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Fully nonlinear computations of waves and wave-structure interaction

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Abstract / Description of Thesis

This thesis concerns the development of an exact or fully nonlinear numerical model capable of describing surface water waves, including the occurrence of wave breaking, and their interaction with structures. The motivation for this work arose, first because of an inability to model limiting and overturning waves in directionally-spread seas and, second because of an inability to describe some of the highly nonlinear free-surface effects which arise when steep waves interact with surface piercing columns. On both counts the available design tools were known to fall well short of accurately describing these important flows. The work has involved the development of a three-dimensional, fully nonlinear, multiple-flux Boundary Element Method (BEM) and has compared the results of this model to detailed laboratory observations.

Quantitative comparisons of the numerical results to both new and existing experimental data, much of which had been gathered as part of the study, are presented. In order to accurately simulate the physical phenomenon associated with wave-wave and wave-structure interactions, it is necessary to formulate, store and solve very large systems of equations. Consequently, the three-dimensional numerical code is executed using a parallel implementation. This is not only necessary to maximise its time efficiency, but to also allow the feasible simulation of realistic problems involving significant directional spreads. The applications of the model include:

(a) Solitary waves overturning on impermeable plane beach slopes.

(b) Irregular (or unsteady) waves interacting with a vertical wall.

(c) Waves interacting with submerged breakwaters and underwater caissons.

(d) Overturning irregular waves, including descriptions of their associated water particle kinematics throughout the water column.

(e) Waves interacting with surface-piercing columns, with details of the scattered waves arising.

As a result of these studies, a new wave model has been fully validated, new numerical descriptions have been obtained, and improved physical insights concerning practically important problems have been realised.