Chapter 5: Experimental set up

All the experiments presented in this thesis were performed in a sediment flume located at the Civil and Environmental Engineering Laboratory of the Université catholique de Louvain. The set up, consisting in a glass-walled channel linked to a water re-circulation system, is illustrated in Figure 5.1.

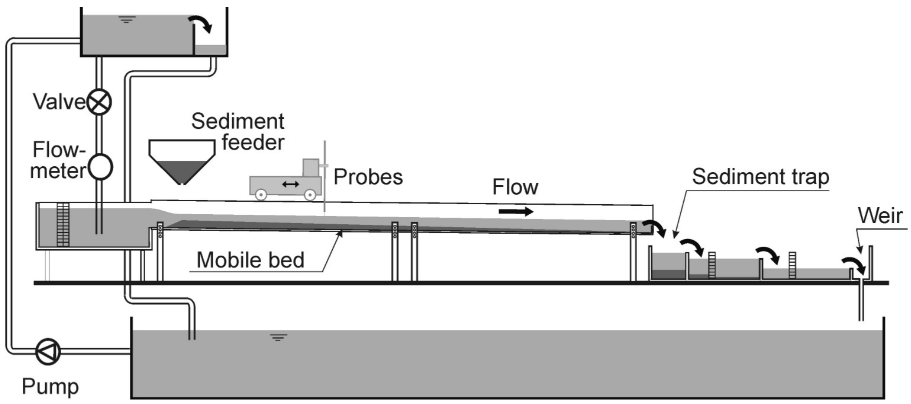

Figure 5.1. Experimental set up (inspired from Bellal et al., 1998)

5.1. The water re-circulation system

The water is stored in a reservoir located under the floor. A hydraulic pump allows a transfer of water from the lower to the upper reservoir, which feeds the upstream tank of the flume. To ensure a constant water level in the upper reservoir, it is equipped with a weir. Always the same discharge, (with a maximum of 50 l/s) corresponding to the opening of the valve upstream the pump, is introduced in the upper reservoir. A part of this discharge, arriving in the upper reservoir, feeds the flume and the complementary part flows over the weir and returns in the downstream tank. The water discharge entering the flume is regulated with a valve and measured with an electromagnetic flow-meter (ABB-MAG-XE) with a precision of 0.25 %.

5.2. Upstream and downstream tank

The water discharge is introduced in the tank located at the upstream end of the channel. The upstream tank is fitted with blocks dissipating energy in order to smooth the water surface. The reservoir is organised to ensure the symmetry of the flow at the entrance of the flume. Moreover, honeycomb are disposed at the entrance of the flume to ensure the fluid filaments are parallel, in some cases, a floating panel is placed to avoid waves at the water surface (Fig.5.2).

Figure 5.2. Floating panel at the upstream end of the flume

At the downstream end of the flume, the water flows in the downstream tank, where is located a pierced basket, which stops a part of the sediment carried along by water. Then, the water flows through a labyrinth composed of successive weirs and blocks in order to dissipate energy and trap the sediments still in suspension. Finally, water flows over a triangular weir and returns in the reservoir located under the floor. A grid is fixed on the weir in order to stop the remaining sediments or floating objects. The maximum water discharge to avoid overflowing in the downstream tank is 40 l/s.

5.3. The flume

The flume is divided in 8 assembled reaches of 0.95 m long, it can be converted by replacing some pieces by non-linear, reduced or enlarged section elements. In its original configuration, the flume is 7.6-m long and

0.5-m wide, the walls, made of glass, are 0.45-m height. The slope of the flume can be adjusted from 0 to 5 % by step of 1 %. Nevertheless, to modify the slope is quite tedious, it makes necessary to separate the flumes in two parts, which have to be re-assembled after the slope has been adjusted, paying attention that the modified junctions are watertight. A weir is located at the downstream end of the flume allowing to regulate the water level, the weir can be moved to obtain an overflow, an underflow or both together. The downstream water level can be adapted during the experiment.

5.4. The sediment supply

5.4.1. Sediments properties

The sediments used are identical for all the experiments described in this thesis. The sediments are coarse, the grain-size distribution (according the norm NBN B11-013) is reproduced in Figure 5.3.

