CHAPTER 69

FLEXIBLE POROUS FLOATING BREAKWATERS

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ABSTRACT

Observation of the effect of towed rafts of pulpwood on lake and ocean waves led to a systematic investigation at model scale. An empirical equation compatible with wave theory was devised and lines representing this equation together with points representing experimental results are shown for different conditions. An example of the application of the equation to prototype wave action is given. Four box booms with porous fronts, arranged in series, were substituted for the model pulpwood jam and proved to be effective in damping waves.

INTRODUCTION

Towed rafts of loose pulpwood, in which the logs are often two or more layers deep, effectively damp lake and ocean waves. Observation of this process led to consideration of the use of a mass of logs, confined between boom sticks, as a floating breakwater. A series of experiments by Farrell (ref. 1) using model logs in a wave basin, Figure 1, demonstrated that log jam breakwaters do cause significant attenuation over a wide range of conditions.

Notation The meaning of the symbols employed is illustrated in Figure 2. The only designation not in common use is d, the depth from the water surface to the mean boundary of the bottom of the mass of logs.

EXPERIMENTS WITH MODEL BREAKWATERS

Most of Farrell's experiments were carried out in a 50 feet by 50 feet subdivision of the large University wave basin in 21.25 inches of water. Tests in differing depths of water indicated that the coefficient of transmission was not significantly affected by variations within the range of .3d to .7d, although the forces on the moorings increased at smaller depths. His data were regular and repeatable but in some instances difficult to explain. Later analysis of these data on a somewhat different basis led to revised relationships which gave a strong indication of a resonance effect when x/λ, the length of the jam divided by the wave length, was an integer. Since it seemed possible that some of Farrell's measurements had been affected by multiple reflections it was decided to conduct additional experiments.

The large wave basin being unavailable, the writers carried out a series of two-dimensional tests in a 3 feet by 60 feet flume in 16 inches of water. The relationship between period and length of wave was checked photographically and found to depart very little from first order deep water theory. The beach was made of layers of fibre matting according to Farrell's design and had a coefficient of reflection of about .07. Wave heights were measured by two resistance probes and traced out by a multiple pen recorder.

The data from these experiments are shown as points in Figures 4, 5 and 6. The resonance effect mentioned above seems to be confirmed by the points in Figure 5, although slightly masked by the scatter in one of the series. The increase in the value of C_T, the coefficient of transmission for waves of small height was unexpected but definitely confirmed by several series of tests of which two are shown in Figure 6.

The coefficient of reflection, C_r, taken as the ratio at a position in front of the breakwater, of the wave height with the breakwater in place to that with no breakwater present, was small, seldom exceeding .10. There was no evidence of substantial change in C_r with change in the wave steepness, H/λ, but some indication of larger values when x/λ had a value in the vicinity of .5, 1.5 etc.

be designed into the breakwater system, if it is to meet the stringent requirements given in the Introduction

It is evident that the mooring arrangement influences the "rolling" motion and hence the waves generated behind the breakwater Consequently, an optimum mooring arrangement must be devised whereby motion is minimized without sacrifice of minimum mooring-line force Figure 32 shows several mooring arrangements that might be considered The top system has already been tested The others show promise of restraining motion They should be studied as physical systems subjected to oscillatory force inputs to determine which is likely to produce the least rolling motion The best of these should be tested in the two-dimensional tank to determine the most effective mooring arrangement

The next step in evaluation is to determine the effectiveness of the bottom of the breakwater in reducing motion The two-dimensional experiments at Webb were made without a bottom while the CERC study included both a perforated and solid bottom The solid bottom appeared to reduce the waves more, but eyes are not to be trusted A study of different bottoms (for the best mooring arrangement) should reveal another aspect of motion and wave reduction that will influence the final design

The last phase of design optimization for the floating breakwater involves perforating the back wall (as in the case of the fixed breakwater) to further reduce rolling This will be associated with the best conditions achieved in the preceding tests The net result will be a final basic design for the unit breakwater that hopefully combines achievement of wave reduction, as specified, with a substantial force reduction in the mooring lines as compared with the solid breakwater It goes without saying that two-dimensional tests should be made to verify the expected performance

Once the optimum design for the breakwater unit is determined, it is essential to evaluate its performance as an operational entity This means testing of 5 unit breakwaters in a three-dimensional tank, such as at Stevens Institute of Technology This would include a variety of wave conditions, and, if physically possible, at least one variation in direction of incident waves. In particular, a series of irregular wave forms corresponding to different states of sea, should be used From this data, spectral analysis will reveal the nature of structural and wave damping effectiveness in moderate and storm conditions, without regard to the nonlinearity of the system

