Discussion of "Gate and Vacuum Flushing of Sewer Sediment: Laboratory Testing" by Qizhong Guo, Chi-Yuan Fan, Ramjee Raghaven, and Richard Field

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The paper under discussion represents a valid experimental contribution to the description of the hydrodynamic and sediment transport processes determined by flushing operations in sewer channels; the data derived by the authors from the described laboratory experiments can be usefully adopted for the validation of numerical models specifically developed for the simulation of the effects of flushing waves on sewer deposits.

This discussion mainly concerns the influence of the laboratory setup adopted by the authors for the experiments. For both the tested flushing devices, the authors analyzed the sediment scouring as a function of the initial water depth in the flume over the sediment bed; in particular, a decreasing of the weight of the flushed sediments was pointed out as the initial water depth increased.

From a general point of view, the discussers agree with this statement, but they are somewhat puzzled about the adequacy of the authors' setup for the experiments. In particular, experiments were carried out inserting a fixed weir downstream of the sediment bed. In the discussers' opinion, from the experimental viewpoint, the use of a downstream weir certainly results as something useful in setting the initial water depth in the flume; nevertheless, depending on the characteristics of the flush and of the sediment, the weir can significantly modify the hydrodynamics and the sediment transport processes during the flushing operation. Consequently, the adoption of such a system setup makes it difficult to distinguish the effects due to the weir from the effects due to the initial water depth in the flume on the decreasing of the flushed sediments.

Laboratory experiments on this subject have been recently carried out by the discussers at the Laboratory of Hydraulics, of the *Dipartimento di Ingegneria Civile e Ambientale* (DICA) of the University of Catania, Italy (Campisano et al. 2004b). The experimental setup was made up of a 3.90-m-long flume with a rectangular 0.15×0.37 cross section, plexiglass sidewalls, and bottom slope set equal to 0.145%. A stainless steel flushing gate (lifting gate) was inserted in the upstream part of the flume and used to generate the flushing waves.

The effect of the presence of a downstream weir was analyzed by means of some specific experimental tests. In particular, a 0.03-m-thick volcanic sand bed (density $\rho=2850\ \mathrm{Kg/m^3}$) was placed into the flume starting from 0.30 m downstream the flushing gate; two different almost uniform sand sizes (ranging between 0.18 and 0.25 mm and between 1.18 and 2.00 mm) were used and tested separately. Moreover, two different kinds of flushes, obtained for different values of the water head upstream the gate h_{up} (0.20 and 0.35 m), were generated; in particular the removal effects of successive flushing waves were analyzed.

A 0.06-m-high weir was positioned downstream (in order to set the value of the initial water depth in the flume) and two different experimental conditions were compared; the first condition (Condition I) was to place the weir fixed at the flume end for the whole flush duration, while the second one (Condition II) was to remove instantaneously the weir in correspondence of the flush wave arrival.

From the experimental point of view, the observation of the hydrodynamics of the phenomena connected with the flush propagation has clearly pointed out differences between conditions I and II. In particular, relevant backwater effects were generated for Condition I at the weir section influencing the transport processes over the sediment bed, while the quasi-undisturbed downstream propagation of the flushing wave was observed for Condition II.

Some of the experimental results are reported in Figs. 1 and 2 in terms of cumulative sediment weights W scoured out of the flume at the end of the nth flush, for both Conditions I and II and for the two values of h_{up}. As can be observed, the presence of the fixed weir significantly reduces the sediment weight scoured out of the flume for each flush.

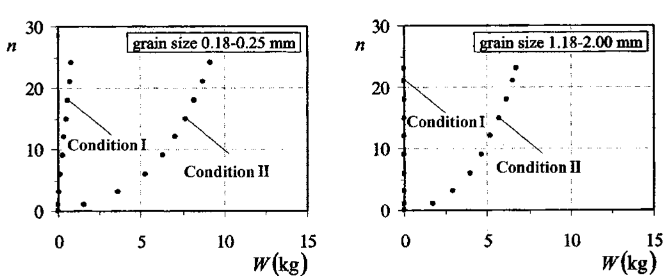

Fig. 1. Experimental scoured sediment weights W after n flushes for $h_{up}=0.20$ m

