GEOMETRIC CHARACTERISTICS OF WAVE-GENERATED SAND RIPPLES: A FULL-SCALE EXPERIMENTAL STUDY

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In the coastal environment, wave-induced sand ripples are usually observed under moderate near-bed flow conditions. Their occurrence significantly changes the local hydrodynamics and sediment transport processes. Over the past few decades, some solid progresses have been made towards understating the ripple dimensions under wave-generated near-bed flows, e.g., O'Donoghue et al. [2006], but very few studies are targeted on the more detailed geometric characteristics, e.g., the generic shape of ripples and the sharpness of ripple crests, which are closely related to the coherent vortex structures. This study is aimed at filling this knowledge gap.

The experiments were conducted in the Wave-Current-Sediment (WCS) facility located at the National University of Singapore. The WCS is essentially an oscillatory water tunnel which can easily produce full-scale approximations of coastal wave boundary layer. A laser-based bottom profiler (LBP) system, described by Yuan et al. [2017], is used for measuring the bottom profile for the 9m-long test section. In this study, sand ripples are generated under sinusoidal oscillatory flows with velocity amplitude from 0.3m/s to 1.2m/s and wave periods from 4.17s to 10.00s. All the tests are conducted over a moveable bed with well-sorted coarse sand (median diameter=0.51mm).

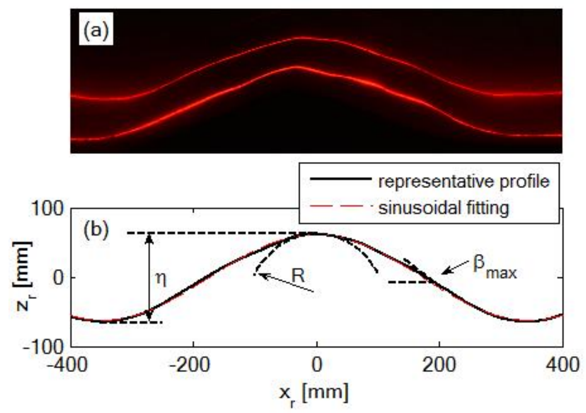

Figure 1 (a) laser image of a 2D equilibrium ripple
(b) representative ripple profile and sinusoidal fitting

The LBP system is used to investigate the development of sand ripples from an initially flat bed. In most tests, both ripple length and height are observed to increase with time until equilibrium 2-dimensional (2D) ripples are developed after O(1000) periods, as shown in Figure 1a. Measurements suggest that ripple length achieves its equilibrium stage earlier than the ripple height and the ripples become 2D quite fast. However, for some flow conditions, the sand bed is still 3D after running the test for many hours. No simple dependency of planform geometry on Shields parameter or mobility number is found in our study. It is hypothesized that the suspended-load transport is a main source of 3D, which can be eliminated if the excursion amplitude of oscillatory flow exceeds the tunnel width.

At the equilibrium stage, a train of uniform 2D ripples can be obtained in the 9m-long test section. They are ensemble-averaged to give a representative ripple profile (black solid line in Figure 1b), which is subsequently used for studying the generic ripple shapes. For a given flow period, it is found that the ripple shape changes from a parabolic-alike profile, e.g., the profile suggested by Du Toit and Sleath [1981], with a relatively sharp crest to a sinusoidal-looking profile with symmetric crests and troughs, as the Shields parameter Ψ_{wmd} (defined with the maximum wave bottom shear stress) increases. For the test shown in Figure 1b (Ψ_{wmd}=0.34), the ripple profile almost coincides with a pure sinusoidal fitting. The normalized radius of the curvature at the ripple crest R/η, where η is ripple height, is calculated to quantify the crest sharpness. The results shown in Figure 2 demonstrate that the crest sharpness remain almost constant for low Ψ_{wmd} but becomes larger as Ψ_{wmd} approaching sheet flow limit. Meanwhile, R/η shows a strong period dependency, i.e., for a given Ψ_{wmd}, the ripple are more rounded in short-period flow. As indicated in Figure 1b, a point with maximum value of bottom slope β_{max}, is identified on the ripple flank. The experimental results suggest that the β_{max} decreases from 33-35°, which is close to an angle of repose, to 28-30°, as Ψ_{wmd} increases. When Ψ_{wmd} approaches the sheet-flow limit, e.g., Ψ_{wmd}=0.7, β_{max} becomes even smaller due to the washing-off processes.

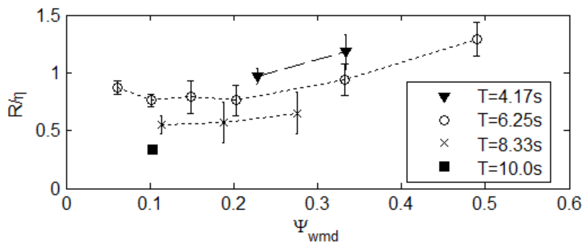

Figure 2 variation of R/η with Shields parameter

Our measurements indicate the ripples under full-scale flow conditions are not similar to those in small-scale wave-flume studies, which may have some significant implications on modeling sediment transport in rippled-bed regime.

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