Flow Measurement and Instrumentation 49 (2016) 40–45

Contents lists available at ScienceDirect

Flow Measurement and Instrumentation

journal homepage: www.elsevier.com/locate/flowmeasinst

New technique for continuous monitoring of sediment height

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ARTICLE INFO

Article history:
Received 7 September 2015
Received in revised form
30 March 2016
Accepted 3 April 2016
Available online 4 April 2016

Keywords:
Deposit
Continuous monitoring
Ultrasonic device
Water-sediment interface

ABSTRACT

A sewer deposit is a complex mix of minerals and organic materials whose dynamics remain difficult to ascertain. One way to improve the knowledge held on sewer processes consists of obtaining detailed long-term measurements. This paper will present the technique developed for long term monitoring of sediment height within a combined sewer. The aim of this device is to acquire long-term records of the sediment height evolution. The current state of the art is discussed and the technical constraints are exposed. Next feasible technical choices are explained and then results are provided and discussed.

1. Introduction

For many years, it has been recognized that waterways and receiving waters are often adversely affected by urban stormwater runoff, primarily due to the sweeping and transport of sewer deposits by stormwater into nearby storm drains and waterways. Excessive sediment deposition in sewers can also cause several problems, including increased maintenance and safety costs. Moreover [1], explained that preventing sedimentation is key to enforcing the NF EN 14654-1 [2] Standard, which introduces the notion of network performance and explicitly states that facility managers should avoid sedimentation [22,23]. offers a manager's point of view in presenting a number of devices currently used to clean channels plus a new prototype. These methods however remain curative.

Moreover, it is recognized that a sewer deposit is a complex mix of minerals and organic materials whose dynamics remain difficult to ascertain, to an extent where the transport formulae, developed mainly for river sediment, still lack accuracy [13]. Delleur [12] and Ashley et al. [4] argued that one way to improve knowledge of sewer processes was to obtain detailed long-term measurements, through admitted that the appropriate set of techniques were unavailable.

IFSTTAR (Institut français des sciences et technologies des transports, de l'aménagement et des réseaux) has undertaken research aimed at assisting networks managers by investigating the hydraulics and solid transport occurring in urban sewer networks. "SER" (French acronym for Solids In Network) was a national project lasting from 2009 to 2012 and involving various teams from both the Technical and Scientific Network within the Ministry of Sustainable Development and GEMCEA (a Research Federation of experts in water research operations), intended to enhance the state of knowledge in sewer solid dynamics and characteristics, ranging from biofilms [15,21] to the existence of lutocline in sewers [14] and even to ultrasonic investigations [10].

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2. Design framework and technical choices

Delleur [12] pointed out that better knowledge of sediment dynamics was required to improve urban drainage. Moreover he cited the case of cohesive deposits. This remark was corroborated by Ahyerre et al. [3] and Oms et al. [19], who showed that a highly organic layer exists above the sandy sediment in a combined trunk in Paris (France). Banasiak [6] and Banasiak and Verhoeven [8] investigated the influence of a partially cohesive material, while Banasiak et al. [7] explored the biological influence on sediment erodibility once Oms [19] had shown that parts of sediments could be extracted by the flow when erosion reaches a given value. Simply the literature showed the importance of sedimentary processes in urban networks, although the current metrology is thin.

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http://dx.doi.org/10.1016/j.flowmeasinst.2016.04.005
0955-5986/

Prior to developing any technique, a list of technical specifications had to be established. The focus is first and foremost to continuously monitor sediment height in a combined sewer in order firstly to increase the existing knowledge on deposit dynamics and latter to propose to sewer authorities tools to manage the cleaning of the sewers. This is a great challenge because, for example in Nantes, 2500 t have to be removed from the sewers whereas the available techniques are a hard task for the workers [22] that have to work in a complex context in term of safety (wastewater, explosive atmosphere, …). Taking into account the results of Oms et al. [19], sediment is defined as the deposit that remains immobile as long as the bottom shear stress lies below a threshold about 0.4 N/m^2. This definition encompasses the Crabtree type A sediment [11], the so-called near-bed solids, and fluid sediment [4]. Continuous monitoring must be performed at a "point" in order to distinguish between variations due to sediment dynamics and variations due to sensor movement above the bottom patterns. The point is defined as the geometric place circumscribed inside a 0.1-m radius circle located in the mean flow cross-section of a sewer trunk whose maximum vertical height equals h_m. To investigate the solid dynamics, the screening time step should be set as short as possible. The recording step may be adjustable in order to balance between deposit dynamic, storage capacity and energy supply. Moreover, the device must be operated in a corrosive and confined environment in order to comply with ATEX directives 1999/92/EC and 94/9/EC (applicable to explosive atmospheres including with the electrical directives regarding safety extra-low voltage (SELV). Moreover, sanitation regulations have to be respected and the prototype should obviously generate as little nuisance as possible to the sewer authority.