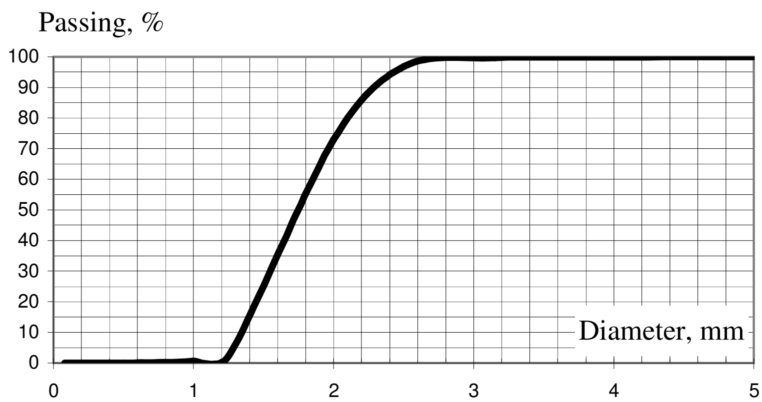

Figure 5.3. Grain-size distribution

The characteristic grain diameters are $d_{16} = 1.4$ mm, $d_{50} = 1.65$ mm, $d_{84} = 2.2$ mm, $d_{90} = 2.35$ mm, the grain volumetric mass is $\rho_s = 2633$ kg/m³ and the porosity is $\varepsilon_0 = 0.43$. The uniformity criterion for a sand sample based on the Raudkivi formulation writes

$$\sigma = \sqrt{\frac{d_{84}}{d_{16}}} \leq 1.35 \tag{5.1}$$

In the present case $\sigma = 1.25$, as the uniformity criterion is respected, the sediments are reasonably considered as uniform.

5.4.2. Sediment feeder

The flume is fitted with an upstream sand feeder (Fig. 5.4) supplying dry sediments at a constant rate. The position of the sediment feeder can change as its structure not fixed. A vibrating system is fixed to the sill in order to facilitate the fall of sediments. The level of vibration (between 0 and 5) can be chosen in order to obtain a wider range of solid discharges. The constant solid discharge introduced in the flow depends on the opening (pierced steel sheet) at the outlet of the silo. For the sediments described above, the available solid discharges are given in Table 5.1.

Opening	Vibration level	Solid discharge (kg/s)
10 Ø12 mm	0/5	0,231
5 Ø12 mm	0/5	0,115
10 Ø10 mm	3/5	0,102
5 Ø10 mm	3/5	0,048
5 Ø10 mm	2/5	0,045

Table 5.1. Solid discharges supplied by the sediment feeder

For the opening corresponding to the largest diameter, the solid discharge is not influenced by the vibration level. Moreover, in all cases, the provided solid discharge revealed to be independent of the level of sand in the silo.

There is no re-circulation of sediments, once they arrive in the downstream tank, where they settle, they have to be manually picked up, dried and re-introduced in the sediment feeder. As this procedure takes a long time, the duration of an experiment is limited by the amount of dry sediment available.

Figure 5.4. Sediment feeder

5.5. Water and sediment level measurements

A trolley is allowed to move along the flume on rails fixed at the top of the side glass walls. The trolley is fitted with a potentiometer allowing to know its position and with two probes measuring the bed and the water levels (Fig. 5.5).

Figure 5.5. Trolley fitted with the ultrasonic probe (on the left) and the bed profiler (on the right).

One of the probes is an ultrasonic probe (Keyence, head UD-020, controller UD-500) allowing to measure the water level. An ultrasonic wave is emitted from the probe, the distance between the water surface and the wave emitter can be deduced from the measurement of the time taken by the wave to reflect and return to the emitter. Without any intrusion in the flow, the probe measures the level of a surface with a precision of 0.1 mm when it is located in a range of 0.1 m to 0.2 m from the concerned surface. In this range, the linearity between the measured voltage and the level is ensured. The angle between the measured surface and the plane perpendicular to the probe axis should not be too important. In order to be able to catch the reflected signal, this angle should be lower than 10° (depending on the distance from the target). As the celerity of the ultrasonic wave depends on the temperature of the air, the probe is connected to a temperature gauge. If the situation does not respect the range in distance or angle, the measurement is not recorded.

The other probe is a profile indicator (Delft Hydraulics PV-09), allowing to measure the water level or the sediment level. The measurement is based on conductivity variations. The probe is constituted of a thin and long rod containing a cylinder electrode. A second electrode has to be introduced in water, in contact with the measurement area. Starting from a reference elevation, the probe is programmed to measure the water level, the rod is lowered into the water by a motorised mechanism. When the probe enters the water, a contact between the two electrodes is established due to the important conductivity of water. Then, the distance covered by the rod is recorded allowing to find the water level. If the probe is programmed to measure the bed level, the rod does not stop going down when a contact is possible between the two electrodes. Instead, it stops when it arrives in a material, in this case the saturated sediments, having a conductivity different from water. Identically to the water level, the bed level is deduced from the covered distance. The precision of the level measurement is about 1 mm, the main drawback of this method is the intrusion of the rod in water, which perturbs the flow. Moreover, when the water velocity is too important, being not rigid enough, the rod is deformed.

