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Hydrodynamics of wave-current interaction at a right angle over rough beds

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In the present work, an investigation on the hydrodynamics of waves and currents interacting at right angle over rough beds has been carried out. The work focuses on the effects of wave motion superposed on the current steady boundary layer, and on how the oscillatory flow affects the current velocity distribution, in the presence of gravel and sand beds.

A laboratory experimental campaign on wave-current orthogonal interaction has been carried out in a shallow water basin at DHI Water and Environment (Hørsholm, Denmark).

Mean flow has been investigated by computing time- and space-averaged velocity profiles. Friction velocity and equivalent roughness have been inferred from the velocity profiles by best fit technique, in order to measure the shear stress experienced by the current mean flow.

Tests in the presence of only current, only waves and combined flow have been performed.

Instantaneous velocities have been Reynolds-averaged to obtain turbulent fluctuations time series and compute turbulence related quantities, such as turbulence intensities and Reynolds stresses.

The analysis of the mean flow revealed a complex interaction of the waves and currents combined flow. Depending on the relative strength of the current with respect to the waves, the superposition of the oscillatory flow may determine an increase or a decrease of the bottom friction experienced by the current.

The superposition of waves always induces an increase of turbulence intensity, except over gravel bed in which a decrease is observed in the very proximity of the bottom. Over gravel bed, the presence of the oscillatory flow determines a decrease of the turbulent intensity gradient, which may be related to the decrease of bottom friction observed in the mean flow analysis.

A turbulence quadrant analysis has been performed and showed that, in the presence of a lone current over a flat gravel bed, the turbulent ejection-sweep mechanism reaches parts of the water column closer to the water surface, similar to what has been observed in the turbulence intensity profiles.

The superposition of the oscillatory flow appears to induce an increment of ejections and sweeps

intensity, which is associated with the shear stress increase at the bottom observed in the mean flow analysis. Moreover, a decrease of the number of ejection and sweep events has been recorded, which suggests a suppression of the ejection-sweep events alongside an enhancement of their intensity.