CHAPTER 79

WAVE REFLECTION BY A NUMBER OF THIN POROUS PLATES FIXED IN A SEMI-INFINITELY LONG FLUME

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ABSTRACT

The reflection of small-amplitude surface waves by a number of vertical porous plates is investigated . The plates are fixed in a semi-infinitely long channel of constant depth.Analytic solutions in dimensionless closed from are presented for the surface wave profiles in the several regions separated by these plates . And from them the reflection coefficient is obtained . Three cases , one to three porous plates, are evaluated. The results show that for incident waves in the range of 1/20 < water depth/wave length < 1/2 , it is appropriate to maintain the spacing between every two adjoining plates,and between the end wall and its nearst plate at a value of 0.88 times the water depth. As two or three porous plates are used for damping wave , an arrangement would be more effective if the front porous plate has a larger porosity and the back one has a smaller porosity. Several experimental tests for these porous-plate wave absorbers are conducted and the reflection coefficients are measured by using Goda's method. It is found that the theoretical solutions agree fairly well with the experimental results.

I. INTRODUCTION

The reflection and transmission of small-amplitude surface waves by a thin vertical barrier were first studied by Dean (1945) . In Dean's analysis , the vertical barrier was submerged in water with its top edge at a distance below the free surface. Since then , several similar problems have been analyzed by authors, such as Wiegel(1960), Newman(1965), Mei(1969), Macaskill (1979) , etc . In most of their analysis, the obstacles are assumed to be placed in a spacious water area without any boundary effect.It is known that if there is any other structure existing around the barriers, such as a back wall , the estimating results will be different . Chwang (1984) analyzed the reflection of small-amplitude surface wave by a thin porous plate fixed near the end of a semi-infinitely long channel of constant depth . Chwang found that as the distance

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between the porous plate and the channal end wall (ℓ) is equal to a quarter wave length plus a multiple of half-wave length of the incident wave, then the reflected wave amplitude is reduced to a minimum . In water areas where the waves have a variety of wave length , it is unlikely to keep a constant value for ℓ / λ (λ the wave length) . Then in this situation , The problems of how the spacing between the porous plate and the end wall may affect the reflection coefficient if a single plate is used,and what might be the appropriate spacing among these plates if a number of porous plates are adopted are investigated in this paper.

II .THEORETICAL CONSIDERATION

Three thin porous plates are assumed to be located in a semi-infinitely long channel of constant depth shown in Figure 1. The first plate is located at x=0,the second at $x=-\ell_1$,the third at $x=-(\ell_1+\ell_2)$, and the end wall at $x=-(\ell_1+\ell_2+\ell_3)$. An incident wave propagating in the negative x direction toward the porous plates is represented by

$$\eta_i = a \sin(\omega t + K_0 x) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where η_i is measured from the undisturbed mean free surface at y=h ,K_0 is the wave number ,ω is the circular wave frequency and a is the incident wave amplitude which is assumed to be very small in comparison with the water depth(h).

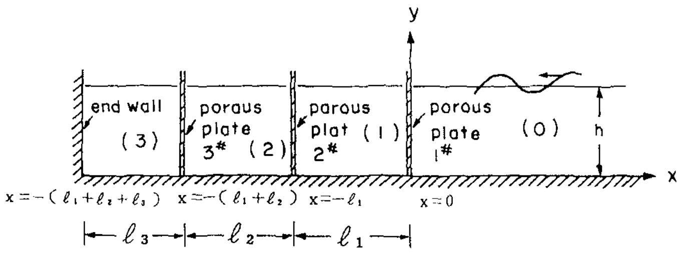

Fig.1. Sketch of three porous plates in a semi-infinitely long flume.

