CHAPTER 54

AN IMPROVED ARRANGEMENT FOR THE PROGRESSIVE WAVE ABSORBER

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Abstract

The progressive wave absorber discussed here in this paper contains several porous plates with different porosity. Four arrangements of progressive wave absorbers were compared in wave absorption. The results indicate that of the four arrangements examined, Arrangement 4 is the most effective at absorbing waves, for a relative water depth ranging from 0.05 to 0.5. The results also show that an eight-plate wave absorber is more effective than a six-plate wave absorber. When waves are well within the relative water depth ranging from 0.05 to 0.5, reducing the G value of the rear plates further may provide even greater wave absorption efficiency .

I. INTRODUCTION

Wave reflection by such structures as wharves, breakwaters, or boundaries in a wave basin is of concern to many investigators, due to the many problems reflected waves can create. Le Me' haute (1972)first presented the concept of a progressive wave absorber, in which the porosity decreases toward the rear of the wave absorber. He developed a theory on progressive wave absorption and conducted model tests on a wave absorber constructed of aluminum shavings, which became more compact in the direction of propagation of the incident waves. Relatively low reflection coefficients were measured and experimental results qualitatively demonstrated the validity of his theoretical development.

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Jamieson & Mansard(1987) conducted experimental studies on a progressive wave absorber constructed of multiple rows of perforated vertical metal sheets, with a progressive decrease in porosity toward the rear of the wave absorber. Their metal sheets were aligned normal to the direction of the incident wave propagation. They concluded that the upright wave absorber can be designed to provide low reflection coefficients (less than 5%) over a wide range of wave heights, wave periods, and water depths.

Twu & Lin(1991)developed a theory on a progressive wave absorber constructed of multiple rows of vertical porous plates, which were similar in structure to those of Jamiesons'. They conducted model tests to verify their theoretical solution and noted that the model test results agree fairly well with the theoretical solution. In their study,a dimensionless porous effect parameter, $G = \rho\omega b/\mu K_0$ (Chwang and Dong,1984),was used to represent the porosity of the porous plates, in which μ is the dynamic viscosity of the fluid, b is a material constant of the porous plate, having the dimension of length, K_0 is the wave number, ω is the circular frequency and ρ is the fluid density. Twu & Lin concluded that the progressive wave absorber should function better if the difference in G value between adjoining porous plates is larger for the front plates than for the rear plates. In Twu & Lin's study, the difference in G values between adjoining porous plates were progressively decreased, but the rate of decrease was arbitrarily selected. The goal of this paper is to determine exactly what decreased rate of G value should be adopted so that the progressive wave absorber will function more effectively, and if fewer porous plates can be installed without adversely affecting the wave absorption efficiency.

II. CALCULATION PROCEDURE AND RESULTS

The progressive wave absorber used by Twu & Lin(1991) contained several porous plates, as shown in Figure 1. They assumed that the flow velocity passing through each porous plate obeys Darcy's Law. Defining the reflection coefficient, C_r, as the amplitude ratio of the reflected wave to the incident wave, they developed the following equations (Twu & Lin 1991):

$$C_r = (A^2 + B^2)^{1/2} \tag{1}$$

in which

$$A = Re(M_1) \tag{2}$$

$$B = Im(M_1) \tag{3}$$

$$M_s = \frac{M_{s+1}(2G_s - 1) + \exp(-i2K_0L_{s-1})}{(2G_s + 1) - M_{s+1}\exp(i2K_0L_{s-1})} \qquad s = 1, 2, 3, \cdots (n-1) \tag{4}$$

$$M_n = \frac{F_1 + iF_2}{F_3 + iF_4} \tag{5}$$

where n is the number of porous plates used in the wave absorber.

$$\begin{aligned}
F_1 &= (G_n - 1)\sin K_0r_n \cos K_0L_{n-1} + G_n \cos K_0r_n \sin K_0L_{n-1} \\
F_2 &= G_n \cos K_0r_n \sin K_0L_{n-1} - (G_n - 1)\sin K_0r_n \sin K_0L_{n-1} \\
F_3 &= -(G_n + 1)\sin K_0r_n \cos K_0L_{n-1} - G_n \cos K_0r_n \sin K_0L_{n-1} \\
F_4 &= G_n - \cos K_0r_n \cos K_0L_{n-1} - (G_n + 1)\sin K_0r_n \sin K_0L_{n-1} \\
G_s &= \frac{b_s\omega\rho}{\mu K_0} \qquad (s = 1, 2, 3, \cdots n)
\end{aligned}$$