Various set-ups were presented in the literature. Oms et al. [19] observed erosion patterns and noted a maximum recording process autonomy of 72 h. Lawler [18] and Sottolichio et al. [24] introduced vertical gauges into the deposit, although preliminary tests indicated that these were very sensitive to clogging, hence unsuitable for use in continuously monitoring deposit in sewers. White [25] and Widdows et al. [26] investigated various devices in coastal situations yet found them inconvenient for the confined sewer environment. Earlier, Laplace et al. [16] developed an attractive ultrasonic device but it no longer exists. Recently, Bassoullet et al. [9] along with Palinkas et al. [20] presented a number of devices, though none was available when our project started up over 5 years ago.

Herein, a system called *Furrina* was introduced. The measurement protocol must be as non-disruptive to the flow as possible, so as to avoid clogging and avoid contact with the sediment. Three options were considered:

- from the roof: this could theoretically be performed using a green laser beam ($520 < \lambda < 560$ nm, where λ is the wavelength); due to the suspended solids concentration however, beam energy must be high, which in turn could cause safety risks for workers assigned to maintain the sewer;
- from the bottom: the idea was to set-up a tomographic array on the invert, but this step created considerable disturbance for the sewer authority;
- from the free surface: this option could be carried out with an ultrasonic sensor, like the previous set-up used by Laplace et al. [16].

The third option was selected. Considering a channel whose maximum height equals h_m, the sediment height h_s can be calculated according to Eq. (1), where h_1 is the distance between the channel roof and the free water surface, h_2 the distance between the free water surface and the interface separating the deposit and the water (see Fig. 1):

$$h_s = h_m - h_1 - h_2 \quad (1)$$

Sewer geometries may vary considerably from one place to another. In Nantes (western France), combined sewer channels mainly have an oval cross-section as sketched in Fig. 1. For the largest one, the maximum height lies between 2 and 3 m with a bank (Fig. 1). This study focuses on channels that are accessible to human intervention. To comply with the measurement point definition, the diameter ϕ of the insonified circle (Fig. 1) is as:

$$\phi = 2h_2 \tan(\theta/2) \quad (2)$$

where θ is the opening angle of the acoustic beam. For $\phi < 0.1$ m; and a vertical distance h_2 equal to 3 m, θ has to be smaller than 1.9°.

To ensure that the ultrasonic device remains at the free surface as presented in Fig. 1, and to ensure its stability in the vertical plane of the measurement point it has been implemented on a raft. The measurement protocol is based on the transit time principle, i.e. the delay required by the acoustic beam to travel from the sensor to the deposit and back. Moreover, the experimental site is located in a combined sewer, thus the channel may be full and then the device would need to resist submergence for a short duration. In addition, the device must comply with the IP68 regulation (for working in submerged situations). The Marine Electronics 11001 sensor has been chosen; its main specifications (based on manufacturer's data) are summarized in Table 1.

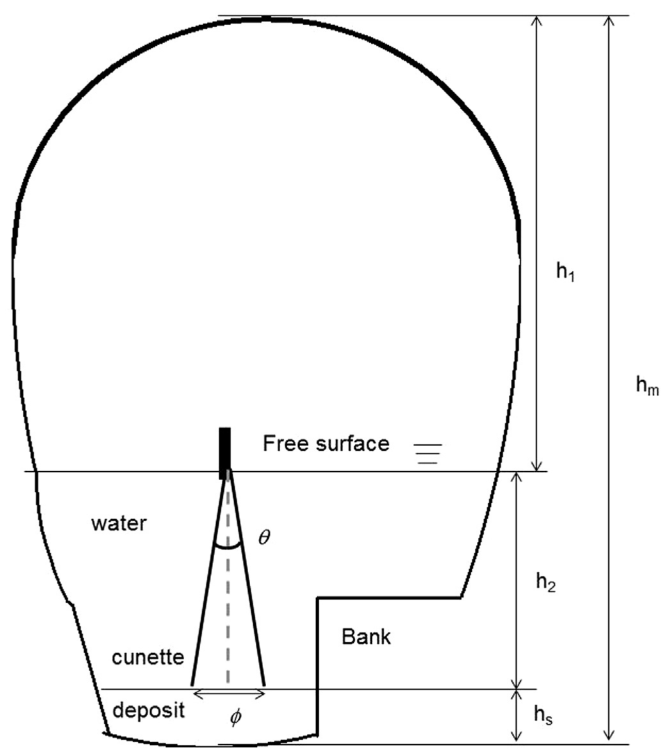

Fig. 1. Measuring principle in a sewer.

Table 1
Marine Electronics' Model 11001 Multi-Return Altimeter specifications.

Acoustic frequency:	1.1 MHz
Beam width:	1.6° (±3 dB) conical beam
Transmit pulse width:	10 μs to 1 ms in 10 μs steps
Gain:	40 dB fixed, 0–40 dB variable in 16 steps
Sample rate:	1 μs to 100 μs in 1 μs steps
Repetition (ping) rate:	0.1–10 Hz in 100 ms steps
Power supply:	15–30 V DC at 120 mA
Digital output:	RS232 at 38.4 k baud or RS485 at 38.4 k baud
Dimensions:	85 mm diameter, 165 mm length (excluding the connector)