RANDOM BREAKING WAVES - HORIZONTAL SEABED

HANS PETER RIEDEL[1] & ANTHONY PAUL BYRNE[2]

ABSTRACT

According to wave theories the depth limited wave height over a horizontal seabed has a wave height to water depth ratio (H/d) of about 0.8. Flume experiments with monochromatic waves over a horizontal seabed have failed to produce H/d ratios greater than 0.55. However designers still tend to use H/d 0.8 for their design waves. Experiments have been carried out using random wave trains in the flume over a horizontal seabed. These experiments have shown that the limiting H/d ratio of 0.55 applies equally well to random waves.

1. INTRODUCTION

Coastal structures are often located in water depths where the limiting wave height is determined by the maximum water level at the toe of the structure. In Australia there are many regions, particularly those with high tidal ranges, where the approach to a proposed coastal structure site has a slope in the range of 1 in 100 or flatter. Presently the breaking wave height used for design by a large percentage of designers is based on Coastal Engineering Research Centre (1984). For near horizontal seabeds the value of H/d is based on classical theories for wave breaking such as McCowan (1894).

However when monochromatic waves have been propagated over horizontal beds in flume studies, the researchers have typically found that a H/d ratio of 0.78 cannot be obtained. Nelson (1983) reviewed the available literature and presented the results of flume studies on wave breaking on horizontal and near horizontal seabeds. He found that for seabed slopes of 1:250 and flatter the H/d ratio did not exceed 0.55. Published data thus far has been for monochromatic waves.

The difference between a H/d ratio of 0.55 and 0.78 will have an enormous impact on the design wave possible on a coastal structure. In order to start applying these less conservative methods for estimating design waves it is important to ensure that random waves occurring in nature behave in a similar manner to monochromatic waves.

1, 2. Directors of Riedel and Byrne Consulting Engineers P/L
1. 146 Leichhardt Street, Spring Hill, Qld., Australia.
2. 396 Rokeby Road, Subiaco, W.A., Australia.

The study and results presented in this paper provide a start to extending the range of applicability to random waves. A limited number of tests were undertaken, for a horizontal seabed and for a slope of 1:100.

2. EXPERIMENTAL PROCEDURE

The wave flume at the Manly Hydraulics Laboratory of the Public Works Department, N.S.W. was used. Random and monochromatic wave generation is possible. The flume is 30m long, 1m wide and 1.4m deep. The bed is constructed of 1.5m long segments, each segment being supported by a pair of screw jacks. The flume floor can be jacked up to form any desired seabed profile. The slopes used in the test section were a horizontal bed and a 1:100 slope.

Near the paddle, the flume is 2m wide, allowing waves to be generated which will be large enough to retain their height after passing through a wave filter in a transition section.

An aluminium sliding wedge mounted on linear bearings is used as the wave paddle. Driving the paddle is a two sided hydraulic piston, whose position is controlled by a servo valve. The servo system consists of the servo valve, a linear voltage displacement transducer for feed back and the servo electronics, which compare the feedback signal with a drive signal provided by a PDP-11 computer.

Waves were generated in relatively deep water and propagated up an approach ramp to the test section. A beach with a reflection coefficient of less than 10% was used to dissipate the waves.

The floor of the flume was accurately levelled to ensure that the test section was horizontal or had a slope of 1:100 for at least 3 wavelengths (based on the peak period of the spectrum) between the approach ramp and the measurement station. Figure 1 shows a typical test arrangement.

Most of the tests were done with random waves with peak periods of 8 to 12 seconds at a model scale of 1:40. A Pierson - Moskowitz spectral form was adopted and its shape modelled on measured wave spectra during cyclones off the north Australian coast. All results are quoted in prototype dimensions. Some comparative tests with 8 to 14 second monochromatic waves were also completed.

