VOLUMETRIC MEASURING OF SEDIMENTS IN A TRANSPORTABLE PRISMATIC CHANNEL

Martin Mundo-Molina[1]

ABSTRACT

Teaching the transporting mechanics of sediments in the civil engineering undergraduate program is not an easy task. It is difficult to achieve the following objectives: transmit theoretical concepts and empiric equations to students in order to motivate them to have interest in these matters and make use of knowledge. Thus, the combination of theory, practice and measurements in the laboratory are necessary. The vast majority of public universities of Mexico lack laboratories for this objective, so in the Research Centre of Engineering Faculty of Chiapas State University (UNACH by its acronym in Spanish) was designed a transportable prismatic channel (CPPV by its acronym in Spanish) which is used to teach and achieve the aforementioned objectives. In this paper, the constructive process for the channel is presented as well as the methodology used to teach the volumetric sediment measurement in the CPPV.

Keywords: Volumetric Measurement of Sediment, Sediment Transport, Transportable Prismatic Channel, Measurement of Sediment in Laboratory.

[1] Engineering Faculty, Chiapas State University, Mexico

INTRODUCTION

One of the serious problems of provincial universities in Mexico is the lack of economic resources to acquire the necessary equipment for their laboratories. Thousands of students of the open channel hydraulics class in the civil engineering degree program receive theoretical classes in a traditional way (blackboard hours). The academic program of the Faculty of Engineering (FI by its acronym in Spanish) of the UNACH contains the class "open channel hydraulics", whose thematic content is: theoretical concepts and principles, specific energy and critical regime, rapidly varied flow, uniform flow, hydraulic transitions and the principles of sediments transport. The last topic is not usually studied for three reasons: lack of training of teachers in this subject, lack of time (especially in the so-called short semesters) and because there is no infrastructure for the student to experiment and analyze: the initiation of sediments transport, the mechanics of their transport, bed forms and the scour phenomena. Thus, the properties of the sediments particles and their main characteristics can be explained on the blackboard without major effort; however, the issues of sediment transport, forces and velocities that occur in the movement of particles, tractive force, resistance to flow, bed forms, flow regimes, transport, movement mechanics, and the criteria for sediment quantification require a greater effort because students fail to internalize the concepts without experimentation. For these reasons the academic objectives are not achieved, meaning that the student does not appropriate knowledge through the internalization of concepts and their materialization through visualization and experimentation. This is why the aim of this investigation is not only to demonstrate the methodology of the construction of a CPPV, but also describes the methodology for volumetrically estimating the amount of sediments that transport a stream in order to later develop semi-empirical or empirical equations that allows for the quantification of the volume of sediments transported by water.

BACKGROUND

The emergence of physical modeling as a scientific topic forms part of the solution which responds to theoretical limitations (Lopardo, 1995). The development of physical models and the construction of artificial channels in laboratories allows for the solving of many problems that theory is not capable of solving, either due to their mathematical complexity or lack of computational tools and computing power. However, by 1950 the appearance of computers and the application of numerical methods marked the beginning of the weakening of hydraulic experimentation in research centers. Thus, in the early 80's, the mass production of personal computers, costing less and less money, furthered the possibilities of these calculation methodologies. Experimentation in public and private universities declined. At present, hundreds of schools or faculties (especially those in the province) that teach civil engineering and / or water sciences in Mexico do not have a hydraulics laboratory. Concerned by this problem, the Research Center (RC) of the FI of the UNACH, Mexico, designed and built an economic prismatic channel, with a rectangular cross section and variable slope with the objective of carrying out hydraulic experiments which include the transport of sediments in order to improve teaching and promote investigation. The materials and methods used to construct the CPPV and a technique for the volumetric measurement of the sediments in the laboratory are presented below.

