Coastal Engineering 83 (2014) 1–14

Contents lists available at ScienceDirect

Coastal Engineering

journal homepage: www.elsevier.com/locate/coastaleng

Measurement and modelling of the influence of grain size and pressure gradient on swash uprush sediment transport

Ilya K. Othman [a,b,*], Tom E. Baldock [a], David P. Callaghan [a]

[a] School of Civil Engineering, University of Queensland, St Lucia, Brisbane, Queensland 4072, Australia
[b] Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johor 81310, Malaysia

ARTICLE INFO

Article history:
Received 27 June 2013
Received in revised form 11 September 2013
Accepted 12 September 2013
Available online 9 October 2013

Keywords:
Sediment transport
Swash
Dam break
Uprush
Grain size
Meyer-Peter Muller

ABSTRACT

The paper examines the dependency between total sediment transport, q, and grain size, D (i.e. $q \propto D^p$) under dam break generated swash flows. Experiments were performed in a dam break flume over a sloping mobile sand bed with median grain sizes ranging from 0.22 mm to 2.65 mm. The total sediment transport was measured by truncating the flume bed and collecting the sediment transported over the edge. The experiments were designed to exclude pre-generated turbulence and pre-suspended sediment so as to focus solely on the swash flow. The magnitude and nature of the grain size dependency (i.e. p value) were inferred for different flow parameters; the initial dam depth, d_o, the integrated depth averaged velocity cubed, $\int u^3 dt$, and against the predicted transport potential, q_p, using the Meyer-Peter Muller (MPM) transport model and variations of that model. The data show that negative dependencies ($p < 0$) are obtained for d_o and q_p, whilst positive dependencies ($p > 0$) are obtained for $\int u^3 dt$. This indicates that a given d_o and q_p transport less sediment as grain size increases, whereas transport increases with grain size for a given $\int u^3 dt$. The p value is found to be narrowly ranged, $0.5 \le p \le -0.5$. On average, the incorporation of a pressure gradient term via the piezometric head into the MPM formulation reduces q_p by 4% (fine sand) to 18% (coarse sand). The measured total transport for fine and coarse sands is best predicted using MPM and MPM + dp^*/dx respectively. However, the inferred optimum transport coefficient in the MPM formulation is about 30, much higher than the standard coefficient in a steady flow and this is not due to the presence of the pre-suspended sediment. The optimum transport coefficient indicates some sensitivity to grain size, suggesting that some transport processes remain unaccounted for in the model.
© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Sand and shingle beaches exhibit median grain sizes that vary by approximately two orders of magnitude, between $D_{50} = 0.15$ mm and 20 mm. Research into the relationship between sediment transport and grain size under field conditions is rare because there are no significant changes of beach median grain sizes over regular time scales (days and months). Data exists for unsteady flows in the coastal literature, but this is for oscillatory flows in water tunnels, OWT (e.g. Dohmen-Janssen, 1999; O'Donoghue and Wright, 2004) or under surface waves (Dohmen-Janssen and Hanes, 2002; Kranenburg et al., 2013; Schretlen et al., 2011), and are limited mainly to sandy beaches with median grain sizes up to 0.5 mm. Few, if any, data exist for swash flows, which are physically different from an oscillatory flow. Oscillatory flows include added complications from phase lags and ripples, and the magnitude and period of the wave orbital velocity. For example, the net sediment transport measurements in a large scale water tunnel of Dohmen-Janssen (1999) revealed two opposite trends, a negative grain size dependency for sand up to $D_{50} = 0.35$ mm but a positive grain size dependency for $D_{50} \le 0.22$ mm when the wave orbital velocity exceeded 1 m/s. Similarly, a negative grain size dependency is also found from the water tunnel measurements of O'Donoghue and Wright (2004) using $D_{50} \le 0.5$ mm. For waves of similar velocity skewness, the presence of onshore streaming under surface waves can lead to an increase in the net transport rates for medium sand ($D_{50} \ge 0.2$ mm) and changes the transport direction from offshore directed to onshore directed.