For each test, measurements of wave heights were made by a series of capacitance wave probes along the flume. With random waves it is not possible to pick the section at which the wave is likely to break so the limiting wave heights were obtained by extracting the maximum wave height from a number of sections for each test over a 20 minute sampling period. For monochromatic waves the wave generator was adjusted progressively until the waves first began to break over the test section.

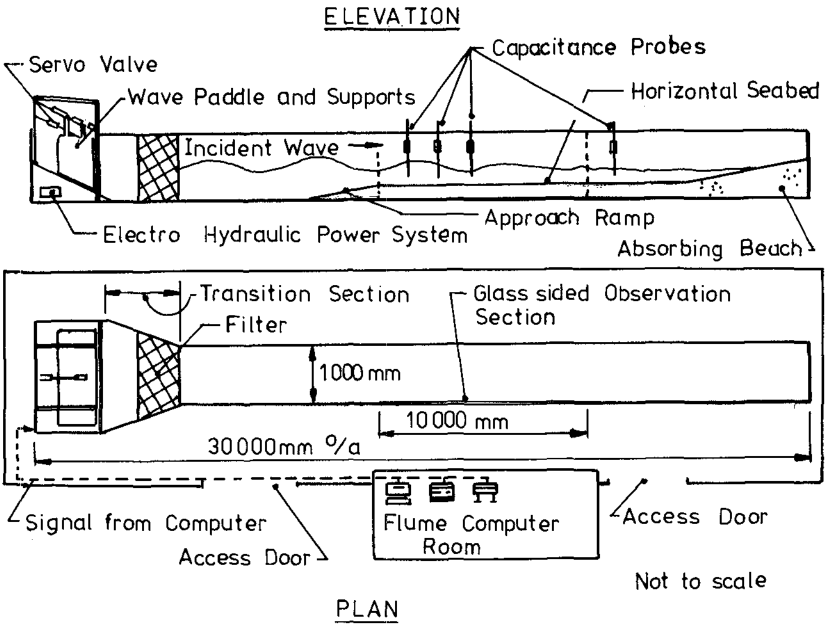


Figure 1. Experimental Setup.

Videotape recordings were made of a number of tests to assist in the interpretation of the results. A measured grid was marked on the side of the flume.

3. EXPERIMENTAL RESULTS

The most convenient method of presenting results in terms of measurable parameters is to use the non-linearity parameter (Fc) of Swart and Loubser (1979). This parameter is a function of T(wave period), d and H.

$$Fc = \left(\frac{H}{d}\right)^{0.5} \left[T\left(\frac{g}{d}\right)^{0.5}\right]^{2.5}$$

Waves of equal Fc have approximately the same relative wave shape.

Table 1 summarizes the results obtained for a horizontal bed. There are 3 data points for each peak period representing three different energy levels in the spectrum. At the lowest energy level only a few waves passed through unbroken. At each higher energy level the proportion of breaking waves increased.

TABLE 1.
TEST RESULTS

Test No.	Wave Type	Peak or Nominal Period	Energy Level	$\frac{Hmax}{d}$	Fc
1	Random	8	Low	0.46	50
2	Random	8	Medium	0.49	52
3	Random	8	High	0.44	49
4	Random	10	Low	0.50	92
5	Random	10	Medium	0.52	93
6	Random	10	High	0.53	94
7	Random	12	Low	0.54	150
8	Random	12	Medium	0.52	147
9	Random	12	High	0.52	148
10	Random	8	Low	0.48	52
11	Random	8	Medium	0.47	51
12	Random	8	High	0.52	54
13	Random	12	Low	0.49	143
14	Random	12	Medium	0.53	148
15	Random	12	High	0.52	148
16	Monochromatic	9	-	0.55	74
17	Monochromatic	10	-	0.56	97
18	Monochromatic	11	-	0.52	118
19	Monochromatic	12	-	0.51	146
20	Monochromatic	13	-	0.55	185

For the random waves the highest value of H/d measured was 0.54 and the values ranged from 0.44 to 0.54. The monochromatic waves had H/d ranging from 0.51 to 0.56 which is in agreement with Nelson's (1983) conclusions.