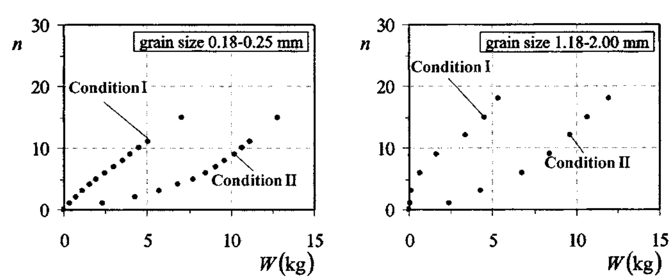

Fig. 2. Experimental scoured sediment weights W after n flushes for $h_{up}=0.35$ m

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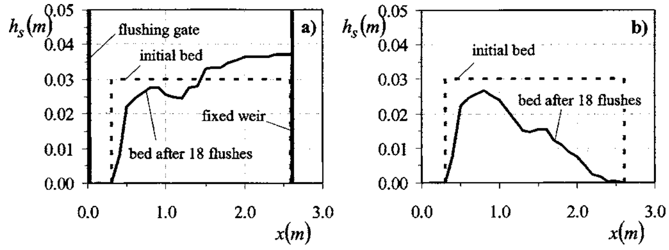

Fig. 3. Influence of downstream weir on sediment bed profiles [comparison for $h_{up}=0.20$ m and grain size 0.18–0.25 mm between (a) Condition I and (b) Condition II after flush $n=18$]

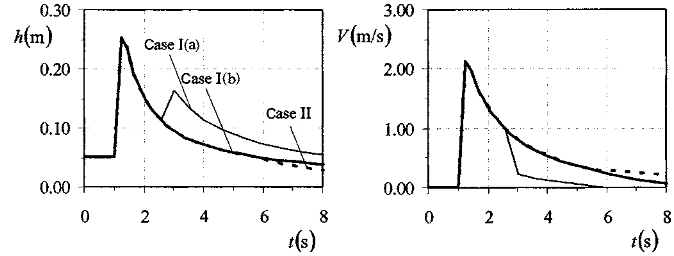

Fig. 5. Water depth h and flow velocities V at sediment bed final section for $h_{up}=0.864$ m

Furthermore, as expected, results show that the differences between the two test conditions decrease as the sediment size becomes smaller and as the upstream water head upstream the gate increases; in fact, for the higher water heads and for the finer sediments, the suspended-load transport is not negligible and allows the sand to overpass the fixed weir. Differently, larger differences between Conditions I and II are obtained for the lower upstream water head and for the larger sediment size; in these situations, in fact, the sand was observed to be transported mainly as bed-load with obvious influence of the fixed weir on the transport processes (sediment blockage and accumulation upstream the weir). The weir influence is clearly shown in Fig. 3, where sediment bed profiles after flush $n=18$ relative to Condition I [Fig. 3(a)] and Condition II [Fig. 3(b)] are compared for $h_{up}=0.20$ m and grain size 0.18–0.25 mm.

The hydraulic influence of the fixed weir downstream was also analyzed numerically. In particular, simulations of the hydrodynamic processes connected with the flushing operations were performed by the discussers. For this purpose, a numerical model already validated in previous works (Campisano et al. 2004a) was used. The model is based on the solution of the fully dynamic De Saint Venant equations and adopts the TVD-McCormack numerical scheme (Garcia-Navarro and Saviron 1992; Garcia-Navarro et al. 1992), which is a "shock-capturing" scheme that has been recognized as suitable for flushing simulations (Bertrand-Krajewski et al. 2004).

The simulations concerned the experimental hydraulic conditions of the authors' system; in particular, a downstream weir was simulated with an initial water depth equal to 0.051 m. According to the authors' setup, a flushing gate was also considered in the upstream part of the flume and two different values for the initial gate water head ($h_{up}=0.445$ m and $h_{up}=0.864$ m) were taken into account. The propagation along the flume of single flushes determined by the flushing device was analyzed considering the downstream weir Conditions I and II. Differently from the authors' conditions, the instantaneous removal of the upstream flushing gate ("dam-break" condition) was simulated.