If such a program is successful, it will culminate in a final basic design for the complete breakwater system (fixed and floating) including all aspects of breakwater geometry and mooring arrangement

It was assumed that the kinetic energy dissipation would be related to x/λ also and that in addition it would be proportional to the fraction of the total kinetic energy present in a top layer of water which could be affected by the jam. The fraction of the kinetic energy present in a top layer of specified thickness, z, for a wave of given dimensions was designated R(KE) and eventually the equation

$$KE = 1.47\, R(KE)\, (x/\lambda)^{.5}$$

was evolved. For numerical evaluation of R(KE), the following expression (ref. 2) was employed.

$$R(KE) = \left[1 - \frac{\sinh\ 2kS}{\sinh\ 2kh}\right] \times 100\%$$

where h is total depth

and $S = h - z - d$

Evaluation of this expression was carried out by computer for a range of values of h/λ, and is shown on Figure 10.

Of course a means of evaluating S for given physical conditions is necessary. Assuming that z is at least related to the thickness of the boundary layer, and that the thickness of the oscillating boundary layer below the extremely rough lower surface of the jam is proportional to the thickness of the turbulent boundary layer formed next to a smooth plate, the following relationship was postulated.

$z \propto (\nu/U)^{1/5}\ x^{4/5}$ where

$U \propto \pi H/T \propto \pi H/\sqrt{\lambda}$, and

$x \propto \pi H$

Thus $z \propto H^{.6}\ \lambda^{.1}$ and, choosing a constant on the basis of fit, $z = .025\, H^{.6}\, \lambda^{.1}$.

C_T, as predicted from the equation, is shown by the lines on Figures 4, 5 and 6.

PROTOTYPE PERFORMANCE

The one set of field measurements obtained showed that waves of length 31 feet and height 1.8 feet had a transmission coefficient of .17 through a jam about .8 feet deep and 300 feet long. The equation indicates a value of .173 for these circumstances but the test is not within the range of practical interest ($x = 10\lambda$) and, while reassuring, should be regarded as inconclusive.

Using the equation it may be predicted that in deep water a wave of length 75 feet and height 3 feet would have a transmission coefficient of .589 through a log breakwater 200 feet wide and 1.5 feet deep. Such a breakwater would contain 200 cords of wood for each 100 feet of length and the transmitted wave would have a height of $(.589)^2$ 3.0 = 1.05 feet. If the breakwater were 300 feet wide the transmission coefficient would be .468 and the height of the transmitted wave .66 feet.

NEW DESIGN

Since a porous floating breakwater of logs is effective in damping waves and is relatively easy to anchor because of its low reflection characteristics and the fact that it acts on both sides of the wave crest at once, it is worthwhile to consider other methods of constructing such a device.

As a beginning tests were carried out using box booms .2 feet deep with open top and one porous side as shown in Figure 8. The booms were more effective and also had lower coefficients of reflection when the porous side faced the approaching waves. During testing the outer booms of the group were anchored in position using chains of length equal to 5 times the depth of the water. The group was effective in damping the waves only when the tension in these anchor lines was sufficient to maintain the centre to centre spacing. The action of a group of 4 box booms in series is shown in Figure 8, while the coefficients of transmission recorded for the same booms are set forth on Figure 7. It appears that such a wave damping device is most effective when the centre to centre spacing of the booms is equal to one half wave length.

CONCLUSION

A flexible porous floating breakwater extending over 2 or more wave lengths can greatly attenuate waves of moderate length. Such a device has two important advantages over most other breakwaters; its action is concentrated near the surface where most of the wave energy exists and it tends to dissipate the energy of each wave over a time and space interval, thus avoiding the creation of large shock forces.

It seems probable that breakwaters designed on this principle could be used to create economical temporary harbours for many purposes, including defence, short term commercial operations and summer recreational facilities.

