Surf and Swash Zone Hydrodynamics

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http://www.maths.bris.ac.uk/~madhp Peregrine's home page.
http://www.coastal.edu/~ias Svendsen's homepage (8 reprints available)
http://www.wldelft.nl/sasme/sasme.htm The home page of the SASME project.

LONG-TERM GOALS

Improve understanding of the hydrodynamics of the near-shore motions on beaches, with particular reference to the zone where the incident waves break, form surf, and run-up on the beach to give a fluctuating shoreline. This includes the waves and currents that the breaking waves, surf and run-up generate together with necessary details of the motions beneath the waves. Particular attention is directed to improving theoretical models of these motions.

OBJECTIVES

The main topics for study are:

(a) the turbulence generated by breaking waves and bores. A rational, non-empirical, approach to modelling unsteady spilling breakers and bores is a major target.

(b) the modelling of surf in the presence of co-existing long waves.

(c) improved, and perhaps simplified, modelling of the swash zone.

(d) understanding the currents, eddies and long waves generated by the incident waves, especially for irregular non-uniform waves over non-uniform bed topography.

APPROACH

This grant is to enhance cooperation between the P.I.s and their respective groups in working towards the above goals. The P.I.s meet each other each year and their more junior associates can make extended visits to each other's institution. In both groups the emphasis is on developing mathematical models through to practical numerical programs, including significant interaction with field and experimental results.

WORK COMPLETED / RESULTS

After some unsatisfactory experience with the accuracy of our existing numerical shallow-water codes when applied to two horizontal dimensions, O. Bokhove and M.D. Patterson have developed

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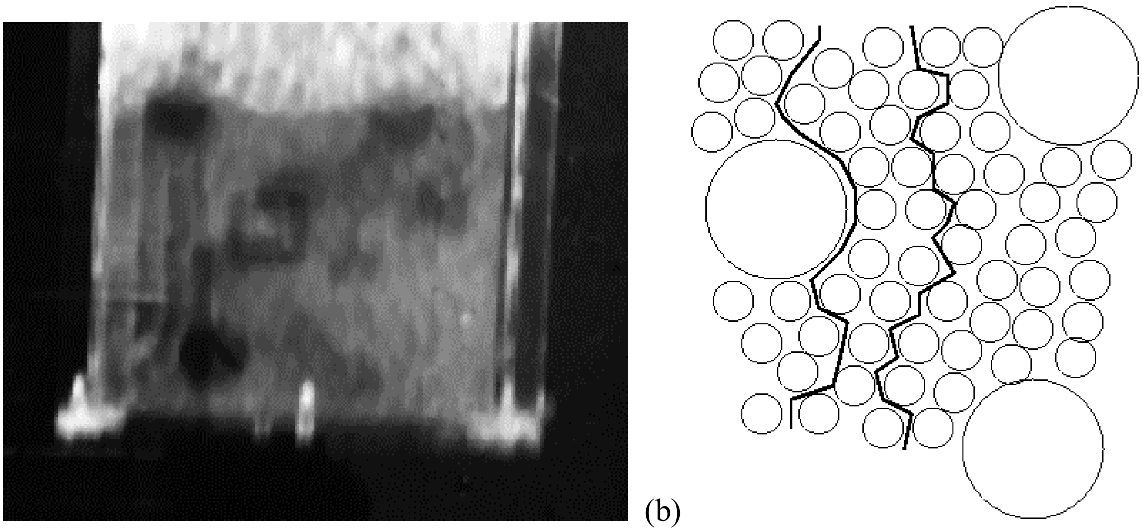
and tested several numerical shallow-water codes for time-domain modeling of breaking waves in the surf zone, trying out various schemes suggested in both the gas dynamics and oceanographic community. Breaking waves in the surf zone are modeled as bores or discontinuities, that are mathematically similar to shocks in gas dynamics. We are especially interested in the bores for two reasons.

1) We have developed ideas that give an alternative approach to the understanding, interpretation and prediction of wave genrated currents (Peregrine 1998, 1999 and Bokhove & Peregrine 1998), and wish to investigate it further.

