SHEET-FLOW SEDIMENT TRANSPORT FORMULAE VERIFICATION UNDER A NEW SET OF EXPERIMENTS

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Paper topic: Beach morphodynamics and sediment transport

1. Introduction

The seashore and nearshore morphological changes, resulting from erosion and accretion processes, either in the long-term and the short-term manifestations, have been a constant societal concern. Particularly, the technical and scientific community has addressed the analysis of the near-bed hydrodynamic and sediment transport processes, which are fundamental to understand and predict the bed-level changes. The actions of coastal waves and currents, and their interaction, are the main responsible for coastal sediment transport. Various researchers have performed several laboratory experiments aiming at analysing and quantifying the role of wave-form asymmetries (around a vertical and a horizontal axis) and wave-current interaction, contributing to a better description of the near-bed sediment dynamics (e.g., Watanabe and Sato, 2004; Silva *et al*., 2011; Dong *et al*., 2013).

The recognition of the importance of those asymmetries has motivated the development of empirical and semi-empirical sediment transport models that include the non-linear effects of the oscillatory flow. For example, some authors developed sediment transport models from the knowledge (or prediction) of the bed shear stresses, estimated from flow velocity and acceleration time series or from conspicuous points of these properties in the corresponding time series (e.g., Drake and Calantoni, 2001; Hoefel and Elgar, 2003; Nielsen, 2006; Silva *et al*., 2006; Abreu *et al*., 2013).

2. Methodology and results

The application of different sediment transport models to the recent experimental data of Dong *et al*. (2013) is presented and further analyzed in this paper. The data were collected at the oscillatory flow tunnel of the University of Tokyo and it concerns different skewed-asymmetric flows with and without the presence of collinear currents. This experimental data complements previous experiments (e.g., Silva *et al*., 2011), introducing 53 new hydrodynamic conditions obtained in the sheet flow regime. Therefore, the collected data is attractive for the validation of sediment transport formulae since it uses three different grain sizes (d_{50}=0.16, 0.2 e 0.3 mm), with oscillating periods ranging from 3 to 7 s, and because part of the skewed-asymmetric oscillatory flows also includes the presence of strong currents, opposing the (implied) direction of the wave propagation, similar to undertow currents.

Figure 1 exemplifies some of the results where the net transport rate predictions were obtained using a new bed shear stress parameterization for non-linear oscillatory flows in combination with a modified version of the Meyer-Peter and Müller (1948) bedload formula (Abreu *et al*., 2013). The estimates use a constant equivalent roughness equal to $15d_{50}$. Although a good result is perceivable for the two coarser grains (d_{50}=0.2 and 0.3 mm), the results could be improved if different roughness were applied for each sediment. Regarding the finest sediment (d_{50}=0.16 mm), some experimental conditions indicate predicted transport rate directions opposite to those measured. That happens in cases where the oscillating period is small (T=3 s), where other mechanisms which are not contemplated by the new parameterization are present. These effects

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are probably due to the significant suspension of fine sediments and/or to unsteady phase-lag effects between the velocity and sediment concentration (e.g., Dohmen-Janssen *et al*., 2002).

In the paper, the whole set of Dong *et al*. (2013) experiments will be simulated using different sediment transport models, assessing their range and limits of applicability.

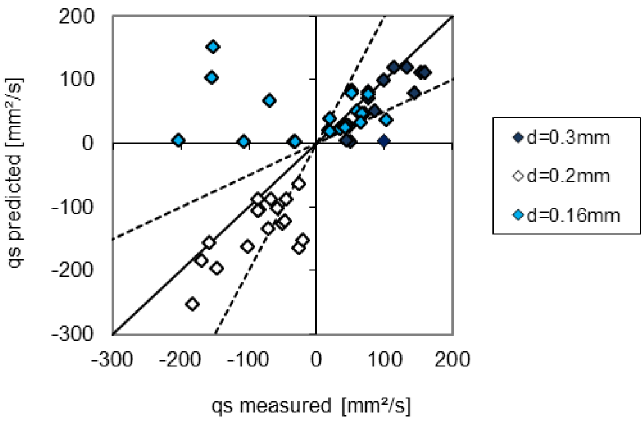

Figure 1. Sediment transport rates, q_s, under the action of asymmetric waves and currents, for different median grain sizes (d_{50}): measured (Dong et al., 2013) *versus* predicted.

References

Abreu, T., Michallet, H., Silva, P.A., Sancho, F., van Der A, D.A., Ruessink, B.G., 2013. Bed shear stress under skewed and asymmetric oscillatory flows. *Coastal Engineering*, 73, pp. 1-10, doi: 10.1016/j.coastaleng.2012.10.001.

Dohmen-Janssen, C.M., Kroekenstoel, D.F., Hassan, W.N., Ribberink, J.S., 2002. Phase lags in oscillatory sheet flow: experiments and bed load modelling. *Coastal Engineering*, 46 (1), pp. 61–87.

Dong, L.P., Sato, S., Liu, J., 2013. A sheetflow sediment transport model for skewed-asymmetric waves combined with strong opposite currents. *Coastal Engineering*, 71, pp. 87–101, doi: 10.1016/j.coastaleng.2012.08.004.

Drake, T.G., Calantoni, J., 2001. Discrete particle model for sheet flow sediment transport in the nearshore. *Journal of Geophysical Research*, 106, C9, pp. 19859-19868, doi: 10.1029/2000jc000611.

Hoefel, F., Elgar, S., 2003. Wave-induced sediment transport and sandbar migration. *Science* 299, pp. 1885–1887.

Meyer-Peter, E., Müller, R., 1948. Formulas for bed-load transport. Report from the 2nd Meeting of the International Association for Hydraulic Structures Research, Stockholm, Sweden. IAHR, pp. 39–64.

Nielsen, P. 2006. Sheet flow sediment transport under waves with acceleration skewness and boundary layer streaming. *Coastal Engineering*, 53(9), pp. 749-758, doi: 10.1016/j.coastaleng.2006.03.006.

Silva, P.A., Temperville, A., Seabra Santos, F. 2006. Sand transport under combined current and wave conditions: A semi-unsteady, practical model. *Coastal Engineering*, 53(11), pp. 897-913, doi:10.1016/j.coastaleng.2006.06.010.

Silva, P. A., Abreu, T., van der A, D.A., Sancho, F., Ruessink, B.G., Van der Werf, J.J., Ribberink, J.S. 2011. Sediment tranport in non-linear skewed oscillatory flows: the Transkew experiments. *Journal of Hydraulic Research*, 49(sup1), pp. 72-80, doi: 10.1080/00221686.2011.592681.

Watanabe, A. and Sato, S. 2004. A sheet-flow transport rate formula for asymmetric, forward-leaning waves and currents. *Proceedings of the 29th International Conference on Coastal Engineering*, ASCE, Lisbon, Portugal, pp. 1703-1714.