Breaking wave design: a case history

M. Birkinshaw, W. J. Easson, C. A. Greated and R. M. Webb

Professor J. R. Chaplin, *City University, London*

The Authors present some remarkable experimental measurements of velocities and accelerations beneath a breaking wave. As a theoretical model of this process, a regular wave theory—such as the stream function theory used in the Paper—is a poor substitute for a time-dependent solution which reproduces the unsteady nature of the flow. As the Authors note, however, it has the advantages of familiarity and relative simplicity.

42. In modelling the flow beneath a breaking wave, presumably the best that can be done with a theory for regular waves, without violating the conditions on which it is based, is to solve the wave which has the desired period and mean water depth but is of limiting height, since this is in many respects the most severe condition. Near the crest the physical process may be very different, thus necessitating the type of empirical corrections proposed. It is known that at its crest, the regular wave of limiting height must have a downwards particle acceleration of $\frac{1}{2}g$.

43. Limiting wave heights for regular waves can be found by interpolation from tabulated data given by Cokelet,²⁴ and are set out in terms of more familiar engineering parameters in reference 25. For the water depth d and period T of the wave used as an example by the Authors, the limiting height H_b is given by

$$HB/L_0 \simeq 0.0728$$

where

$$L_0 = gT^2/2\pi$$

This is about 4% less than the wave height H used in the example, and is therefore outside the range of conditions for which one may hope for an analytical solution to the regular wave problem. This probably makes little difference to the outcome, but any results computed in this region must consequently reflect those errors in the model which permit a solution to be reached; in the case of series-type expansions, such as stream function theory, these come from series truncation and incomplete convergence. I would suggest that these considerations render the Paper's conclusions on the performance of stream function theory rather subjective; with other stream function programs (taken to different orders, or with different formulations), other results can be obtained.

44. By way of an example, Figs 14 and 15 show results from a 23rd order stream function solution, using a method²⁶ slightly different from Dean's. The results shown are for $d = 18$ m, $T = 10.3$ s (the conditions used by the Authors), and $H = 11.93$ m ($H/L = 0.072$), about 99% of the limiting height. Particle velo-

Fig. 14. Horizontal velocity beneath the crest

cities beneath the crest agree better with measurements, although they still require some modification as recommended.

45. Figure 15 shows vertical accelerations beneath the crest. Slightly below the water surface, the numerical results from both sources exhibit a maximum which is due to computational problems. The present results, presumably like those computed by the Authors, are total accelerations and should come close to $\frac{1}{2}g$ at the surface. The experimental results, however, calculated from subsequent velocity measurements at a point, appear to refer to local accelerations. If this is correct, is it not inappropriate to compare the two sets of data? It is worth noting that the experimental results do not agree with computed local accelerations either; in the 23rd order solution at the crest, the downwards local acceleration in the vertical direction exceeded 20 m/s^2 .

Fig. 15. Vertical acceleration beneath the crest

Mr Birkinshaw, Dr Easson, Dr Greated and Mr Webb

It is accepted that a time-dependent solution will give a more adequate description of the breaking process than regular wave theory. However, this will give solutions only up to the breaking point and is of limited use for spilling breakers. Modifications of regular wave theory have been resorted to almost exclusively for design purposes in this situation because time-dependent solutions have, until very recently, been impractical to implement in an engineering project. Two of the Authors are currently making comparisons with a time-dependent model developed by Professor Peregrine at Bristol University.

47. Professor Chaplin correctly states that the acceleration measurements were made in a fixed frame, while the computer program calculated material acceleration. However, in engineering practice, and in particular for structures

DISCUSSION

where the drag term dominates, the convective term is often ignored.²⁷ The convective term could have been estimated from velocity distributions, but this would have entailed more extensive measurements and the drag dominance of the structural forces did not warrant these in this case. For large diameter members in very steep waves the convective term assumes greater importance.

48. With regard to the final point, it should be noted that accelerations were not measured right up to the crest height. Also, the resolution of the analysis system was limited by the time duration between gating pulses. In a more recent and extensive study, vertical accelerations in excess of 14 m/s^2 have been measured for a similar wave.

References

24. COKELET E. D. Steep gravity waves in water of arbitrary uniform depth. *Phil. Trans. R. Soc.*, 1977, **A286**, 183–230.
25. HOLMES P., CHAPLIN J. R. and TICKELL R. G. Wave loading and structure response. *Proc. Conf. on Design in Offshore Structures*, London, Mar. 1983. Thomas Telford, London, 1983, 1–12.
26. CHAPLIN J. R. Developments of stream function wave theory. *Coastal Engng*, 1980, **3**, 179–205.
27. SARPKEYA T. and ISAACSON M. *Mechanics of wave forces on offshore structures*. Van Nostrand Reinhold, Amsterdam, 1981.