The fluid in the channel is assumed to be inviscid and incompressible,and its motion irrotational. Therefore,the velocity potentials $\Phi_j(x,y,t)$ exist in all regions and the velocity of the fluid can be expressed as

$$\vec{V}_j = \vec{\nabla} \Phi_j \quad (j=0,1,2,3) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

where the subscript j refers to the j th fluid region . Region (0) represents the region x>0, region (1) represents $-\ell_1<x<0$, region (2) represents $-(\ell_1+\ell_2) < x < -\ell_1$, and region (3) represents $-(\ell_1+\ell_2+\ell_3) <x< -(\ell_1+\ell_2)$. The velocity potentials satisfy the two-dimensional Laplace equation

$$\nabla^2 \Phi_j = 0 \quad (j=0,1,2,3) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (3)$$

The linearized free-surface kinematic and dynamic condition are, respectively

$$\frac{\partial \Phi_j}{\partial y} = \frac{\partial \eta_j}{\partial t} \quad \text{at } y=h \ (j=0,1,2,3)\ldots\ldots\ldots\ldots(4)$$

$$\frac{\partial \Phi_j}{\partial t} + g\,\eta_j = 0 \quad \text{at } y=h \ (j=0,1,2,3)\ldots\ldots\ldots\ldots(5)$$

Where g is the gravitational constant . From equation (4) and (5) we obtain the linearized free-surface condition for the velocity potentials Φ_j

$$\frac{\partial^2 \Phi_j}{\partial t^2} + g\frac{\partial \Phi_j}{\partial y} = 0 \quad \text{at } y=h \ (j=0,1,2,3)\ldots\ldots(6)$$

The normal velocity of the fluid must vanish at the bottom of the channel. Hence

$$\frac{\partial \Phi_j}{\partial y} = 0 \quad \text{at } y=0 \ (j=0,1,2,3)\ldots\ldots\ldots\ldots\ldots(7)$$

Let the normal velocity of the fluid passing through the porous plate from region 0 to region 1 be W_1 (y,t), that from region 1 to region 2 be $W_2(y,t)$ and that from region 2 to region 3 be $W_3(y,t)$. Then, the boundary conditions on both sides of each thin porous plate are

$$\frac{\partial \Phi_j}{\partial x} = -W_1 \quad \text{at } x=0 \ (j=0,1) \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$\frac{\partial \Phi_j}{\partial x} = -W_2 \quad \text{at } x=-\ell_1 \ (j=1,2) \ldots\ldots\ldots\ldots\ldots(9)$$

$$\frac{\partial \Phi_j}{\partial x} = -W_3 \quad \text{at } x=-(\ell_1+\ell_2) \ (j=2,3) \ldots\ldots\ldots(10)$$

The end wall is assumed to be solid and vertical, and the normal velocity vanishs at the wall. Therefore

$$\frac{\partial \Phi_3}{\partial x} = 0 \quad \text{at } x=-(\ell_1+\ell_2+\ell_3) \ldots\ldots\ldots\ldots\ldots(11)$$

It is assumed that the flow inside the porous plate obeys the Darcy's law. Hence the flow velocity inside the porous plate W is linearly proportional to the pressure difference between the two sides of each porous plate.

$$W_1(y,t)=\frac{b_1}{\mu}(P_0-P_1) \quad \text{at } x=0 \quad \ldots\ldots(12)$$

$$W_2(y,t)=\frac{b_2}{\mu}(P_1-P_2) \quad \text{at } x=-\ell_1 \quad \ldots\ldots(13)$$

$$W_3(y,t)=\frac{b_3}{\mu}(P_2-P_3) \quad \text{at } x=-(\ell_1+\ell_2) \quad \ldots\ldots(14)$$

where μ is the dynamic viscosity and b_1 、b_2 、b_3 are material constant,having the dimension of length.The hydrodynamic pressures $P_j(x,y,t)(j=0,1,2,3)$are related to the velocity potentials through the linearized Bernoulli equation

$$P_j = -\rho \frac{\partial \Phi_j}{\partial t} \quad (j=0,1,2,3) \quad \ldots\ldots(15)$$

where ρ is the density of the fluid. Since the incident wave is a periodic wave, the velocity potentials, porous flow velocities and the hydrodynamic pressures are assumed to have a time factor exp $(i\omega t)$.

$$\Phi_j=\phi_j(x,y)\exp(i\omega t) \quad (j=0,1,2,3)\ldots\ldots(16)$$

$$W_j = w_j(y)\exp(i\omega t) \quad (j=0,1,2,3)\ldots\ldots(17)$$

$$P_j = p_j(x,y)\exp(i\omega t) \quad (j=0,1,2,3)\ldots\ldots(18)$$

Here , a complex expression is used and only the real parts should be taken to represent physical quantities.