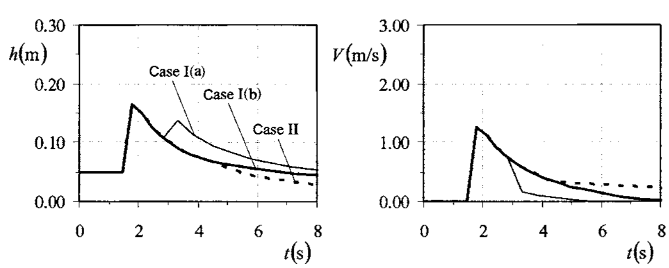

Fig. 4. Water depth h and flow velocities V at sediment bed final section for $h_{up}=0.445$ m

The results of the simulations are reported in Figs. 4 and 5; the figures show water levels and flow velocities in correspondence of the final section of the bed deposits, for three different cases:

1. a. Downstream weir fixed 3.50 m far from the flushing gate (representative of the authors' setup);
   b. Downstream weir fixed 7.00 m far from the flushing gate; and
2. Downstream weir located 3.50 m far from the flushing gate and removed in correspondence of the flush passing.

The figures point out that the fixed weir significantly affects the propagation of the flushing wave by generating additional up going waves and reducing the average flow velocities. As expected, this influence results much more evidently as the fixed weir is located closer to the flushing gate and as the upstream water head decreases. Differently, the backwater effects caused by the downstream weir results are clearly negligible when removing the weir in correspondence of the flush passing.

Globally, the obtained laboratory and numerical results allow the discussers to point out that, depending on the characteristics of the flush and of the sediment, the use of a fixed weir can significantly affect both the hydraulic and the sediment transport processes during the flushing experiments.

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Closure to "Gate and Vacuum Flushing of Sewer Sediment: Laboratory Testing" by Qizhong Guo, Chi-Yuan Fan, Ramjee Raghaven, and Richard Field

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The discussers' expanded research work on effects of the downstream weir on hydrodynamics and sediment transport is valuable and appreciated. However, the discussers measured the amount of the flushed sediment differently from the writers, and the discussers' results cannot be directly used to compare with those of the writers. The writers' laboratory tests were already designed to exclude the artificial weir effects, and closely duplicate the actual sewer sediment flushing process.

It appears the discussers overlooked the role of the acrylic sheet that was placed immediately upstream of the weir at the downstream end of the flume during the writers' laboratory experiments. Sediment flushed from the upstream portion of the flume onto the downstream acrylic sheet and beyond was defined as the flushed sediment, including that blocked by the weir. That is, all the flushed sediment, both as bed and suspended loads, were accounted for in the writers' laboratory tests. In contrast, the discussers measured only the amount of the sediment that bypassed the weir, mostly as suspended load.

The weir did reflect a portion of the initial, downstream-progressing, positive flushing water wave. However, the wave reflected by the weir at the downstream end of the flume was reflected back at the upstream end of the flume. Therefore, net longitudinal transport of the sediment, if resuspended by the reflected waves, was insignificant in comparison to the flushing of the original bottom sediment by the initial, relatively strong, downstream-progressing, positive wave.

In the discussers' laboratory experiments, instantaneous removal of the downstream weir possibly resulted in an artificial, rapid draining of water from the flume and artificially increased the sediment removal. The discussers' Fig. 3 appears to show the effect of artificial draining on the sediment removal as the depth of the bottom sediment decreased toward the downstream end. The discussers' Fig. 3 also appears to show that the amount of the flushed sediment, defined in the writers' laboratory tests as that actually moved by the initial flushing wave from the upstream portion of the flume, remained essentially the same with or without removal of the artificial weir.

In conclusion, the use of an artificial, fixed weir enabled the writers to create and maintain initial water depth in the flume, but had a minimal effect on the amount of the flushed sediment as defined by the writers.

Discussion of "Finite Volume Model for Two-Dimensional Shallow Water Flows on Unstructured Grids" by Tae Hoon Yoon and Seok-Koo Kang

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The authors should be congratulated for their interesting paper regarding the numerical model, which is based on a second-order upwind finite volume method on unstructured triangular grids applied to the shallow water equations (SWE). Because of this unstructured grid, complex geometries can be handled with ease. It is clearly an important advantage of the proposed method.

