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Hydrodynamics in the Swash Zone

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ABSTRACT

This paper describes a study of the hydrodynamics in the swash zone using an impermeable concrete beach in a laboratory flume. Analysis was made of the measurements achieved using level wave gauges and a laser Doppler velocimeter. From these measurements we could derive the mean motion and turbulence characteristics along the main flow direction in 3 vertical sections of the swash zone. Fluid velocity seems almost uniform along the vertical, especially during the up-rush; the behaviour of turbulence dynamics is a mixture of free turbulence generated during wave breaking and convected by the mean motion, and wall turbulence. This work covers analysis in the time and frequency domain, and discusses the turbulent properties of the flow field derived from our measurements.

INTRODUCTION

Coastal region management is becoming increasingly important and requires a detailed knowledge of the numerous phenomena that occur near the coast. There are several problems to solve, connected with sediment transport, pollutant dynamics, currents and waves near harbours and beaches; thus many numerical models have been developed and successfully applied. The first models, based on a linear approach, have led to a better understanding of the dynamics of sea waves, solving wave propagation and wave-structure interaction in deep and shallow water. Their conceptual and computational simplicity leads to some engineering applications and indeed these models are successfully used, even though it is well known that there is a fair amount of nonlinear behaviour. For the most complex cases, the results of linear models are used as a first approximation to address more detailed approaches.

The dream of numerical researchers is to integrate the full Navier-Stokes equations, but this is not feasible, due to the computational limitations at a high Reynolds number even in limited integration domains. A relatively simpler approach is the integration of the shallow-water or Boussinesq equation, a depth-integrated version of the Euler equations for potential flow (Mei, 1989; Abbott, 1978, 1979). In 1989, Deigaard and Fredøse introduced the roller concept, modelled as an hydraulic jump, and suggested possible modifications of the Boussinesq equation to take into account the dissipation occurring in the shear layer beneath the surface roller. A lot of researchers proposed modified Boussinesq equations, adding a dissipation term to the depth-integrated momentum equation. Karambas and Koutitas (1992) modelled turbulence using the eddy viscosity concept; Schäffer et al. (1993) used the roller concept proposed by Deigaard and Fredsøe; Drago and Iovenitti (1995) used both concepts, evaluating the eddy viscosity by a k-l equation model. Even though a calibration of the parameters associated with these models was required, all authors found their results tied in with laboratory data in terms of wave height evolution in the surf-zone; very good results were obtained for spilling-breaking rather than for plunging, but this was expected from the roller assumption. Knowledge of the velocity field in the surf and swash zone is very important in understanding the dynamics that govern sediment transport, one of the main problems in coastal regions. On observing that the accuracy of the velocity field obtained from the above-mentioned models had not been established, Lin and Liu (1998) proposed a k-ε model based on the nonlinear Reynolds stress model with a new evaluation of the empirical coefficients. Good results were obtained in terms of free-surface profiles, mean velocities and turbulent kinetic energy for shoaling and breaking cnoidal waves.

At present, the researchers' opinion is that depth-integrated models are unable to adequately predict dynamics in the inner surf zone and swash zone, where the turbulence generated by breaking and at the bottom spreads in the fluid domain. Models based on 2-D Reynolds equations in the main flow direction and in the vertical, with closure equations, appear to be more promising. Of course, such an approach requires a good understanding of the turbulence characteristics involved to make an appropriate closure. These can be understood mainly via laboratory experiments.

Many researchers have studied the turbulence dynamics in the surf zone, as seen by the works of Stive (1980), Nadaoka et al. (1989), Flick and George (1990); more recent work has been done by Ting and Kirby (1994,1995,1996), Pedersen et al. (1998), Rodriguez et al. (1999). However, most have focused mainly on the outer or inner surf zone instead of the swash zone, often considering the swash zone as an inner part of the surf zone. In reality, the swash zone is the region where the up-rush/backwash cycle occurs on the beach face, thus the bottom in this region is periodically wet and dry; in the most landward sections, the still water level is simply not defined. Thus some of the classical scales used in surf zone analyses cannot be used here. First of all, then, new scales have to be defined to describe the turbulence dynamics in the swash zone.

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