Wave height?
A study of the impact of wave groups on a coastal structure

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1 Introduction

The determination of the most violent water wave impacts on marine and coastal structures, and on ships, is a key issue in engineering design. The strength and type of impact depends on the wave properties, which are most frequently cited as a wave height and period. However, in practice the wave shape at the structure, which results from the interplay between the incident waves and the structure, can be more important. Here we give results of an investigation into the effects of wave phase within a wave group, where interaction with a preceding wave is also relevant.

Recent work on the details of wave impact with incident wave groups show a variety of behaviour which is not simply dependent on incident offshore wave height. Greco et al. (2007) report on different impact types of green water loading on a ship. Peregrine et al. (2004) gave numerical evidence to the sensitivity of the strongest impact forces to the waves, for a coastal sea wall on top of a mound. By varying the offshore wave height of an incident wave group, impacts of sloshing type to overturning type were obtained. The most violent impacts occur in a narrow band of wave and structure parameters, and are associated with the entrapment of a small air pocket.

Further study of wave groups incident on a coastal structure demonstrates that the offshore wave height alone is insufficient to distinguish between impact types. Our computations suggest that a key parameter is the lowest water depth at the wall as the wave crest approaches. This trough depth is governed by the impact of the previous wave and is thus dependent on both the wave sequence and the structure.

The simplest example is when a wave group reaches the structure with either a crest or a trough at the maximum of the wave group envelope. Such differences are reported in the overtopping study of Hunt (2003), where ’trough focussed’ wave groups were found to give larger overtopping volumes than ’crest focussed’ groups. Here, we present two-dimensional computational results to illustrate the influence of the phase of waves relative to the group envelope. We also illustrate the effect of the preceding wave on a wave impact by varying the group length.

The effect of varying wave sequences has been discussed by Günbak & Bruun (1979) noting particularly the effect of a deep trough. We are able to give detailed examples and find that in some situations, the interplay between the impacting wave, envelope and trough depth leads to a more violent impact from the wave *following* the largest wave in the group.

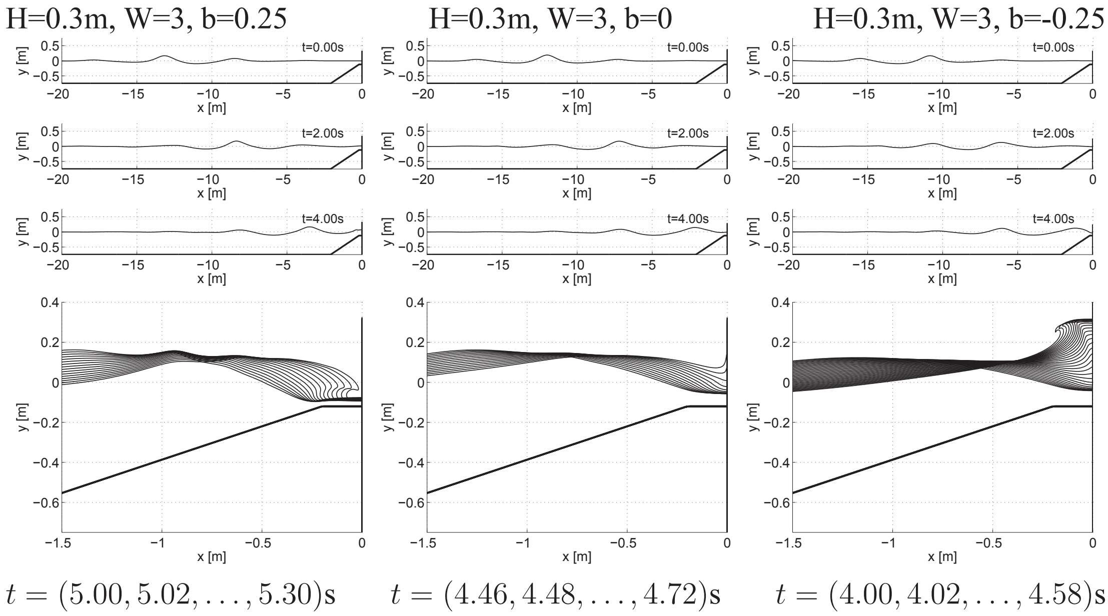

Figure 1: Impacts for varying relative phase between carrier wave and envelope. The initial wave crest is placed offshore (left column), aligned with (middle panel) and onshore (right column) to the envelope center. The upper panels show the group propagation towards the wall. The lower panels show details of the impact with timings given below each plot.

