Pressure near wave impacts and the role of trapped air

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Summary

Comparisons between experimental measurements and simple pressure-impulse models for wave impact reveal that in some circumstances the pressures due to a nearby wave impact can be as great as those due to direct wave impact. In addition air trapped by a breaking wave can lead to an increased impulse from a given wave.

Introduction

Consider a given wave impact on a vertical wall. The pressure from that impact decays with distance from the impact region. Now, consider the same impact, with the same pressure distribution, but acting on the horizontal water surface adjacent to the vertical wall. The effect of the wall is to provide an image plane which doubles the apparent horizontal spread of the impact with corresponding implications for the magnitude of the pressure distribution that results. Typically the pressure will be doubled, and may be especially increased in that part of the near field which in the case of a vertical impact is influenced by the negligibly small pressure disturbance at the free surface.

This effect was brought to our attention by the difficulty of explaining some breakwater failures where the structure appeared to have been subjected to a large seaward force. Within the PROVERBS project of MAST 3, J. van der Meer (private communication) provided some pressure measurements from Delft Hydraulics that indicated that high seaward forces had occurred in experiments when a wave overtopped a low structure. Further experiments designed to measure this effect were performed at the University of Edinburgh, (Walkden et al, 1999) and interpreted by using the concept of pressure impulse (Cooker & Peregrine, 1992, 1995).

Overtopping experiments and their interpretation.

A model caisson of relatively low height was instrumented with pressure sensors on the rear face, which was in water of the same level as that at the front of the caisson. A two-dimensional wave, designed to break at the structure was sent along the flume and after meeting the front of the caisson formed a substantial jet which landed on the water behind the caisson. Video of the experiment enabled a good estimate of the velocity and shape of the water at impact on the horizontal surface. Perhaps fortuitously, the falling jet had an almost horizontal lower surface as it hit the water (figure 1) With the geometry and velocity of the falling jet it is possible to estimate the pressure impulse distribution on the surface of the water behind the caisson. Then pressure-impulse theory can be used to model pressure impulse on the rear face of the caisson.

Figure 1. Video frame just before jet impact.

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The initial comparison is shown as a broken line in figure 2 and has a clear discrepancy with the experimental measurements. The measured pressure close to still water level is comparable with the pressure on the rest of the caisson, whereas the theoretical result is close to zero (atmospheric) pressure. This is due to using pressure equal to zero on the free surface immediately behind the caisson: the jet hit the water further away. However, since the experiment was two-dimensional the air close to the caisson formed part of an air pocket that was trapped by the falling jet and was not at atmospheric pressure. When an increased air pocket pressure was included in the pressure impulse distribution, excellent agreement between experiment and theory was obtained as shown.

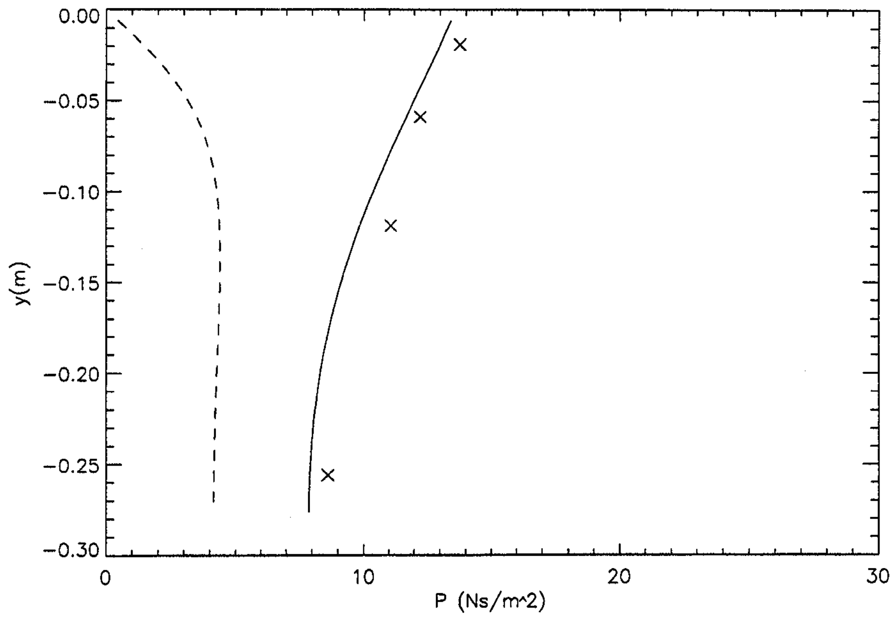

Figure 2: Predicted and measured (×) pressure impulse on the rear face of the breakwater.

Discussion

The pressure at the rear of the caisson was relatively high for two reasons:

(i) the confined circumstances of an impact close to a wall (the image effect already mentioned) and also of water of only moderate depth with a rigid bed, see Wood & Peregrine (1996).

(ii) the air pocket appears to have a suprisingly high pressure within it.

The effect of pressures within air pockets is also significant for direct impact on a wall as discussed in Wood & Peregrine (1998). Further studies of the effect of trapped air may be reported at the meeting.

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