2) The swash zone over which the shoreline moves with each wave is an importnat region where we are developing the fundamental work of Brocchini & Peregrine (1996). This works aims at improving wave averaged models which at present often have a very simplistic swash zone boundary condition, i.e. that the water depth is zero, a result that is only true in averaged models at the utmost extremity of the runup.

The results of our assessment of shallow water numerical schemes are summarized in Bokhove, Patterson & Peregrine (2000), and a full review paper is in preparation. In essence, three schemes have been shown to give good improvements and to be worthy of further study. In brief, they are the convex essentially non-oscillatory scheme of Liu & Osher (1998), the central difference scheme of Jiang & Tadmor (1998) and the essentially non-oscillatory scheme of Shu & Osher (1989). The first two schemes appear to be distinctly more computationally efficient than the last one.

In many schemes for hyperbolic partial differential equations such as we are solving there are often problems with 'source' terms. In our case, these correspond to friction terms, which give little trouble and the effects of varying depth where we did have trouble. However, a neat logical way of overcoming that defect has been found. A more severe problem, which has become notorious in swash modelling, is that of the shoreline boundary condition, and the development of various instabilities and inaccuracies. This has been investigated in detail and useful results have emerged.



(a) (b)

Figure 1. (a) Still from a video of colored water advancing through a matrix of a mixture of two sizes of glass marbles. The air-water interface is near the top. (b) A sketch to indicate that flow paths near the larger marbles offer less resistance.

In addition, particular focus has been given to the modelling of the moving shoreline in the case where the beach is made of coarse materials so that there is easy flow into the beach and the interior flow is at high Reynolds number. A number of fundamental aspects of this problem appeared to be poorly modelled in the literature. Several measurements have been made for especially simplified flows, in order to obtain better insight into these problems. An initial report is given in Patterson, Peregrine & Loveless (2000). Of particular interest is the effect of mixed sizes in sediment. An experiment with the porous medium made up of a mixture of glass marbles, of diameters 20mm and 8mm diameter, with advancing colored water is shown in figure 1. The larger elements within the matrix provide a low resistance path for advancing water, which shows up as a bulge in the advancing air-water interface.

Long-term work to improve the modelling of strong turbulence at a free surface, such as occurs in a splashing breaker, has lead to the submission of two papers: Brocchini & Peregrine (2000a,b) and to the organization of a Euromech meeting on 'Strong turbulence at free surfaces'. Both principal investigators took major roles in this meeting at Genoa, Italy in September 2000.

The work at the Center for Applied Coastal Research (CACR), University of Delaware has included development of a reference version of the quasi-3D circulation model SHORECIRC(SC) and a detailed manual describing both this model and how to operate it (with Haas, Zhao, and others). Model and manual have been made available for selected nearshore scientists for further testing and comments.

Work has started on the analysis of how errors in how particularly the cross-shore boundary conditions influences the solution inside the modelling domain (Chen). The purpose is to clarify if it is possible by extending the model domain in the longshore direction to relax on the accuracy required for the boundary values along cross-shore boundaries, because such boundary conditions are hard to obtain in practical applications. Indications are this will be possible but work in ongoing.

Finally, modelling of rip currents has been continued with particular emphasis of the vertical variation of the currents (Haas). A spectacular result is the finding that offshore of the rip channels rip currents quickly develop into currents mainly flowing in the surface. There is a strong variation over the vertical in the direction of the currents.

Personnel Exchanges 1999-2000

Name	Position	Visit dates	Home institution	Place of visit
I.A.Svendsen	Professor	March 2000	CACR	U. of Bristol
M.Brocchini	Professor	June 2000	U. of Genoa	U. of Bristol CACR

WORK IN PROGRESS

Earlier work by Bird (1999) on two-dimensional wave groups approaching a beach showed interesting features that indicated that the relative phase of waves in such modulation had a substantial effect on the evolution of such groups. This is now being investigated further. B. Mapp is making good progress in studying how robust the phenomenon is when considered with a three-dimensional model. The work is mainly based on using the Davey-Stewartson modulation equations.