G_s is a dimensionless porous-effect parameter of the plate "s". L_n, L_{n-1} and r_n are indicated in Figure 1. According to Twu and Lin (1991), wave reflection by a progressive wave absorber is closely related to the spacing between the adjacent porous plates, as well as to the progression of G value of these plates. In this investigation a distance of 0.88 times the water depth has been adopted as the spacing between adjacent plates, as suggested by Twu and Lin. Four methods of reducing the G value along the direction of incident wave propagation are compared for both six-plate and eight-plate wave absorber. The G values of the first and

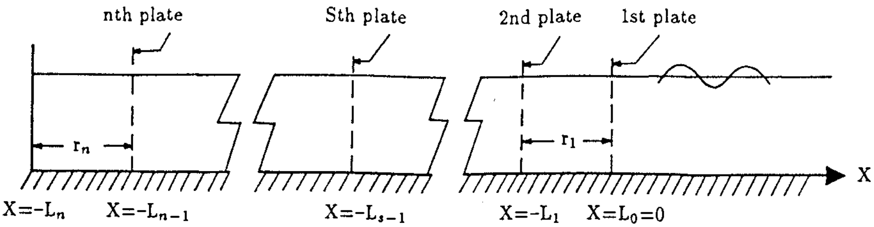

Fig.1 Schematic diagram of a progressive wave absorber

last plates are fixed at 16 and 1, respectively, for the first part of the study. The G values of the first and last plates were varied in the second part of the study.

The four arrangements of six-plate wave absorbers analyzed in this study were determined as follows:

1. The G values of the plates were evenly distributed, to obtain values of 16, 13,10,7,4 and 1, for plates 1 through 6, respectively.
2. The G value of each succeeding plate was reduced by the formula "16 exp (-x)", with x ranging from 0 to 2.7726, yielding G values of 16, 9.19, 5.28, 3.03,1.74,and 1.
3. The G value of each succeeding plate was reduced by the formula "16/x", with x ranging from 1 to 16, yielding G values of 16, 4, 2.28,1.6,1.23, and 1.
4. The G value of each succeeding plate was reduced by the formula "16/x^2", with x ranging from 1 to 4, yielding G values of 16, 6.25, 3.31, 2.04, 1.38 and 1.

The G values for each arrangement are summarized in Table 1.

Table 1. G Values for Six-Plate Wave Absorber

Arrangement number	Method of G reduction	G					
		Plate number					
		1	2	3	4	5	6
1	linear	16	13	10	7	4	1
2	$16\exp(-x_1)$	16	9.19	5.28	3.03	1.74	1
3	$16/x_2$	16	4	2.28	1.6	1.23	1
4	$16/(x_3)^2$	16	6.25	3.31	2.04	1.38	1

x_1 ranges from 0 to 2.7726
x_2 ranges from 1 to 16
x_3 ranges from 1 to 4

The reflection coefficient of these progressive wave absorbers were calculated over a relative water depth ranging from 0.05 to 0.5. The results are shown in Figures 2 through 5. The figures indicate that the reflection coefficient is higher for the first wave absorber (Figure 2) than for the last three. This verifies the conclusion reached by Twu and Lin, that the progressive wave absorber would function better if the difference in G values between adjacent porous plates is larger in the front part than in the rear part of the wave absorber. These figures also indicate that Arrangement (4), shown in Figure 5, is most effective in wave absorption among these four arrangements.

