Violent water wave impacts on a wall

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Violent impact of an extreme wave onto a structure can be the criterion that determines a number of design parameters. Within the BWIMCOST (Breaking Wave IMpacts on COastal STructures) project such impacts have been measured in the field and the laboratory for waves breaking onto a sea wall or breakwater, see Bullock et al. (2003). The time and space scales of impact are sufficiently small that the hydrodynamics of impact is unlikely to differ for waves in deep water which hit fixed or floating structures. In practical situations when pressures exceed a few atmospheres, it is appreciated that compressibility of air becomes important. This is particularly so for air that is entrained into or trapped by water, so special efforts have been made to measure the air-fraction in the water. Peregrine (2003) is a recent review: work subsequent to that review is reported here.

The overturning jet of the breaker may trap a 'pocket' of air, and/or the water may have already entrained a multitude of air bubbles. Both types of air distribution influence the effect of wave impact, due to their greater compressibility compared with pure water. The compressibility, evident in the very low velocity of sound in the air-water mixtures that occur as and after waves break, is a primary concern when small-scale laboratory data is being used to estimate large-scale prototype impacts, since the usual Froude scaling is unlikely to be correct.

The three main strands of data are from prototype:

1) the Admiralty breakwater, Alderney, which is exposed to waves from the Atlantic Ocean.
2) 1:4 scale: in the big wave channel (Grosser Wellenkanal, GWK) Hanover.
3) 1:25 scale: laboratory experiments in Plymouth with both fresh and sea water.

Few examples of violent impacts have been obtained from Alderney, the most severe impact occurred on an otherwise quiet day and may be described as a rogue wave. On the other hand the GWK measurements have yielded exceptionally violent impacts with pressures up to 3 MPa. These impacts vary in character, some details will be presented.

The theoretical studies include

a) careful analysis of the data for waves approaching the breakwater, and for the impacts.
b) development of simple mathematical models.
c) development and study of detailed numerical models.

Here attention is focussed on the detailed modelling.

Figure 1. Wave impact on a wall sloping at 27º to the vertical. Spray caused by air escaping from a trapped air pocket at high pressure can be seen. The exposure time is 1/125 second, and the width of the flume (GWK) is 5 metres.

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Waves approaching the wall are approximated with irrotational flow for which a boundary-integral computation is used Tanaka et al. (1987). This computation stops when the wave hits the wall or the flow becomes too violent, rough, or a jet extends too far.

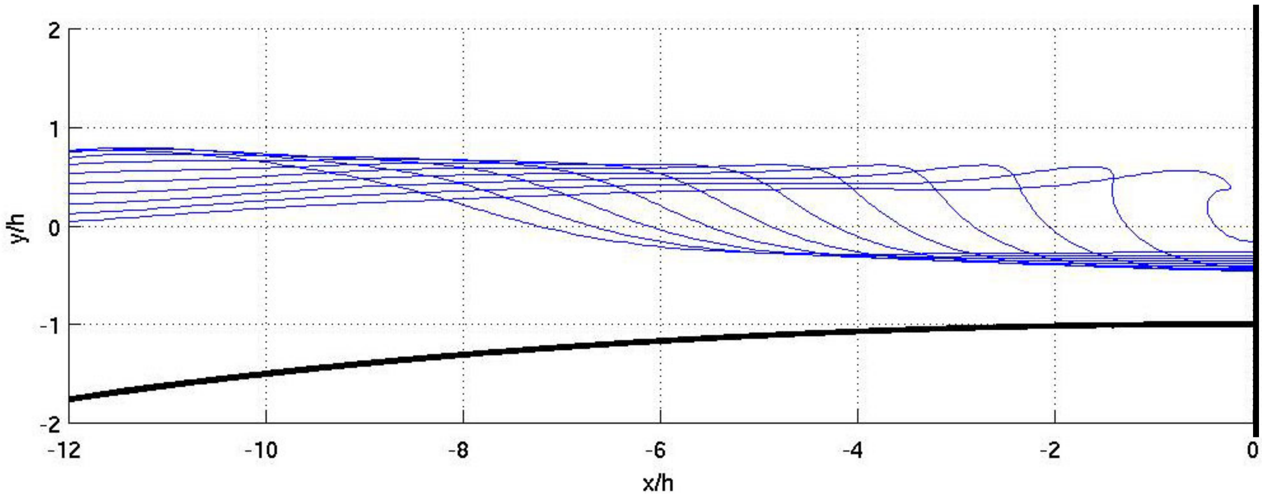

Figure 2 Wave profiles from a boundary-integral computation of a wave propagating over a berm towards a wall.

The compressible model. is the simplest possible, essentially the two-dimensional unsteady Euler equations for an air-water mixture with variable air volume fraction. It assumes adiabatic compression of the air and no relative movement between the phases. There are numerical problems with such a model when shock waves pass from light medium to a denser one, but, so far, they do not seem to be of importance in the first few wave impact examples that have been run at the time of writing.

The initial conditions for the compressible flow computations are taken for a region near the wall from the boundary-integral computation: for example, from a profile which is intermediate between the last two in figure 2. The computations provide a complete time history for the flow field and pressure on and near the structure. The analysis of these computations is in progress.

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