To a great extent, the research on sediment transport with different grain sizes under oscillatory flow has focussed on several aspects; phase lags between velocity and sediment concentration, the thickness of the sheet flow layer, the apparent roughness height in the sheet flow layer (e.g. Dohmen-Janssen et al., 2001) and the influence of onshore streaming in surface waves (Dohmen-Janssen et al., 2001; Kranenburg et al., 2013), rather than on the influence of grain size directly. Nielsen and Callaghan (2003) were probably the first to suggest a way of quantifying the boundary layer streaming effect in flumes versus tunnels and their treatment was refined by Nielsen (2006). Processed based models (i.e. hydro-morphodynamic model) are more complex and theoretically

* Corresponding author at: School of Civil Engineering, University of Queensland, St Lucia, Brisbane, Queensland, 4072, Australia. Tel.: +61 733653767.
E-mail addresses: i.othman@uq.edu.au (I.K. Othman), t.baldock@uq.edu.au (T.E. Baldock), dave.callaghan@uq.edu.au (D.P. Callaghan).

0378-3839/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.coastaleng.2013.09.001

capture the grain size influence in unsteady flow by modelling the boundary layer, the vertical structure of the sediment concentration and turbulence diffusivity that feed back into the sediment transport calculation (e.g. Hassan and Ribberink, 2010; Kranenburg et al., 2013; Teakle, 2006). Note that some of the processed based models do not model the boundary layer directly (i.e. they use a fixed friction factor) and the grain size influence still depends on the empirical transport formulae adopted in the morphological module (Briganti et al., 2012; Kelly and Dodd, 2010; Postacchini et al., 2012).

Whilst run-up and overtopping in the swash zone are reasonably represented as a one dimensional flow (Young et al., 2010), no clear theory has emerged to explain how the transport rate and grain size are related (i.e. $q \propto D^p$, where q is total transport (m^3/m per swash) and D is a measure of grain size) in the swash zone. Indeed, there are no experimental data that explicitly consider the influence of grain size on swash zone sediment transport, albeit with wide acceptance that grain size influences beach morphology and the morphodynamics response (Masselink et al., 2010; van Rijn et al., 2007). The current transport models, largely derived from steady flow based on the Shields (1936) approach in terms of bed shear stress, have a positive dependency ($p \approx 1$) on grain size solely through the friction factor. Additionally, the widely applied CERC formula for longshore transport is also independent of grain size, although it has been argued (e.g. King, 2005; Van Wellen et al., 2000) that the constant in the CERC formula has an inverse grain size dependency, which mathematically yields $q \approx D^{-1}$. Similarly, the field-derived experimental value of the CERC constant also indicates a negative grain size dependency (Del Valle et al., 1993). To date, this effect cannot be seen directly from typical parametric or empirical sediment transport models (e.g. Sleath, 1984 pg 292), as it is always embedded in a friction factor (i.e. $\tau_b = 0.5\rho f u^2$) or some proportionality constant (e.g. Bailard and Inman, 1981) and the sediment transport results are frequently plotted in term of non-dimensional transport and Shields parameter. Note that there are also uncertainties in the proportionality constants appropriate for the swash zone, which may differ from steady flow values (Baldock et al., 2005; Hughes et al., 1997). This maybe for two reasons; the interlinking of the friction factor and the sediment transport coefficient, and the presence of pre-existing turbulence and pre-suspended sediment generated during bore collapse, which may increase the sediment transport.

Even for simpler steady flows, there is no consensus as to the influence of grain size on transport rate, with disagreement found across the riverine-sediment transport literature (see Martin and Church, 2000). The q–D correlation was originally introduced empirically by Bagnold (1980, 1986) using an inhomogeneous formula (i.e. with unbalanced dimensions). However, a contradiction exists between Bagnold's (1956) theory and his (1980; 1986) empirical correlations. The former support the Meyer-Peter Muller (MPM) transport relationship, with an additional constant dependent on D, but the latter demonstrated an inverse dependency, $q_b \propto D^{-1/2}$.

Owing to the uncertainty in the q–D dependency, the present study examines this dependency experimentally for a range of different parameters using an unsteady dam break flow. The p values are inferred for different flow parameters; the initial dam depth, d_o, the integrated depth averaged velocity, $\int u^3 dt$, and the predicted transport potential, q_p, using the Meyer-Peter and Muller (1948) transport model. The inferred dependency is intended for application to the beach face and might not be valid outside this zone when the non-linear effects of (bore) turbulence induced sediment pickup, sediment settling and phase lags becomes dominant (i.e. different physics occur).