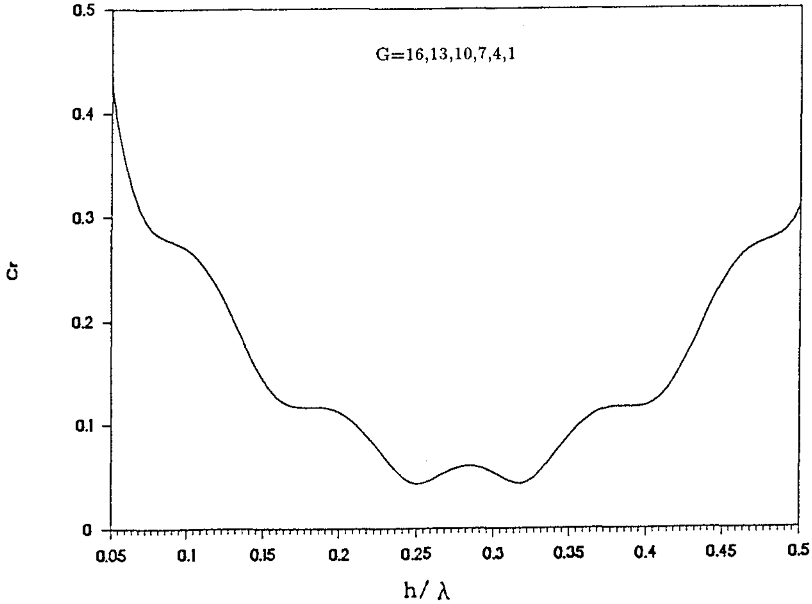

Fig.2 Wave reflection coefficient for the Arrangement (1) of six-plate wave absorber

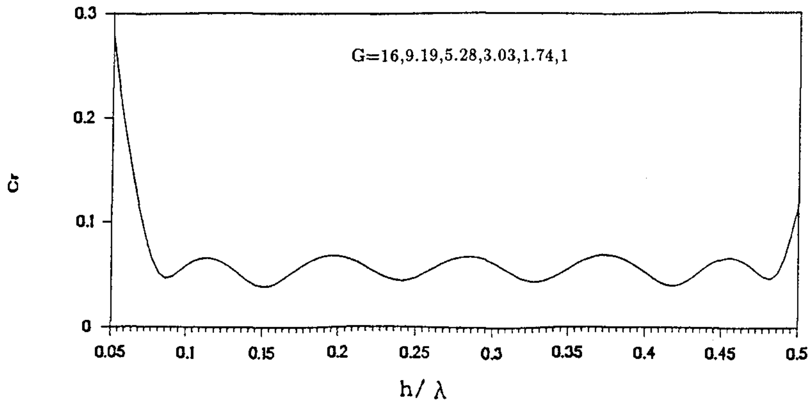

Fig.3 Wave reflection coefficient for the Arrangement (2) of six-plate wave absorber

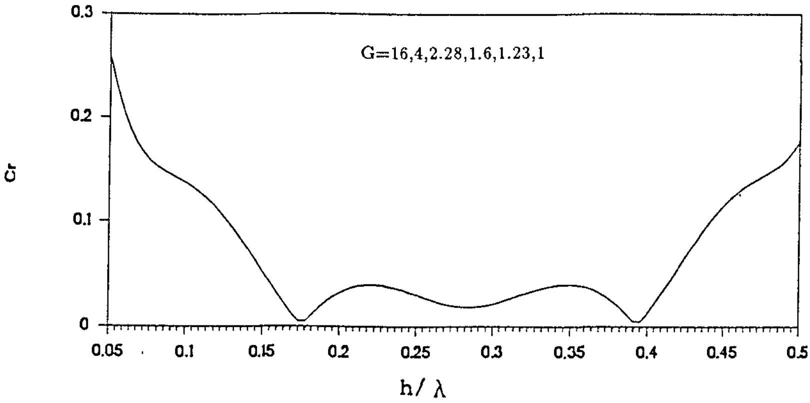

Fig.4 Wave reflection coefficient for the Arrangement (3) of six-plate wave absorber

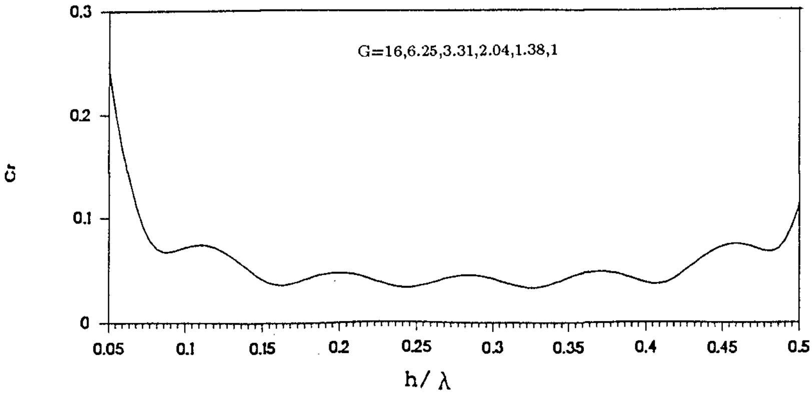

Fig.5 Wave reflection coefficient for the Arrangement (4) of six-plate wave absorber

The G values for each arrangement of the eight-plate wave absorber were determined by applying the same formulas used to determine the G values for the six-plate wave absorber.