2 Numerical results

The computational method is based on Tanaka et al.'s (1987) extension of Dold & Peregrine's (1986) method, with a Schwarz-Christoffel transformation used to avoid any need to place discretisation points on the bed. These computations have been performed as part of the design of a laboratory study and are thus reported in dimensions appropriate for future experiments.

The structure is a vertical wall placed on top of a mound with a 1:3 slope up from the offshore uniform depth of 0.75m. The top of the mound has a short horizontal section of width 0.2m in front of the wall, with a still water depth of 0.12m. Coordinate axes (x, y) have their origin at the intersection of the still water level and the wall, with the water in $x < 0$. Thus the base of the approach slope is at $x = -2.09$m.

The initial condition for the impacting wave group is constructed from a fully non-linear stream function solution for given offshore wave length and wave height. While various wave heights are used, the wave length is fixed to $L = 4.8$m which is much longer than the total size of the structure. The initial condition is obtained by multiplying the stream function solution by an envelope function to give the surface elevation (η) and the velocity potential on the free surface (ϕ):

$$\eta_{\text{ini}} = \text{sech}(k(x - x_0)/W)\eta_{\text{stream func}}(x - x_0 - bL)$$
$$\phi_{\text{ini}} = \text{sech}(k(x - x_0)/W)\phi_{\text{stream func}}(x - x_0 - bL)$$

where W is a measure of the width of the envelope and k is the wave number. The envelope is centred at $x = x_0 = -12$m for all tests. The parameter b determines the relative phase of the carrier wave to the envelope, such that $b = 0$ produces a wave crest at the envelope centre, and $b = 0.5$ gives a trough, for the initial condition.

The wave group can thus be characterised by an offshore wave height H, the group width parameter W and the phase parameter b. We give H for the carrier wave at envelope maximum, rather than the precise maximum wave height. As the group propagates towards the wall, the wave crests move forward relative to the envelope since group ve-

