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Swash zone boundary conditions for long-wave models

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Abstract

In this note, a description of swash zone boundary conditions for implementation in wave-resolving and wave-averaging long-wave models is given along with a discussion of the role of such conditions on the modelling of the entire surf zone hydro-morphodynamics.

Keywords: Flow modelling; Swash zone; Boundary conditions; Long waves; Run-up

1. The motivations

Swash zone (SZ) flows are of fundamental importance not only because of their local effects (e.g. structures overtopping, longshore sediment transport, etc.): they can affect the surf zone dynamics as a whole. In particular the SZ is a region in which intense interaction of wind waves can lead to generation/reflection of Low Frequency Waves (LFW) i.e. wave motions with typical periods between 30 and 300 s (Watson et al., 1994; Mase, 1995).

These, in turn, are powerful agents of sediment transport as they remove from the area of interest large amounts of the sediment which are put into suspensions by breaking wind waves. This mechanism of suspension and transport can be very efficient in the vicinity of Low Crested Structures (see also Fig. 1). The impact of overturning waves over or around the structure is responsible for much of the local scouring and sediment suspension (Fredsöe and Sumer, 1997). However, the suspended sediment is efficiently removed from the structure area by large-scale flow features like the LFW (Russell, 1993; Smith and Mocke, 2002) and the macrovortices shed at the breakwater edge (Brocchini et al., 2002). The suggested scenario seems to adequately explain the large erosion areas which often characterize Low Crested Structures in shallow waters and sometimes lead to their failure.

It is evident that both the amount and shape of LFW must be correctly represented to suitably assess sediment transport around LCS; hence the need of a proper modeling of SZ flows.

Also note that wet and dry conditions are not typical only of the SZ, rather, they deeply influence operability of LCS. In dependence of wave conditions

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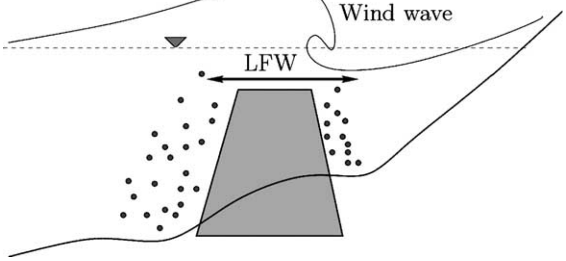

Fig. 1. Sketch of the fundamental agents for sediment transport at a submerged breakwater: the sediment put into suspension by wind waves is removed from the area by long-period motions like LFW.

the crest of these structures can either be always above the instantaneous water level (emerging LCS), or always below (submerged LCS), or alternatively above and below during a wave cycle (periodic overtopping of the structure). The resulting water level set-up and currents can be extremely different in the three cases. In particular in the third case, SZ-type conditions occur over the LCS which, though important, find no suitable representation in available models.

It seems clear that SZ dynamics is not of purely academic importance but it deeply influences the surf zone hydro-morphodynamics. Notwithstanding such importance SZ dynamics is often neglected in computations of coastal flows being they carried out at a wave-resolving (Boussinesq-type models) or at a wave-averaging (circulation models) level. Simplified Shoreline Boundary Conditions (SBCs) are most often used such that either a perfect radiation or a perfect reflection is enforced at the inshore boundary of the computational domain. Both of them are clearly incorrect as they prescribe the wrong amount and shape of LFW reflecting out to sea. In the former case, generally obtained through a *sponge layer*, all incoming waves are lost. On the other hand, for perfect reflection, usually obtained by fitting a rigid wall at the still water shoreline, all incoming LFW are reflected at one single point and no LFW can be generated within such infinitesimal SZ. One third type of SBCs, i.e. a SZ condition, should be enforced. To clarify the importance of the SBCs type a simple comparison has been performed by means of a NSWEs shock-capturing solver (Watson et al., 1994). Fig. 2 illustrates the main difference in the pattern/intensity of seaward-propagating LFW induced by groups of wind waves either incoming onto a wall (left panels) or allowed to generate a SZ (right panels). Not only the intensity of the outgoing waves (thick lines in the lower panels) is different, the outgoing Riemann variable produced by this specific swash event being about 20% larger than that induced by wall reflection, but also the shape of the waves cannot be compared to the presence of the incoming short waves being completely smoothed out by the SZ.

It seems, therefore, unavoidable to fit SZ conditions to any nearshore circulation models. Because of the above-mentioned issues we believe that the use of appropriate SBCs in computations is particularly

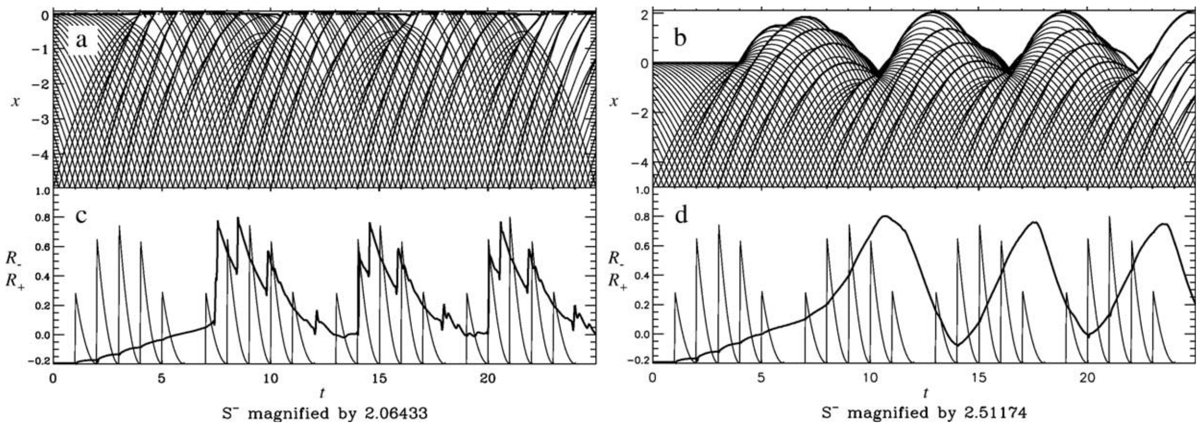

Fig. 2. Illustration of the role of the SZ in generating/reflecting LFW. Wave groups reflected at a wall (panels a and c). Wave groups generating a SZ (panels b and d). Characteristic curves and shoreline position in the (x,t)-plane (panels a and b). Normalized incident (thin line) and reflected (thick line) Riemann variables at the offshore boundary (panels c and d).