However, we would like to draw the reader's attention to a serious problem with discretization of the SWE for arbitrary geometry with a triangular grid, namely, the compatible treatment of the pressure and bed-slope terms. Unfortunately, the authors did not describe how they demonstrated the stability of their method for an arbitrary bed geometry. As described by Nujić (1995), improper treatment of the bottom slope term may lead to inaccuracies; by referring to Komaei (2004) and Farshi (2002), it is important for an unstructured grid, where the method presented in the paper could be neither compatible nor conservative. For water initially at rest, a typical instability form is a movement without physical reason after a few computational cycles. To demonstrate this outcome, consider a triangular cell according to Fig. 1 and apply the method presented in the paper.

With the authors' notation, the summation of the flux terms of the continuity equation over the cell edges on the basis of the HLL solver gives

$$\sum_{1}^{3} S_{Ri}S_{Li}[h_{Ri}-h_{Li}] \neq 0; \quad h_{Ri} \neq h_{Li} \tag{1}$$

Although there is no movement, the left-hand side is not equal to zero. The authors did not explain exactly how the linear reconstruction was applied to avoid this effect. We presented an attractive technique to prevent this "unphysical" flux (Farshi 2002; Komaei 2004). In our method, the water surface elevations have been used instead of the depths in the linear reconstruction. After interpolating the water surface elevation, the depth values at the right (R) and left (L) sides of the edge are calculated. Therefore, the strong depth fluctuations attributable to the arbitrary bed ge

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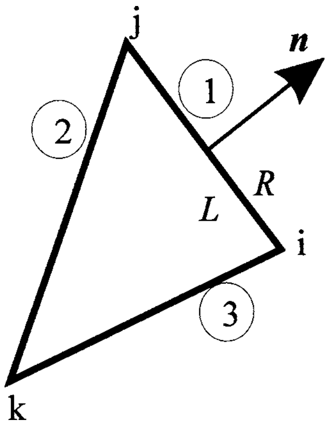

Fig. 1. Typical finite-volume cell (values in the circle show the edge number)

ometry are prevented and the calculated depths do not produce any unphysical flux.

By applying the solver according to the author's Eq. (6) to the momentum equation in the x direction, one obtains

$$\sum_{1}^{3} (\text{Flux})_x = \frac{S_{R1}(1/2gh_{R1}^2) - S_{L1}(1/2gh_{L1}^2)}{S_{R1} - S_{L1}} \cdot \Delta y_1 + \frac{S_{R2}(1/2gh_{R2}^2) - S_{L2}(1/2gh_{L2}^2)}{S_{R2} - S_{L2}} \cdot \Delta y_2 + \frac{S_{R3}(1/2gh_{R3}^2) - S_{L3}(1/2gh_{L3}^2)}{S_{R3} - S_{L3}} \cdot \Delta y_3 \quad (2)$$

The summation of the pressure terms has to be in balance with the bottom-slope term. The authors considered the source terms constant over the cell according to their Eqs. (5) and (25), which do not guarantee this balance. In a triangular cell, the slope is constant but the water depth is not. Unfortunately, the authors did not discuss this important point and just computed the cell slope on the basis of the coordinates of its vertices. Considering the depth constant over the cell, as in the paper, leads to the following relation in the x-direction:

$$\int ghS_{ox}dA = gS_{ox}\int hdA = gS_{ox}h_{\text{cell}}, \quad (3)$$

As can be seen, Eqs. (2) and (3) are not balanced in all cases.

Komaei (2004) described a novel and robust method to handle this problem. In his work, the water surface elevation was considered constant over the edges in the momentum flux computation and over the cell in calculating the bottom-source term. This gives a modified depth of the pressure term in the momentum equation for the edge i-j as

$$\frac{1}{2}gh^2 = \frac{1}{2}g\overline{\overline{h^2}} = \frac{1}{2}g\frac{h_i^2 + h_j^2 + h_ih_j}{3} \quad (4)$$

and an exact relation for the bottom-slope term as

$$\int ghS_{\text{ox}}dA = gS_{\text{ox}}\int hdA = gS_{\text{ox}}\text{Vol}_{\text{water}} \quad (5)$$

where

$$\text{Vol}_{\text{water}} = \left(\frac{h_i + h_j + h_k}{3}\right)A \quad (6)$$

These equations satisfy the compatibility condition described by Nujić (1995), and their application to practical cases agrees with measurements for both explicit and implicit schemes.

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