MATERIALS AND METHOD

Materials

The materials that were used to build the CPPV were the following (Mundo, 2014): tubular metal with a rectangular profile (PTR by its acronym in Spanish), 10 cm wide and 5 m long, to build the base (photos 1); hydraulic jack to change the slopes of the CPPV (photo 2); acrylic sheets to build the walls and the bottom of the channel (photo 2); two tripods constructed with three piece of steels of 3 inches diameter in order to support the weight of the channel (photo 2); volumetric tank that serves not only as "reference model" for validate Q but also as a deposit "water intake" for the circulation of the flow rate (Q) into the CPPV (photo 3); 4 HP gasoline pump (photo 4) with 2 inches diameter of output to drive water from the deposit "water intake" to the CPPV and to circulate the flow in a closed system. Once the CPPV was designed, it was built as shown in photos 1 and 2.

Photo 1. Metallic PTR for the base of the channel (Prepared by the author, 2018)

Photo 2. Hydraulic jack, tripods and energy dissipation tank (Prepared by the author, 2018)

Photo 3. Calibrated volumetric tank (Prepared by the author, 2018)

Photo 4. 4 HP gasoline pump (Prepared by the author, 2018)

METHOD

Thus, once the CPPV was built the volumetric tank shown in photo 3 was calibrated. The calibration curve is shown in figure 1. With this curve, the flow rate of the CPPV can be estimated using equation (1).

$$Q = \frac{V}{t} \quad (1)$$

Where Q is the flow rate (l/s), V is the volume (l) and t is the time (s).

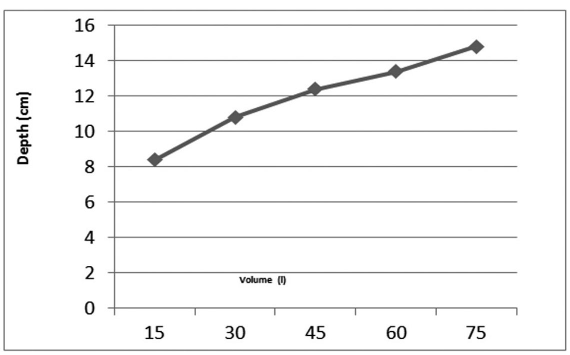

Fig.1 Calibration curve (Prepared by the author, 2018)

Subsequently, 1 .2 m^3 of silt from the Grijalva River was collected (located 12 km from the RC of the FI of the UNACH). The sediment that was collected is inorganic silt with an approximate diameter of 0.004 mm that was transported to the soil mechanics laboratory of the UNACH where its submerged specific weight was estimated to be 1200 kg/m^3. Before placing the silt in the channel, the CPPV was weighed with a mechanical scale. Its weight was 110 kg. Subsequently, a uniform layer of silt 10 cm thick was spread over the base of the CPPV's entire 5 m length and 9 cm width (photo 2). The weight of the soil mass (W) of the extended layer, according to equation 2, was 54 kg.

$$W=\gamma V \quad (2)$$

Where W is the weight of the soil mass in kg, γ is the specific weight of the soil in kg/m^3 and V is the volume in m^3. Thus the total weight of the CPPV and the extended silt is 164 kg. Once the CPPV and the extended layer of silt were weighed, a flow rate of 3.5 l/s was circulated through the CPPV to empirically estimate Manning's "n" using the following equation:

$$n = \frac{A_h R_h^{0.666} \sqrt{S_o}}{Q} \quad (3)$$

Where Q is the flow rate m^3/s, Ah, is the hydraulic area in m^2, Rh is the hydraulic radius in m, and So is the slope of the CPPV. The "n" obtained was 0.034. This value is consistent with the equation of Maza et al (1986, 1996):

$$n = \frac{D_m^{\frac{1}{8}}}{16.27} \quad (4)$$

Where D_m is the mean diameter of the sediment. The lost sediment was replaced and then a flow rate of 3.5 l/s for 8 continuous hours was circulated in the CPPV. The average velocity of the flow was 0.66 m/s. The velocity curve is presented in Figure 2.

