TURBULENT STRUCTURE OF WATER AND CLAY SUSPENSIONS WITH BED LOAD[a]

Discussion by Hubert Chanson[3]

The discusser wishes to congratulate the authors for their excellent paper. He would like to discuss some possible drag reduction effects.

The discusser has reanalyzed the authors' data assuming quasi-uniform flows at the end of the channel. For the clear-water flow experiments (runs C-1 and C-2), the data suggest an equivalent roughness height k_s of the flume (smooth plexiglass) between 0.15 mm and 0.19 mm. With these values, it is possible to compute the clear-water friction factors f for the clay-mud–flow experiments (M-1 and M-2), and to compare these values with the mudflow friction factor f_s. It is interesting to note that the clay-mud flow (runs M-1 and M-2) exhibits smaller flow resistance f_s than the clear-water flow: i.e. $f_s/f < 1$ (Fig. 18).

Other researchers observed similarly some drag reduction caused by the presence of suspended sediments (Table 4). Fig. 18 presents model and prototype data of friction factor reduction as a function of the mean volumetric sediment concentration C_v. Most data were obtained with suspended sediments without depositing material. The data of Buckley (1923) must be considered with great care as the changes in friction factor due to variation in bed configuration might be important.

Despite earlier controversies, several researchers, including the authors, observed a logarithmic velocity distribution in the inner flow region and a viscous sublayer. Chanson and Qiao (1994) suggest that the presence of sediment particles in the flow layers next to the bottom increases the density and the viscosity of the flow, and induces a thickening of the sublayer and a reduction of bottom shear stress. By analogy with dilute polymer solutions, an increase of the viscosity in the flow layers next to the boundary might explain the observed drag reduction in suspended particle flows.

It must be emphasized however that drag reduction in suspended sediment flows is observed only: (1) for starved-bed flows or rising-flood flows (i.e. with no sediment deposition); and (2) with microparticles.

An increase of friction is indeed observed with large particle sizes. Rashidi et al. (1990) investigated particularly the effects of particle size, density, and concentration. Their results indicate that the particle density has little effect, but the particle size is an important parameter. Large particles (d = 1.1 mm) cause an increase in the number of turbulent bursts, an increase of Reynolds stresses and larger friction losses. But small particles (d = 0.088 mm) bring about a decrease in the number of wall ejections, Reynolds stresses and friction losses. And these effects are enhanced by the particle concentration.

The authors stated, "The measured rate of bed-load transport was considerably greater in mud flow than it was in clear-water flow for the same energy gradient." The discusser wonders if this observation would in fact be caused by a possible drag reduction, i.e., mudflows exhibit smaller flow resistance than clear water. The resulting increase of flow velocity might increase the bed-load transport. The subject is open to discussion.

[a]May, 1994, Vol. 120, No. 5, by Zhaoyin Wang and Peter Larsen (Paper 3599).

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TABLE 4. Sediment-Laden-Flow Experiments

Reference (1)	Q (m³/s) (2)	Sediment concentration (3)	U (m/s) (4)	Comments (5)
Buckley (1923)	900 to 6,700	120 to 1,620 g/m³	0.5 to 1.4	Prototype data (silt). Nile River at Beleida discharge station.
Buckley (1923)	47 to 68	14 to 2,050 g/m³	0.52 to 0.68	Prototype data (silt). Canal derivation from the Nile River.
Vanoni (1946)	0.03 to 0.15	0 to 3,190 g/m³	0.55 to 1.2	Flume data. Silica sand (d_{50} = 0.16 mm). $\bar{W}$ = 0.84 m.
Vanoni and Nomicos (1960)	0.014	0 to 8,100 g/m³	0.69 to 0.70	Flume data. Sand (d = 0.1 and 0.15 mm). $\bar{W}$ = 0.27 m.
Simons and Richardson (1960)		40,000 ppm		Fine sediments (clays).
Gust (1976)	0.29 E − 3 to 1.68 E − 3	130 to 380 g/m³	0.06 to 0.32	Flume data. Clay. $\bar{W}$ = 0.08 m. H = 0.06 m.
Wang et al. (1983)	0.054 to 0.087	3.4 to 25.1%	0.51 to 1.22	Flume data. Clay and silt: d = 0.021 to 0.027 mm. $\bar{W}$ = 0.5 m.
Wang and Qian (1989)	0.044 to 0.06	0.5 to 2.1%	1.9	Flume data. Sand (d_{50} = 0.15 mm). $\bar{W}$ = 0.3 m.
Rashidi et al. (1990)	0.42 E − 3 to 1.3 E − 3	8.9 to 3.5%	0.077 to 0.236	Flume data. Polystyrene or glass (ρ_s = 1,030 or 2,500 kg/m³): d = 0.088 to 1.1 mm. $\bar{W}$ = 0.20 m. H = 0.0275 m.
Wang and Larsen (1994)	6 E − 3 to 8.2 E − 3	7.66 and 9.43%	1.81 to 2.18	Flume data. Mud clays (ρ_s = 2,680 kg/m³): d_{50} = 0.004 mm. $\bar{W}$ = 0.1 m.

APPENDIX I. REFERENCES

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Simons, D. B., and Richardson, A. M. (1960). "Resistance properties of sediment-laden streams. Discussion." *Transactions, ASCE*, 125, Part I, 1170–1172.