REFERENCES

1. Farrell, J.C: The Attenuation of Water Waves by Hovering Breakwaters, M.Sc. Thesis, Queen's University, Sept. 1965.

2. Ippen, A.T: Estuary and Coastline Hydrodynamics, McGraw-Hill, 1966.

FIGURE 1. Farell's Apparatus

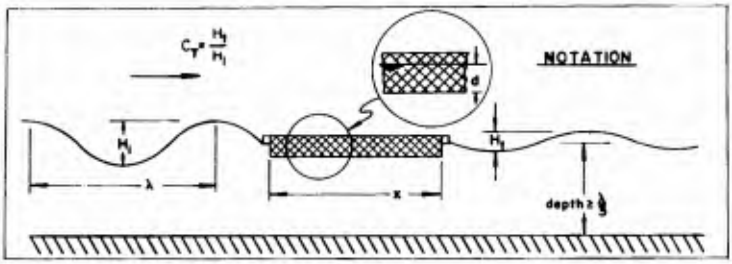

FIGURE 2. Notation Sketch

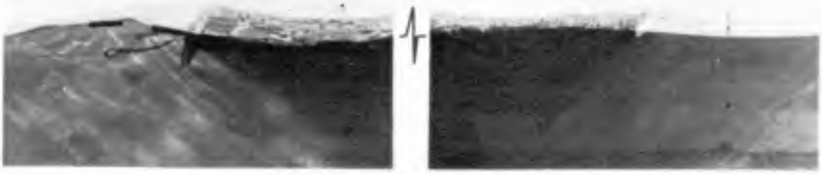

FIGURE 3. Wave Damping by Log Jam

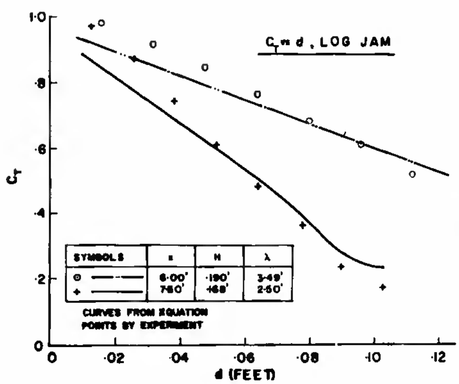

FIGURE 4. C_T vs d, Log Jam

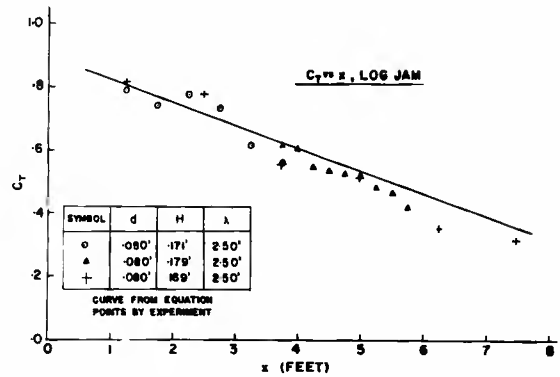

FIGURE 5. C_T vs x, Log Jam

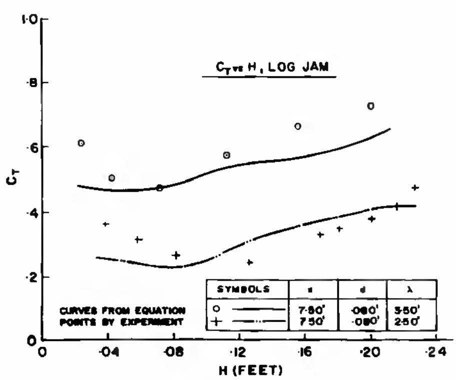

FIGURE 6. C_T vs H_i, Log Jam

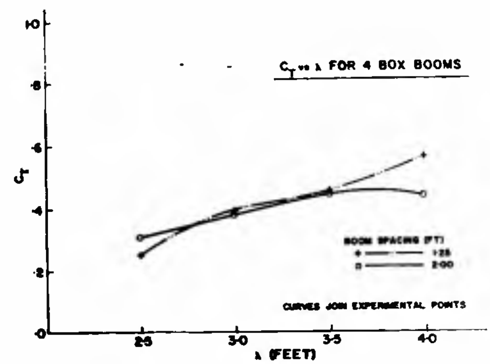

FIGURE 7. C_T vs λ For Box Booms

FIGURE 8. Box Boom

FIGURE 9. Action of Box Boom

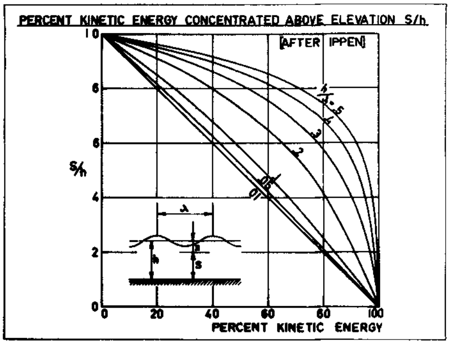

FIGURE 10. Vertical Distribution of Kinetic Energy
(After Ippen)