Bokhove and Patterson continue to develop the numerical shallow water code and with emphasis on the generation of unsteady currents such as eddies and rip currents, and on including the effects of porous beds.

The work with Brocchini on averaging over the swash zone is being continued with the assistance of R. Archetti to examine the effect of frictional terms which are at their most influential in the swash zone. R.Moraes, at Bristol, is working on detailed hydrodynamic models for the interaction of waves and currents that allow investigation of the effect of strong current gradients. This also gives comparisons with corresponding experimetnal work recently completed at Delaware: Chawla (1999).

Svendsen and his group at CACR, U. of Delaware are continuing the development of the quasi-3D circulation model SHORECIRC(SC). This includes developing boundary conditions for the shoreline (in collaboration with Brocchini and his colleagues) that can be used in various models, with different numerical grids and a variety of physical situations. The effects of errors in the specified cross-shore boundary conditions are analyzed and model development is taking place to extend applications to deeper water. Work also continues on analysis of the hydrodynamical mechanisms of rip currents, and a version of the model for generalized curvilinear coordinates is being developed. Finally application to sediment transport and comparison to laboratory measurements of both hydrodynamics and sediment motion and to field data from Duck, North Carolina (in collaboration with Kaihatu, NRL, Stennis. MS), is in progress.

IMPACT/APPLICATIONS

In all areas mentioned under OBJECTIVES major improvements in modelling are arriving.

(a) At a wave-resolving scale the improvements in modelling two horizontal dimensions now give a capability to investigate many features due to three-dimensional wave fields or bed topography.

(b) The development of averaged models for the swash region gives a valuable tool for the land-sea boundary which is an area where sediment erosion or deposition are of special significance.

(c) presently the best models for the surf zone include 'rollers' to model the breakers. The parameters describing these rollers are obtained from best fits to data. We are gaining understanding of the hydrodynamic feedback between the foot and crest of a breaker such that a more deterministic model that includes breaker initiation, merging and decay can be created.

(d) Quantification of the changes of circulation and generation of vorticity by bores gives a new and simpler way of assessing currents from observation of the wave field, in addition they promise new insights into horizontal mixing and transport properties of the surf zone currents.

RELATED PROJECTS

Related projects in Bristol are:

"Surf and swash zone mechanics" (the "SASME project"), PI Peregrine. (sponsor E.U. MAST).
"Probabilistic Design Tools for Vertical Breakwaters" ("PROVERBS"), PI Peregrine. (sponsor E.U.).

"The optimisation of crest level design of sloping coastal structures through prototype monitoring and modelling" ("OPTICREST"), PI Peregrine. (Sponsor E.U.).

"Effects of surface currents on the patterns and breaking of surface waves with reference to remote sensing", PI Peregrine. (Sponsor: the U.K.'s Defence Evaluation and Research Agency (DERA).

Related projects at Delaware are:

"The generation of rip currents and circulation around coastal structures" (Sponsor:NOAA, Sea Grant.

"Modelling nearshore waves, currents, and IG wave motion" PI: Svendsen (Sponsor: ONR).

"Development and verification of a comprehensive community model for physical processes in the nearshore ocean". PI's Kirby, Svendsen, (at UD, and others outside UD)(Sponsor: NOPP).

"A computational model for the hydrodynamical and littoral processes at the large-scale sediment transport facility at WES" PI: Svendsen (Sponsor: ARO).

Several of the twelve other groups in the SASME project cooperate with Bristol. This includes contacts with experimental groups e.g. at the Universities of Cantabria, Edinburgh, Florence, and Plymouth. Similar interactions occur with those running complex computer programs (e.g. Danish Hydraulic Institute [DHI], and Delft Hydraulics).

Interactions occur between Delaware and the groups conducting hydrodynamic field experiments at Duck, North Carolina (Scripps, Naval Postgraduate School, Oregon State University and others). Close interaction continues between Delaware and the researchers at the Dept. of Mathematical Modelling (IMM) at DTU in Denmark (Per Madsen and his group) and at the University of Genova (Brocchini).

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