The G values for each arrangement are presented in Table 2, and the results are plotted on Figures 6 through 9. These figures indicate that the wave reflection coefficient follows a similar trend for both six-plate and eight-plate wave absorbers, and that Arrangement 4 again yields the most effective wave absorption over the considered range. This wave absorber maintains a wave reflection coefficient of less than .04 over the relative water depth ranging from 0.11 to 0.46, which satisfies the requirement for a wave basin wave absorber.

Table 2. G values of an Eight-Plate Wave Absorber

Arrangement number	Method of G reduction	G							
		Plate number							
		1	2	3	4	5	6	7	8
1	linear	16	13.86	11.71	9.57	7.43	5.29	3.14	1.0
2	$16\exp(-x_1)$	16	10.77	7.25	4.88	3.28	2.21	1.49	1.0
3	$16/x_2$	16	5.10	3.02	2.15	1.67	1.37	1.15	1.0
4	$16/(x_3)^2$	16	7.84	4.64	3.06	2.17	1.62	1.25	1.0

x_1 ranges from 0 to 2.7726
x_2 ranges from 1 to 16
x_3 ranges from 1 to 4

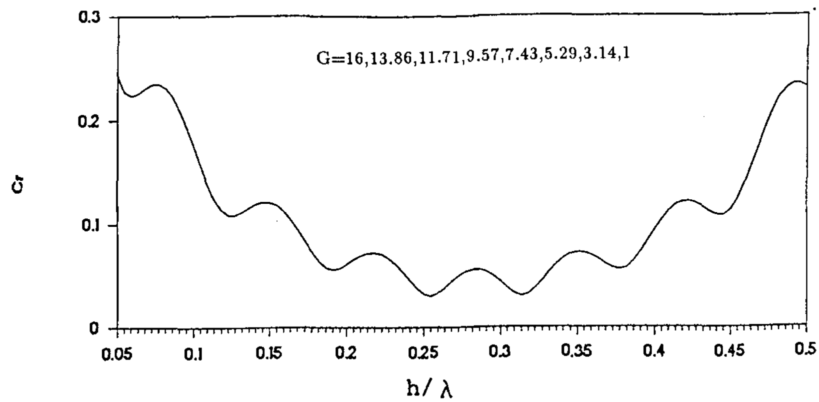

Fig.6 Wave reflection coefficient for the Arrangement (1) of eight-plate wave absorber

The next step was to analyze the effect on the reflection cofficient of varying the G value of the first and last plate. The best arrangement in the previous analysis, Arrangement 4, was selected for an eight-plate wave absorber. For the first case, the G value of the first plate was changed from 16 to 14 and from 16 to 20 , while holding the G value of the last plate constant. The G values of the plates

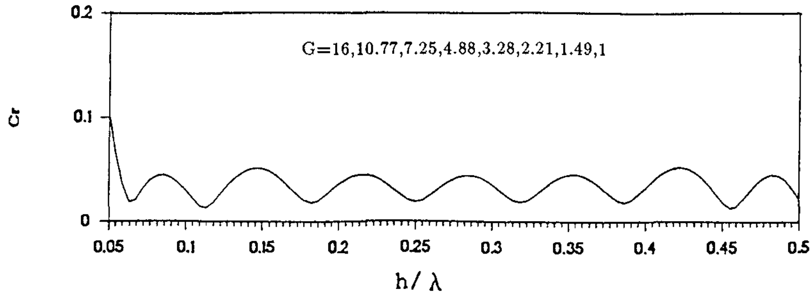

Fig.7 Wave reflection coefficient for the Arrangement (2) of eight-plate wave absorber

