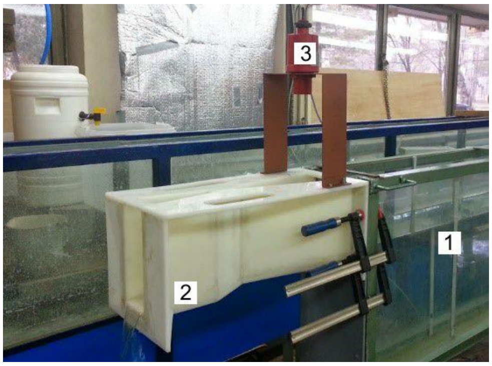

Figure 2. Laboratory Structure Scheme
1. Channel, 2. Parshall flume, 3. Ultrasonic transmitter

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 Parshall flume back to the reservoir.
For steady flow Q under free flow conditions in the flume measured 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 NIVELCO ultrasonic transmitter EasyTREK SPA-380-4, accuracy of ±(0.2 % of measured distance +0.05 % of range). Water volume was defined by measuring the weight and temperature of the water. Water weights of 2-12 kg were measured by a weighing scale of 5 g accuracy and weights of 14-230 kg by scale of 100 g accuracy.
Flowrate measurement errors were calculated by using the following equation [12]:

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

Where Q_i is the flowrate calculated as a function, while Q_m is the measured value of the flowrate.

3. RESULTS

Figure 3 shows the measurements of eight flows with five repetitions. During measurements, water temperatures varied between 11.5 and 16 °C.

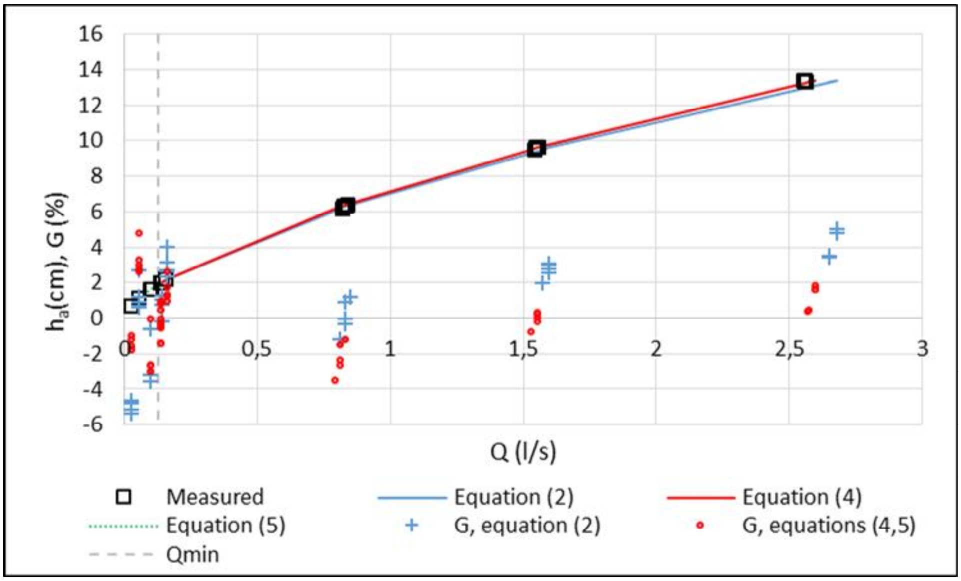

Figure 3. Measured results, equation (2), (4), (5) curves and their errors

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

4. DISCUSSION

For the declared flow ranges in the flumes of large sizes, Parshall's measurements are indicating error dissipation between -2.4 and +7.7%.

Earlier tests (18-24th January 2014) for this flume in declared flow range are showing errors between +4 and +7.2%. Flows calculated using equation (2) were always larger than measured flows. Reanalyzing the same measurements with the new equation, those errors of +4 to 7.2% were reduced to -1.05 to +1.23% – there is a possibility of reducing errors using alternative equation instead of equation (2).
The results of new measurements are compared with flows calculated using equation (2). For declared flow range, errors are between -1.18 and + 4.99%. They are both positive and negative. In order to reduce error dissipation, new equation is proposed:

$$Q = 0.0575 h_a^{1.5407} \tag{4}$$

With this equation the error range is from -3.46 to +1.83%.
Wider error range is caused by reducing measurement accuracy – an ultrasonic transmitter was used instead of a point gauge.
Errors for flows below Q_{min} and for original measuring profile are considered only by new tests. By using equation (2) flow error range was between -5.36 and 2.67%, while equation:

$$Q = 0.0519 h_a^{1.5119} \tag{5}$$

gave an error range between -3.02 and +4.77%. Equation (5) doesn't reduce error dissipation relatively to equation (2).
The results are indicating that equation (2) or equations (4) and (5), for water temperatures of 11.5 and 16 °C and by using an ultrasonic transmitter, have acceptable errors for the whole flow range.

5. CONCLUSION

For Parshall flume size of 25 mm volumetric measurements of flow were performed. Water level was measured by ultrasonic transmitter.
The stated goals are fulfilled: hydrograph measurement for flow range of 0 – 3 l/s is possible by equation (2) (with accuracy range of -5.36 do +4.99%) or by equations (4) and (5) (with accuracy range of -3.46 do +4.77%).
Considering water temperatures on the experimental catchment during summer period, further investigation should be performed for water temperatures above 17 °C.

ACKNOWLEDGEMENT

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КАЛИБРАЦИЈА ПАРШАЛОВОГ СУЖЕЊА ЗА МЕРЕЊЕ ХИДРОГРАМА

Резиме: *За Паршалово сужење ширине б=25 мм стручна литература даје зависност протицаја и дубине воде у сужењу за дијапазон протицаја 0.13-4.38 л/с. Волуметријским мерењем протицаја воде и нивоа ултразвучним сензором, доказано је да је мерење хидрограма за дијапазон протицаја од 0- 3 л/с омогућено једначином (2) (тачношћу од -5.36 до +4.99%), односно једначинама (4) и (5) (тачношћу -3.46 до +4.77%), при температурама воде од 11.5 до 16 ºЦ.*

Кључне речи: *грешка мерења, калибрација, Паршалово сужење, непотопљено течење, ултразвучни сензор*