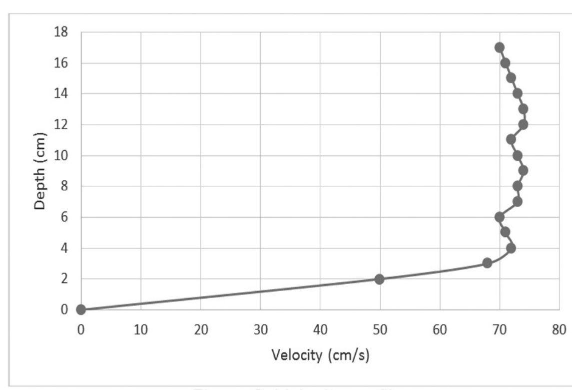

Figure 2. Velocity profile (Prepared by the author, 2018)

During this period of time, an intense sediment transport (biphasic flow) was generated that allowed to observe: beds form, transport mechanics, slight scouring in the head of the CPPV, as well as the transport and accumulation of sediments (by suspension, saltation and depositing) in the volumetric tank shown in photo 3. The hydraulic and geometric data of the experiment were as follows: Q = 3.5 l/s, n = 0.034, b = 0.09 m, S_o = 0.05. The total amount of sediment (suspension plus bottom deposits) transported by the CPPV during 8 continuous hours was: V=0.008325 m^3. This volume was collected in the volumetric tank of the CPPV shown in photo 3. Thus, according to equation 2, this volume corresponds to a weight W = 9.991 kg, which means that an average layer of 1.85 cm thick was lost in the whole extension of the CPPV that corresponds to 18.5% of the original thickness of 10 cm. For this reason the final weight of the CPPV with the silt, after the realization of the experiment, was 154.10 kg, which is consistent with the described estimates.

CONCLUSIONS

The following objectives were obtained: the traditional teaching of the mechanical transport of sediments in the civil engineering undergraduate program of the FI of the UNACH was overcome. Not only were the theoretical concepts of sediment transport transmitted, but they also implemented and observed the phenomenon in practice. This was achieved by building a transportable variable slope prismatic channel. Thus, in this paper was presented the constructive process of the CPPV (patent pending) and the methodology used to teach the mechanics of sediment transport and it volumetric measurement. In order to achieve the final objective, a layer of 10 cm thick inorganic silt from the Grijalva River was placed in the CPPV, then was generate a flow rate in the CPPV of 3.5 l/s with a slope So = 0.05 and an average velocity of 0.66 m/s associated with a n = 0.034, whereby an estimated volume of 0.008325 m3 of sediment was collected and measured in the CPPV volumetric tank. The total sediment transported during the 8 hours of the experiment represents a thickness of 1.85 cm (loaded in its two phases: monophasic and biphasic).

It is suggested that at a later date the results of these experiments are used to develop empiric and semi-empiric equations to quantify the volume of transported sediments, both in suspension and settled. Finally, it is suggested that a thematic area called "Teaching and training in sediment management" is included in the "7th International Symposium on Sediment Management", in order to promote teacher training in the subject of "transport and sediment management".

REFERENCES

Lopardo, R. (1995). La formación del ingeniero hidráulico para el siglo XXI. Revista Ingeniería del Agua, vol. 2, no.4, pp.67-76.

Mundo, M.M. (2014). "Diseño y construcción de una canal económico en el laboratorio de hidráulica de la Facultad de Ingeniería de la UNACH. Congreso Latinoamericano de Hidráulica, Santiago de Chile.

Maza A. J. A., García Flores M. (1986). Distribuciones de los tamaños de los sedimentos del fondo en cauces naturales. Memorias del XII Congreso Latinoamericano de Hidráulica, volume 3, pages 104 to 109, Sao Paolo, Brasil.

Maza, A. J., García, F.M. (1996). Manual de Ingeniería de Ríos. Series del Instituto de Ingeniería de la UNAM.