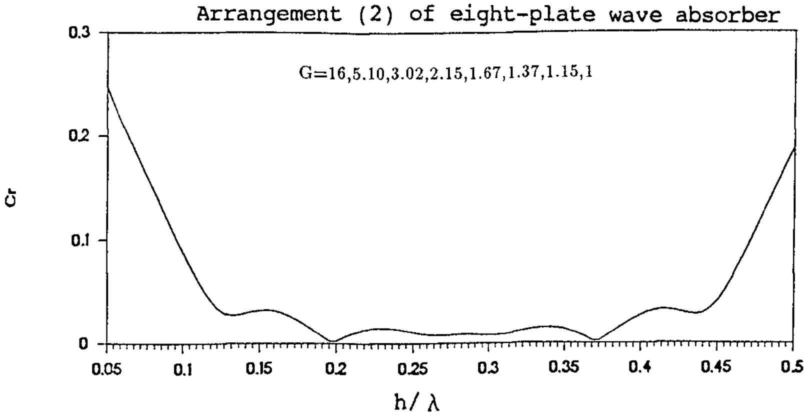

Fig.8 Wave reflection coefficient for the Arrangement (3) of eight-plate wave absorber

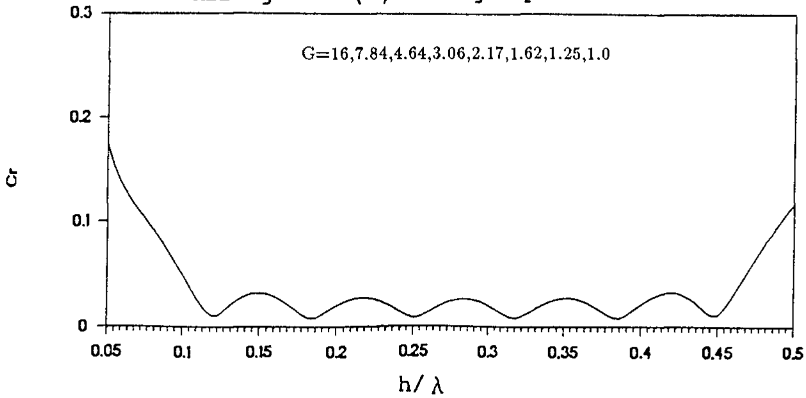

Fig.9 Wave reflection coefficient for the Arrangement (4) of eight-plate wave absorber

in between were determined from the formula G_1/x^2 where G_1 is the G value of the first plate. The results are plotted on Figures 10 and 11. A comparison of Figures 10 and 11 with Figure 9 indicates a slight increase in the reflection coefficient when the G values of all but last plate is either increased or decreased.

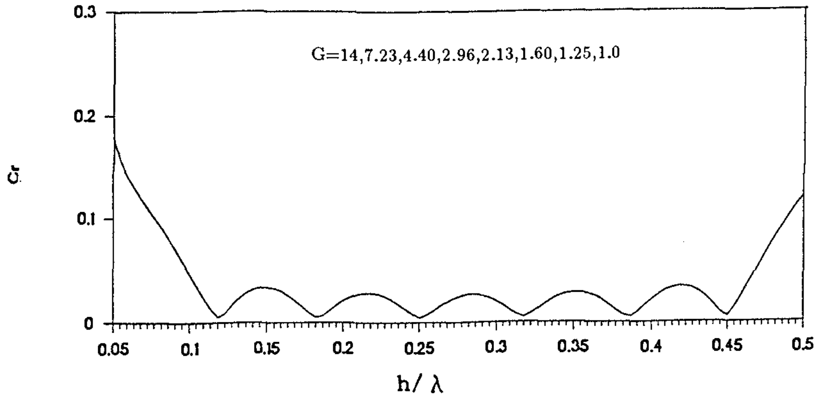

Fig.10 Wave reflection coefficient for the Arrangement (4) of eight-plate wave absorber with G value reduced for the front plates

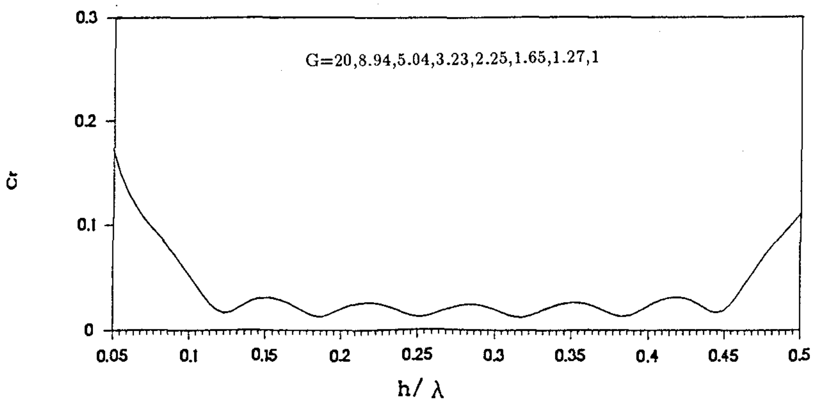

Fig.11 Wave reflection coefficient for the Arrangement (4) of eight-plate wave absorber with G value increased for the front plates

