Effects of Particle Material on Oscillatory Sheet-Flow

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1.Introduction.

At high fluid shear stresses, sediment transport occurs as an assembly consisting of several layer thicknesses. The sediment-fluid mixture is high-concentrated and the grains in this layer are supported mainly by *intergranular collision* forces. This mode of the sediment transport, which is dominating during stormy wave condition, is termed as *sheet-flow* condition. Our present understanding of sheet-flow is rather qualitative since reproducing it in an experimental flume is possible if only the flume size is comparable to the prototype. However, as an alternative, light particles, which are large enough for the visual observation, are often used in a relatively small flume. Using the large light particle would be justified on the assumption that the sediment transport in a flume is equivalent to the prototype as long as the Shields number is the same. Nevertheless, experimental studies have revealed the systematic differences between natural sand grains and large light particles. And even finding in pneumatic transport engineering indicates that transport properties strongly depend upon the particle material, so far no systematic study on sheet-flow sediment transport has been reported.

In this study, the effects of the particle material on sheet-flow properties are examined. Systematic analyses based on existing data- set have been performed on the following properties; concentration profile, velocity profile, transport flux profile and transport layer thickness. The condition of the used data-set is summarized in Table 1.

Table 1 Existing Data-Set

Author(s)	year	Case	S	D	U(cm/sec)	T(s)	fw	Θ	Ψ
Horikawa et al.	1982	1-1	2.66	0.02	127	3.60	0.009	495.7	2.236
Ribberink et al.	1992	1-C7	2.65	0.021	85.5	6.5	0.009	215.3	0.949
Ribberink et al.	1992	2-C11	2.65	0.021	85.0	9.1	0.008	212.8	0.858
Ribberink et al.	1992	3-C12	2.65	0.021	171	7.2	0.007	861.1	3.143
Sawamoto et al.	1986	5-3	1.60	0.50	102	3.8	0.029	35.0	0.515
Sawamoto et al.	1986	5-4	1.60	0.50	88.7	3.8	0.031	26.8	0.419
Yamashita et al.	1988	4	1.41	0.28	89.0	3.53	0.025	70.4	0.871
Yamashita et al.	1992	A	1.41	0.28	43.7	1.30	0.061	17.0	0.514
Yamashita et al.	1992	C	1.41	0.28	135.2	5.49	0.017	162.5	1.416
Asano	1995	C1	1.24	0.417	92.6	4.64	0.026	87.4	1.123
Asano	1995	C2	1.24	0.417	85.0	4.64	0.027	73.7	0.984
Asano	1995	C4	1.24	0.417	63.7	4.28	0.032	41.4	0.658

2. Concentration Profile.

Fig. 1 shows the concentration profiles of both natural sand grain and large light particle over wide ranges. The profile of large light particles show the different tendency than those of the natural sand grain. The light particles have convex shape profiles, whereas the sand grains have not a convex profiles above the flat bed level z=0, (where concentration is low). However, the profiles of sand grain change to convex shape below the bed

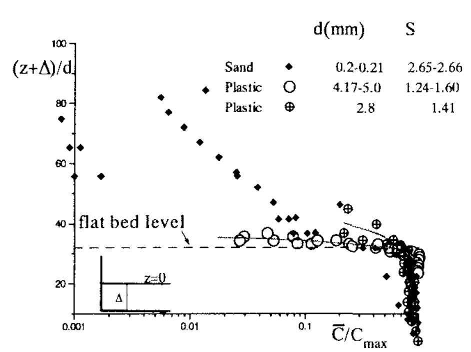

Fig. 1 Concentration Profile

level (where concentration is much higher). The different tendency in the concentration profiles is probably caused from the different mechanism of sediment transport.

3. Velocity Profile.

Fig. 2 shows the velocity profiles of natural sand grain as well as large light particles at $\pi/2$ phase. It can be concluded from Fig.2 that the velocity distribution in the case of the large light particle is different from the natural sand grain above the flat bed level. The different mechanism of sediment transport is also suggested by the different velocity distributions for the large light particle and for the natural sand grain.

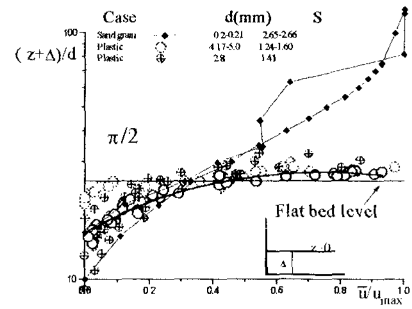

Fig. 2 Velocity Profile

4. Transport Flux Profile.

Transport flux is calculated by the products of the concentration and the grain transport velocity. The phase-averaged transport flux of the same data set as Figs. 1 and 2 is shown in Fig.3. As the figure indicated, the maximum flux of the large light particle occurs above the flat bed level z>0, whereas for natural sand the maximum flux occurs below the bed level.

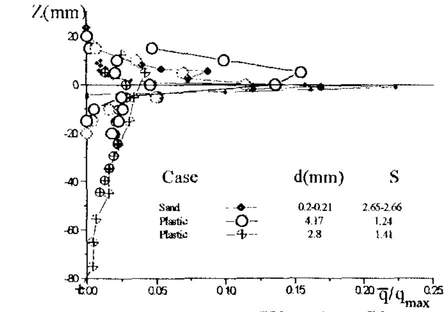

Fig. 3 Transport Flux Profile

5. Transport Layer Thickness

The thickness of the moving layer δ_m is shown in Fig.4. It is found that the normalized δ_m/d could be fairly classified by Shields number ψ and the ratio of the grain settling velocity to friction velocity w_0/u_*. Also, it shows the thickness of moving layer decrease with increasing grain diameter.

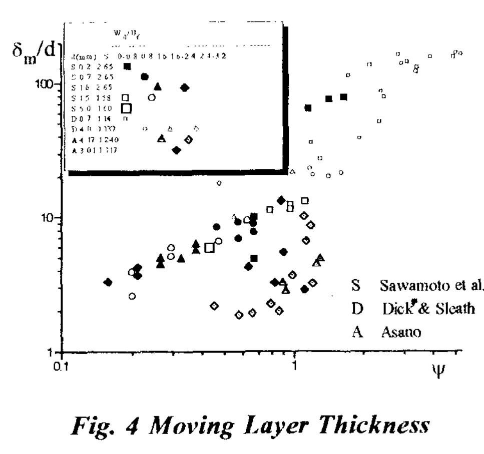

Fig. 4 Moving Layer Thickness

Reference

Asano,T., 1995, "Sediment transport under sheet-flow condition ", J. of Waterwave, Port, Coastal and Ocean Engineering, ASCE, Vol. 121 No. 5