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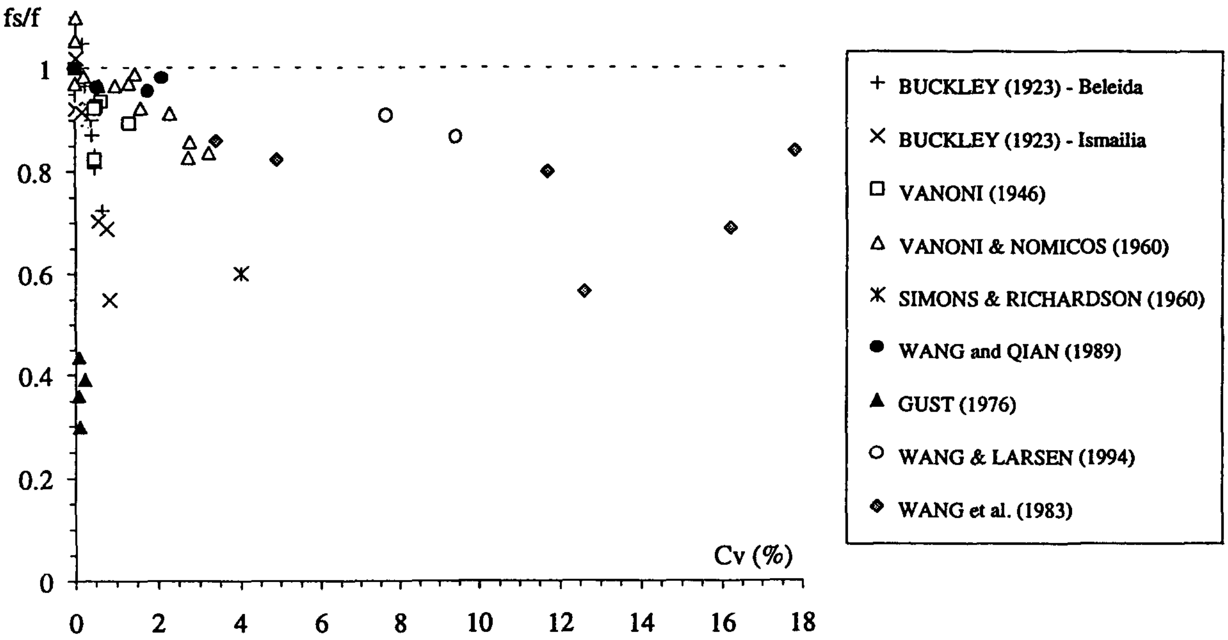

FIG. 18. Observations of Drag Reduction in Sediment-Laden Flows

APPENDIX II. NOTATION

The following symbols are used in this paper:

f = friction factor of clear-water flow;
f_s = friction factor of sediment-laden flows (e.g. mudflow);
$\bar{W}$ = channel width (m); and
ρ_s = sediment density (kg/m³).

Determination of Watershed Features for Surface Runoff Models[a]

Discussion by Maria Manuela Portela[3] and João Reis Hipólito[4]

The present discussers carefully analyzed the authors' paper, not only because of its high interest and current relevance, but also because the discussers developed a methodology to identify the watershed features that is, in many aspects, similar to the one presented by the authors.

The discussers' methodology was included in a model for flow analysis in natural rivers and applied to a Portuguese river (Hipólito and Portela 1994). From the morphological point of view, the discussers' model includes a digital terrain model built upon a triangulated irregular network (TIN). The hydraulic model was developed using the principles of the kinematic wave theory and takes into account the two components of the surface flow: overland flow and channel flow. As shown in the corresponding paper (Hipólito and Portela 1994), the procedures developed by the discussers to obtain the drainage network model from the TIN are almost coincident with those proposed by the authors. In fact, the algorithms developed by the writers are also based upon the calculation, through simple vector analysis concepts, of the steepest slope vectors of the two triangles contiguous to each edge of the triangular grid, followed by the analysis of their relative position, in a way also utilized by the authors.

As referred by the authors, to ensure the efficacy of this method, it is necessary to guarantee that those slope vectors have the same direction, always pointing either downwards (as adopted by the authors) or upwards. However, the writers think that the procedures presented by the authors need a complementary verification in order to ensure the downward direction of the slope vector.

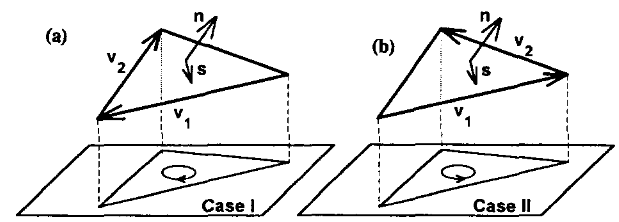

FIG. 26. Orientation of Triangles: (a) Case I—Clockwise Direction; (b) Case II—Counterclockwise Direction

To guarantee an unambiguous definition of the slope vector, one can take advantage of the fact that a triangular irregular network is usually associated with a structural or topological matrix (Sloan 1987; Palacios-Velez and Renaud 1990) where the vertices of the triangles are ordered according to a fixed direction. Thus, considering the vertices of the triangular grid ordered according to the same direction in all triangles (Fig. 26), let $\mathbf{v}_1$ and $\mathbf{v}_2$ be the vectors defined by two consecutive oriented sides of a triangle. The vector $\mathbf{v}_2$ must have its origin at the extremity of $\mathbf{v}_1$. To ensure the downwards direction of the slope vectors and to make use of the remaining expressions presented in the paper, it is necessary to guarantee that the vector $\mathbf{n}$ normal to each plane of the triangles points upward (increasing elevation direction) which can be accomplished through the following cross products:

[a]April, 1994, Vol. 120, No. 4, by N. K. Garg and D. J. Sen (Paper 5003).

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