For the second case, the G value of the first plate is held at 16 and the G value of last plate changed to 0.5 and 2.0. The G values of the plates in between are modified relative to the G value of the last plate following the formula G_1/x^2. The results are plotted on Figures 12 and 13. A comparison of Figure 12 with Figure

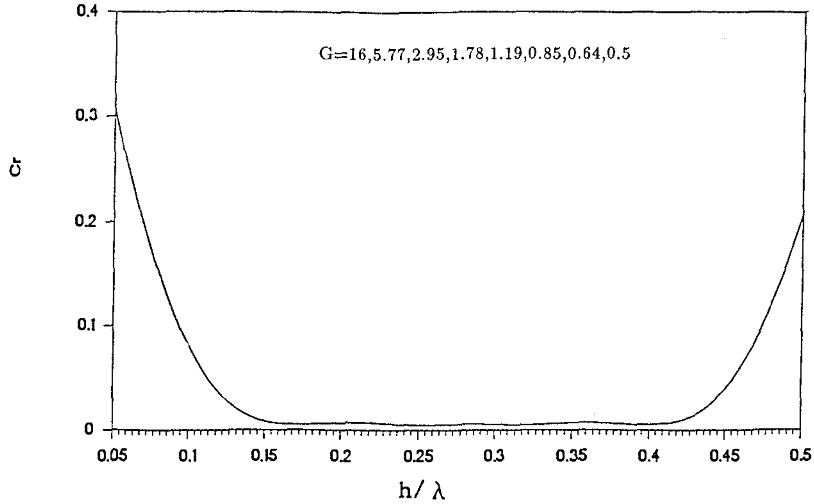

Fig.12 Wave reflection coefficient for the Arrangement (4) of eight-plate wave absorber with G value reduced for the rear plates

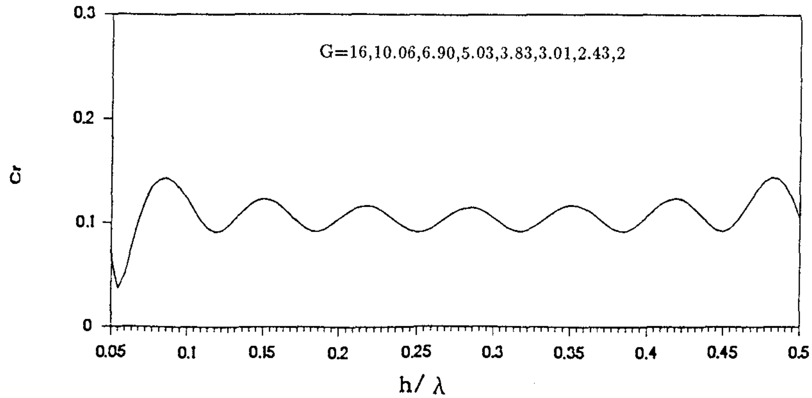

Fig.13 Wave reflection coefficient for the Arrangement (4) of eight-plate wave absorber with G value increased for the rear plates

9 indicates that, when the G value of the last plate is equal to 0.5 the reflection coefficient is lower for h/λ values between approximately 0.15 and 0.42, but higher for other h/λ values. Changing the G value of the last plate to 2.0 resulted in a larger reflection coefficient for most values of h/λ, as shown on Figure 13.

This comparison indicates that the reflection coefficient is more sensitive to the G values of the rear plates than the front plates of the progressive wave absorber. If waves which contain only a small range of wave lengths require damping, such as for $0.15 < h/\lambda < 0.42$, the G values of plates in the rear part of the wave absorber can be reduced.

III. CONCLUSIONS

The wave absorption efficiency of a six-plate and eight-plate wave absorber was investigated mathematically to determine the most effective distribution of G values. The results indicate that of the four arrangements examined, Arrangement 4 is the most effective at absorbing waves, for a relative water depth ranging from 0.05 to 0.5. The results also show that an eight-plate wave absorber is more effective than a six-plate wave absorber. When waves are well within the relative water depth ranging from 0.05 to 0.5, reducing the G values of the rear plates further may provide even greater wave absorption efficiency.

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