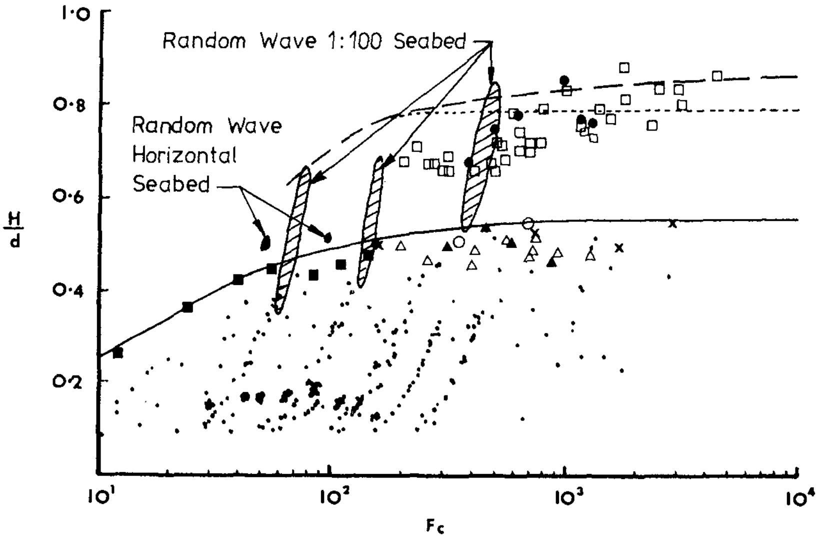
The tests for random waves over the horizontal seabed show a weak dependent of H/d on Fc. Note that the second sets of test results for each wave period correspond to different cut-off frequencies for the spectrum.

Figure 2 shows our data superimposed on the results presented by Nelson (1983). It is evident that for waves within a random wave train the limiting value of H/d is 0.55. There appears to be slightly less dependence on the non-linearity parameter than shown for experiments with monochromatic waves.

△ Nelson, slope 0.0000, data set 1.
▲ Nelson, slope 0.0000, data set 2.
x Mehaute, slope 0.0000.
■ Keating and Webber, slope 0.0000.
• others, slope 0.0000 (see text and Table 1).
○ Nelson, slope 0.00286.
□ Goda, slope 0.0100.
● Nelson, slope 0.0153.

Limiting Criteria

— — —Shore Protection Manual, slope 0.0100 (based on experimental data).
---------Shore Protection Manual, slope 0.0000 (based on theory).
————Nelson, slope 0.0000 (based on experimental data).



Adapted from Nelson 1983

Figure 2. H/d versus Fc.

In a separate set of tests about a year before the above tests were undertaken, some observations were made of the limiting breaking wave heights on 1:100 slope. The same facility and wave spectra were generated as described above. These tests produced a range of wave height to water depth ratios which showed quite a strong dependence on Fc. These observations were made less rigorously than the test results already discussed. Wave heights and water depth were measured off replays of video tapes.

The results are also shown on Figure 2.

4. DISCUSSION AND CONCLUSIONS

The ratio of limiting wave height to water depth over a horizontal seabed is 0.55 for both monochromatic and random waves. This can be important in the determination of extreme waves in shallow water where the seabed is horizontal or nearly horizontal. These results apply to a unidirectional wave train.

At slopes of 1 in 100 there is already a significant increase in the ratio of H/d and there is also a dependence on the non-linearity parameter Fc.

The extent of testing undertaken was limited and there may be other wave spectral forms that will not produce the same results. The spectra adopted here related to measured spectra in the area where the results were applied.

Most real sea conditions consist of more than one wave train where each wave train has an independent wave direction. It is not clear whether the same limits of H/d would apply. Also superimposed steady currents may have an influence.

There is an urgent need for continued research of depth limiting breaking wave heights

5. REFERENCES

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