

The near-bed mass transport under surf-zone spilling breakers

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ABSTRACT

Experimental observations for the vertical distributions of velocity profiles and corresponding Eulerian mass transport under spilling breakers in outer and inner surf-zone boundary layer are presented. A particular efficient and non-intrusive high-resolution particle image velocimetry (PIV) is employed to measure the flow on a slope of 1/20. Particle velocities within the viscous boundary layer with thickness of 1mm were measured simultaneously over ten points. The velocity overshooting and velocity gradient are clearly observed in the viscous bottom region. The variations of velocity profiles in the outer and inner surf zone were examined and discussed. It is found that the near-bed mass transport is still onshore in the outer surf zone but change to offshore in the inner surf zone. Combined with previous observations, it is suggested that the near-bed mass transport is onshore from the shoaling region to the outer surf zone, but changes to offshore from the outer to the inner surf zone, which implies the amassment of sediment in the borderline. These findings may further provide an explanation for the formation of a sand bar in the surf zone.

KEY WORDS: mass transport, boundary layer, surf zone, spilling wave, PIV

INTRODUCTION

Understanding boundary layer flow in the surf zone is important to geophysical, oceanic, coastal, and environmental researchers because of its significance for energy dissipation and sediment transport. Surf-zone turbulence is generated primarily in the crest region through wave breaking and secondarily by shear stress in the wave bottom boundary layer (WBBL). The turbulence produced in the crest region stretches into the interior region below the wave trough during the breaking process (Lin and Hwung 1992; Ting and Kirby 1996; Christensen et al. 2002). Turbulence may further penetrate into the WBBL and change the internal characteristics of flow motion. However, few studies have addressed boundary-layer turbulence as well as the effect of the interaction between the turbulence generated by these two sources in the crest region and WBBL (Christensen et al. 2002).

Because the WBBL is so thin (on the order of 1 mm), measurement of the flow in a laboratory boundary layer in an ordinary small wave flume is arduous work. For this reason, some experimental studies have used oscillating fluid tunnels in which higher near-bed orbital stream velocity can be obtained. For example, Jonsson and Carlsen (1976) measured the near-bottom velocity on a smooth bed in an oscillating water tunnel. Hino et al. (1983) used a laser Doppler velocimeter (LDV) and hot-wire anemometers to measure the smooth boundary layer flow in an oscillating wind tunnel. However, an oscillating water tunnel poses a methodological problem: It can not produce wave breaking. To overcome this problem, the turbulence generated by wave breaking can be simulated using a series of grids placed a certain distance above the bottom (e.g., Fredsøe et al. 2003). However, it is better to investigate the surf-zone WBBL with turbulence generated naturally by wave breaking instead of artificial grids.

Measurements of boundary layer flow in a laboratory wave flume are difficult to perform and rarely have been made. Deigaard et al. (1991) used a hot film probe to measure the temporal variation of bottom shear stress under breaking waves on a smooth sloping bottom. Cox et al. (1996) employed the LDV technique to measure the velocities under spilling breakers on a rough, impermeable 1:35 slope, and the bottom shear stress and bottom roughness were estimated as well. Recently, Lin and Hwung (2002) used the LDV technique to measure the WBBL of shoaling waves in the pre-breaking zone. They found that the boundary layer flow was similar to a laminar flow and that the Stokes layer thickness remained constant in the pre-breaking zone.

Prior to this study, the mass transport near the wall region in the surf zone has not been examined using efficient and non-intrusive measuring instruments, such as a particle image velocimeter (PIV). According to a wide literature survey, this study is the first to investigate the surf-zone WBBL using PIV in an ordinary wave flume. Because the viscous boundary layer thickness was approximately 1 mm, a macro photography technique was applied in the ordinary PIV system to improve the optical magnification. This allows 10 points of velocities to be measured simultaneously near the wall region. The measurement also relies on other techniques, such as delivery of the light sheet beneath the bed, a high concentration of seeding particles and minimum depth of field of camera. The results of a traditional cross-correlation