In order to obtain the water and bed levels at the same place and the same time, the water level can be measured by the ultrasonic probe while the bed profiler is measuring the bed level. Both probes are aligned along the width on the trolley (Fig.5.5), their position along the flume is given by the potentiometer.

5.6. Acquisition device

The two probes, the potentiometer and the electromagnetic flow-meter produce a voltage reading. To record the measured voltages, the devices are connected to a computer equipped with a data acquisition card (National Instrument PCI 6023 E). A software using LabView computational language was developed by the staff of the laboratory. It records the measurements and converts them in physically correct units.

5.7. Digital imagery

A digital camera video (Dalsa DS21-01M150) is used to film the flow in a square frame of 1024 / 1024 pixels, at the maximum rate of 150 frames per second. The size and the acquisition rate can be adapted to the problem. If one of the dimensions of the flow to film is predominant, the frame can be reduced in the other direction. If the flow is submitted to rapid variations (e.g. dam break flow), the acquisition rate has to be important, which is not the case if the flow varies slowly. More the frequency of the acquisition and the size of the images are important, lower can be the duration of the movie due to the limitation in memory space. The images are filmed in grey scale, each picture is translated in a matrix, each number in the matrix corresponding to the colour of one pixel. On the basis of these data the interfaces between the bed and the water and/or the water and the air can be semi-automatically located (Spinewine and Zech, 2002). First, the area of the picture where the chosen interface is located is isolated. Then each row of the matrix is analysed and the interface is located on the basis of the variation in grey level. A threshold value is imposed, only the pixels having with its neighbours a difference in grey level higher than this threshold value are recognised as points of the interface. As graduations were filmed as a calibration reference, it is possible to determine the size of one pixel and to deduce the bed and water levels. The precision depends on the size of the pixels. The detection of the bed level is exemplified in Figure 5.6, in this case a pixel represents 0.8 mm, the white points correspond to the pixels recognised as points pertaining to the interface because they correspond to an important change in grey level.

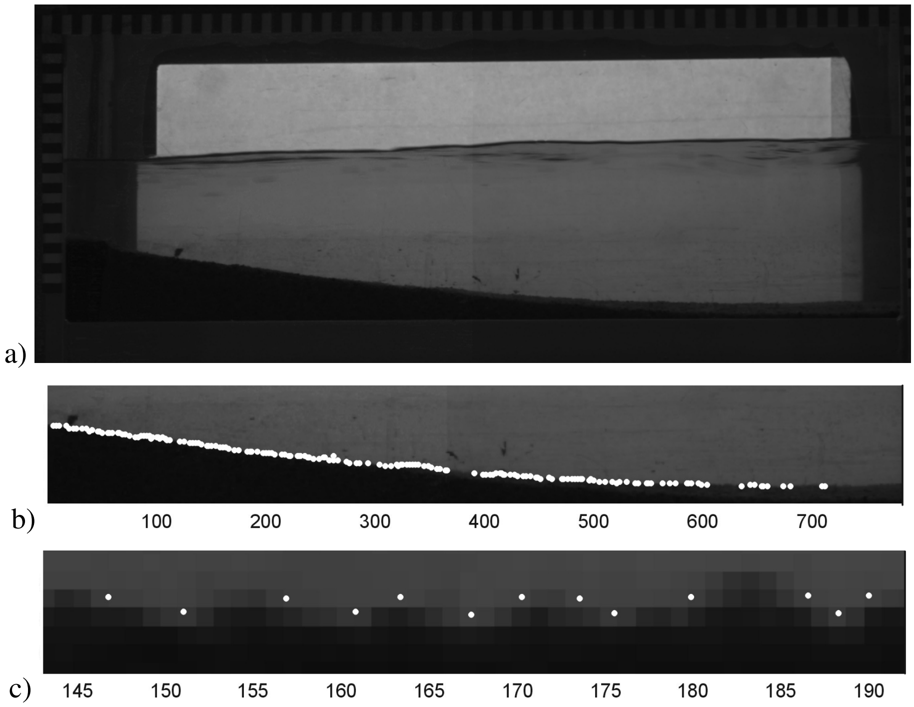

Figure 5.6. Digital imagery technique, exemplified in the case of a erosion hole: (a) Image taken by the digital camera, (b) white points located at the interface (c) zoom of the interface (abscissa in pixel)