The aim of the current study is to test the following hypotheses:

- Is the total transport dependent on grain diameter, for shallow sheet flow conditions typical of swash uprush? If yes, then is it proportional or inversely proportional, and to what power (i.e. $q \propto D^p$)?
- Is the difference in the sediment transport coefficient compared to steady flow caused by pre-suspended sediment?

This paper is structured as follow. Section 2 presents the experimental setup and test conditions, followed by the model-data comparisons of the experimental hydrodynamics in Section 3. Section 4 presents the results of the q–D dependency, examined for the different flow parameters and Meyer-Peter and Muller (1948) sediment transport model with/without pressure gradient and bed slope corrections. Final conclusions are given in Section 5.

2. Experimental setup and instrumentation

Idealised experiments simulating swash uprush overtopping a mobile sediment bed were conducted using a tilting dam break apparatus at the Seddon Hydraulics Laboratory, The University of Queensland (Fig. 1). The dam break flume is 3 m long, 0.4 m wide and 0.4 m height and has been used previously in a number of studies studying bed shear stress (Barnes and Baldock, 2010) and overtopping (Hogg et al., 2011) during swash-type dam break flows over initially "dry" fixed beds. The gate opening was performed manually using a pivoting arm and video analysis showed that the gate was fully opened to a height greater than 0.2 m in less than 0.12 s (Barnes, 2009), hence the opening can be considered as nearly instantaneous. In order to avoid and minimise leakage and resistance during gate opening, the gate sides and base were covered with silicon seals and a small amount of silicon grease. For the present experiments, the reservoir length was kept constant at 1 m, leaving a 2 m long section of mobile sediment bed downstream. In order to minimise seepage under the gate, and scour prior to gate opening, the reservoir section is fitted with a 2 cm thickness of acrylic false bed. Careful consideration was given to the intersection between the sand and the false bed to minimise significant scour once the gate is lifted and piping action from water leaking from the gate. Prior to each run, any water in front of the gate was removed using a pump and this, in conjunction with a 0.5 cm diameter drain hole just downstream from the gate, ensured a "dry" but saturated downstream sediment bed.

A 2 cm thick layer of sand was placed over the entire length of the downstream side of the gate, and levelled between each run with a 'T' shape profiler running on rails along the top of the flume to maintain an even surface throughout. Four different sediment sizes, with median grain sizes of $D_{50} = 0.22$, 0.5, 0.9 and 2.65 mm, and three bed slopes, $\tan\beta = 1/10$, 1/20 and 1/30, were used in the experiments. Since it is impossible to measure bed load and suspended load separately in such shallow and transient flows, the total sediment transport was measured by allowing the fluid and sediment to overtop the end of the flume, where it was collected. At the overtopping edge, sand was prevented from avalanching and maintained in place by a 2 cm height aluminium strip acting as a toe board. The toe board is designed not to protrude above the sand level so that the overwash processes is not affected. Since the bulk of the transport occurs during supercritical flow, the presence of the edge has a negligible impact on the sediment transport. Note that the same method was used by Baldock et al. (2005) in a wave flume to study overtopping and overwash due to wave run-up. The surface elevations and water depths were measured at 0.535 m, 1.235 m, 1.635 m, 1.775 m and 1.955 m downstream of the gate using Microsonic acoustic displacement sensors, Mic + 25/IU/TC (MS25) with accuracy ±1 mm, sampled at 50 Hz. These sensors have a response time of 32 ms and a sensing distance between 30 and 250 mm (Microsonic, 2010).

The experiments provide highly reproducible measurements with low initial free stream turbulence intensity and exclude pre-suspended sediment. The total transport, q_m, was measured by trapping the overtopped sediment using a removable sediment trap of 0.8 m length, 0.6 m width, 0.2 m height and a monofilament fabric filter of 0.043 mm aperture. The trap sits on the overtopping tank of 1.22 m length, 0.6 m width, 0.6 m height. The trap length was designed to cope with the trajectory of the overtopping sand–water mixture and the splashing is minimised using a 30 cm height plastic cover screwed on the frame at

Download English Version:

https://daneshyari.com/en/article/8059850

Download Persian Version:

https://daneshyari.com/article/8059850

Daneshyari.com