MORPHODYNAMICS OF SAND-SILT RIPPLES IN FULL-SCALE OSCILLATORY FLOWS

Van Thi To Nguyen, University of Twente, v.thitonguyen@utwente.nl
Jebbe J. van der Werf, University of Twente & Deltares, j.j.vanderwerf@utwente.nl
Lukas Raadschelders, University of Twente, l.t.raadschelders@student.utwente.nl
Dominic A. van der A, University of Aberdeen, d.a.vandera@abdn.ac.uk
Pieter C. Roos, University of Twente, p.c.roos@utwente.nl

INTRODUCTION

Ripples are small-scale bedforms created by the interaction among waves, currents, and sediments, and are common features in coastal environments. Ripple development is primarily controlled by hydrodynamic conditions – in this study, by oscillatory flows – and sediment characteristics.

Many studies have investigated wave-generated ripples in sand mixtures (e.g. Nielsen, 1981; O'Donoghue et al., 2006). However, despite the existence of silt-dominated environments in coastal areas (e.g., the Mekong Delta, Yangtze Estuary, Yellow River Delta), there remains a lack of studies on bedforms formed in sand-silt mixtures, which behave differently from sand-sand mixtures. In addition to grain-size distribution, this different behaviour is due to interactions between sand and silt particles (e.g., packing effects) and the apparent cohesion of the silt fraction.

The aim of this study is to quantify and understand ripple patterns and dimensions in various sand-silt mixtures and orbital velocities based on new full-scale oscillatory flow tunnel experiments.

EXPERIMENTAL SET-UP

Experiments were conducted using artificial glass beads in the full-scale Aberdeen Oscillatory Flow Tunnel (AOFT). Three sediment fractions were used: one fine sand fraction ($D_{50} \approx 144\ \mu m$) and two silt fractions ($D_{50} \approx 52\ \mu m$ and $D_{50} \approx 31\ \mu m$). These were combined to create five mixtures: one pure sand and four sand-silt mixtures containing 20% or 40% silt for each silt fraction. All five mixtures were tested under skewed oscillatory flows (skewness r = 0.5), with a flow period of 4 s and root-mean-square velocities (U_{rms}) of 0.2, 0.3, and 0.4 m/s.

To quantify ripple development, an acoustic Sand Ripple Profiler (SRP) was deployed to provide time-varying measurements of bed morphology, capturing the transition from a flat bed to a fully developed rippled bed. Specifically, the SRP performed two-dimensional scans of the bed elevation over a 1.6 m transect every 18 s. In addition, high-resolution (1.6 mm), three-dimensional bed scans of the entire 6 m long (in x-direction) by 0.3m wide (y-direction) test section were conducted using a Laser Bed Profiler pre- and post-experiment (Figure 1).

RESULTS AND DISCUSSION

Figure 1 shows the fully developed ripples for the pure-sand bed and 0.2 m/s flow condition, measured by the LBP. Ripple height (η) and length (λ) were obtained from the bed elevation scans and normalized by the water semi-excursion amplitude (a). Figure 2 shows dimensionless ripple heights and lengths as a function of the mobility number, compared against three empirical formulas developed for sands (Nielsen, 1981; Williams et al., 2004; O'Donoghue et al., 2006). The sand-silt ripple dimensions generally follow the predictions by the sand-only formulas, but the values are slightly lower. This indicates the influence of fine material within the mixtures. Further analysis and testing will be carried out to better quantify the effect of silt content on bed mobility and ripple dimensions.

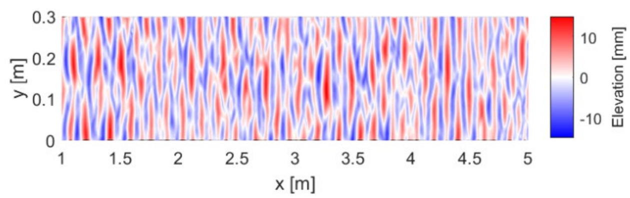

Figure 1 - Bed elevation of the pure-sand bed after the 0.2 m/s flow condition, where x and y represent the position along the tunnel and the cross-section positions, respectively.

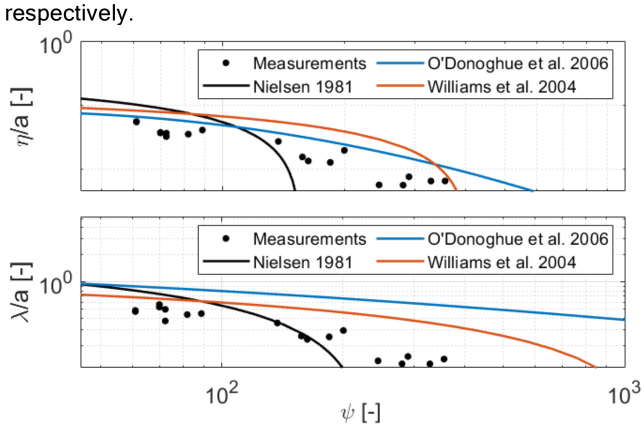

Figure 2 - Dimensionless ripple heights (η/a) and lengths (λ/a) as a function of mobility numbers (ψ).

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