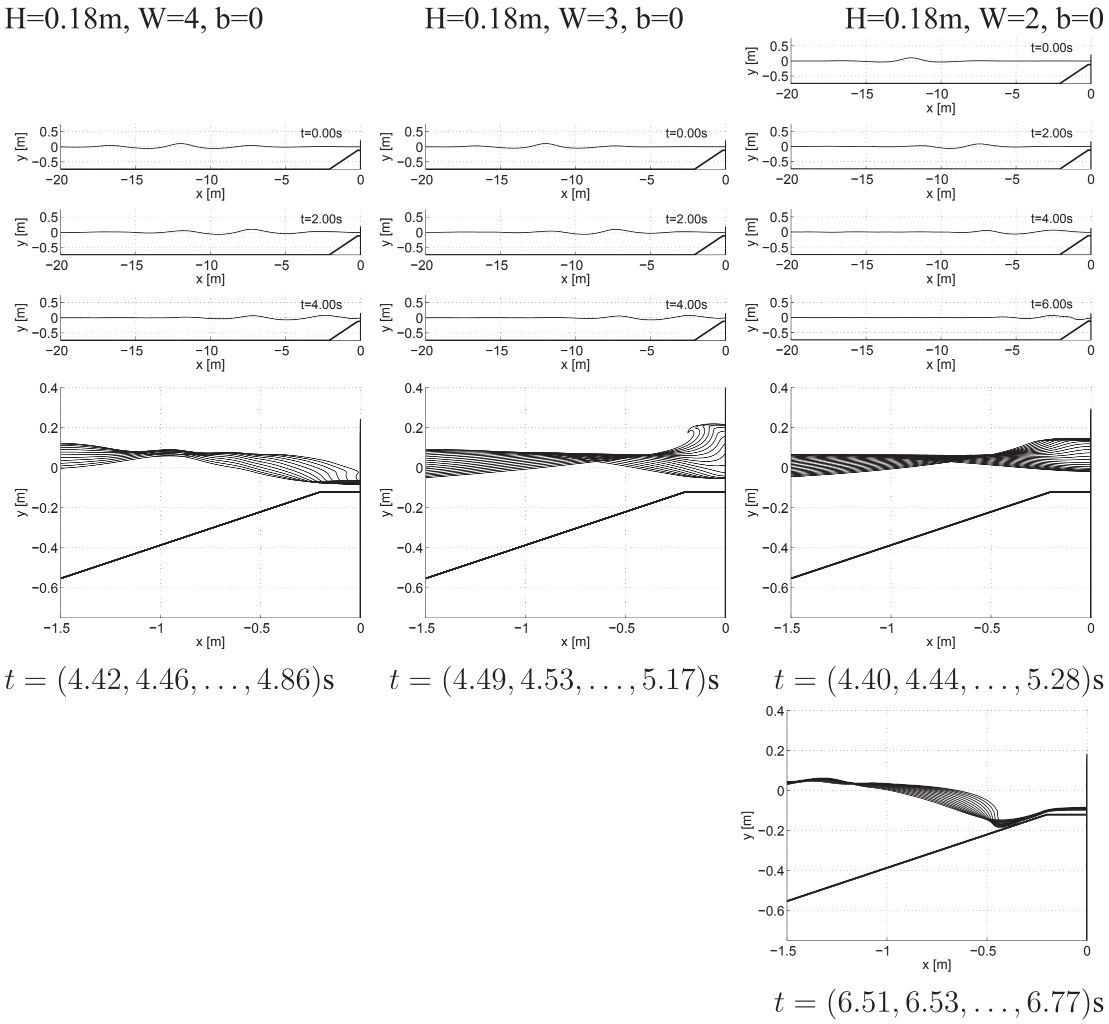

Figure 2: Impacts for varying group width. Upper panels show the group propagation towards the wall. The lower panels show details of the impact with timings given below each plot.

locity is less than phase velocity. There is also some slight dispersion of the envelope since there are no envelope-soliton solutions for this depth-wavelength combination.

2.1 Variation of phase inside envelope

Results showing a wide variation in wave behaviour at the wall for wave groups with phase differences of a quarter wavelength relative to the wave envelope are illustrated in figure 1. As is readily seen there are big differences between the three examples at the wall, which result in very different maximum forces and pressures. The left-hand example is clearly the most violent and is associated with the lowest trough level at the wall.

Consideration of any one of the examples shows that it is not easy to determine a wave height at the wall. This is partly due to interaction with reflected waves, and to the strong time variation of the wave profiles.

2.2 Variation of envelope width

As may be seen, a fairly short group is shown in figure 1, giving a strong variation in the height of successive waves. We illustrate the importance of the height of successive waves by varying the group width, as illustrated in figure 2. The left column has the widest group and the right column the narrowest. The maximum height and phase of the waves relative to the envelope is not changed. The impact of the largest wave is shown in the row of close-up profiles and as before shows that there are significant differences. However, for the narrowest group, at the right, some further profiles are shown since it is the smaller crest following the largest which gives a significant breaker.

3 Summary and discussion

We have illustrated that for compact wave groups with the same offshore wave heights there can be very different wave behaviour at a structure. This is seen to be partly due to the phase of the peak wave as it reaches the structure, and partly related to the preceding wave.

These results are for one particular structure, clearly other structures are likely to have different behaviour. The last panel of figure 2 shows a breaking wave on the slope with a different character to that of the other examples breaking on the horizontal top of the mound. Floating structures introduce the further complication of their own motion.

Overall, detailed studies of wave impact are showing great variations from nominally similar waves. It seems that the way forward to making practical use of such results is to assess the probabilities of the differing types of impact.

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