The solutions of equation (3) , satisfying boundary conditions (6),(7),(11) for each region are ,respectively,

$$\phi_0= A_0 \cosh K_0 y \exp(ik_0x) + A_0^* \cosh K_0 y \exp(-ik_0x) + \sum_{m=1}^{\infty} A^*_{0m} \cos K_m y\exp(-K_mX)\ldots\ldots(19)$$

$$\phi_1= B_0 \cosh K_0 y \exp(ik_0x) + \sum_{m=1}^{\infty} B_{0m} \cos K_m y\exp(K_mX) + B_0^* \cosh K_0 y \exp(-ik_0x) + \sum_{m=1}^{\infty} B^*_{0m} \cos K_m y \exp(-K_mX) \ldots\ldots(20)$$

$$\phi_2 = C_0 \cosh K_0 y \exp(ik_0 x) + \sum_{m=1}^{\infty} C_{0m} \cos K_m y \exp(K_m X)$$

$$+ C_0^* \cosh K_0 y \exp(-ik_0 x) + \sum_{m=1}^{\infty} C^*_{0m} \cos K_m y \exp(-K_m X) \quad \ldots\ldots\ldots\ldots\ldots(21)$$

$$\phi_3 = D_0 \cosh K_0 y \cos K_0(x + \ell_1 + \ell_2 + \ell_3)$$

$$+ \sum_{m=1}^{\infty} D_{0m} \cos K_m y \cosh K_m(x + \ell_1 + \ell_2 + \ell_3) \quad \ldots\ldots\ldots(22)$$

where the first term on the right hand side of equation (19) corresponds to the incident wave. A_0 is the incident wave constant and is related to the incident wave amplitude, a, by

$$A_0 = \frac{ag}{\omega \cosh k_0 h} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(23)$$

k_0, k_m $(m=1,2,3,\ldots\ldots\ldots)$ satisfy the dispersion relation

$$\omega^2 = gK_0 \tanh K_0 h = -g K_m \tan K_m h \quad \ldots\ldots\ldots\ldots\ldots(24)$$

Noting that $\cosh k_0 y$ and $\cos K_m y$ $(m=1,2,3,\ldots)$ form a complete set of orthogonal functions over the range from $y=0$ to $y=h$, substituting equations (19)~(22) into equations (8) ~ (11) by using equations (12)~(18), then equating the coefficients of terms with the same function, we obtain

$$A_{0m}^* = B_{0m} = B_{0m}^* = C_{0m} = C_{0m}^* = D_{0m} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots(25)$$
$$(m=1,2,3\ldots.)$$

$$\left.\begin{aligned}
\frac{A_0^*}{A_0} &= F_1^* + i F_2^*, & \frac{B_0}{A_0} &= F_3^* + i F_4^* \\
\frac{B_0^*}{A_0} &= F_5^* + i F_6^*, & \frac{C_0}{A_0} &= F_7^* + i F_8^* \\
\frac{C_0^*}{A_0} &= F_9^* + i F_{10}^*, & \frac{D_0}{A_0} &= F_{11}^* + i F_{12}^*
\end{aligned}\right\} \quad (26)$$

in which

$$F_1^* = \frac{F_9 F_{11} + F_{10} F_{12}}{F_{11}^2 + F_{12}^2}, \quad F_2^* = \frac{F_{10} F_{11} - F_9 F_{12}}{F_{11}^2 + F_{12}^2}$$

$$F_3^* = \frac{-2G_1\ (F_7F_{11} + F_8F_{12})}{F_{11}^2 + F_{12}^2}, \quad F_4^* = \frac{-2G_1\ (F_8F_{11} - F_7F_{12})}{F_{11}^2 + F_{12}^2}$$

$$F_5^* = \frac{-2G_1\ (F_5F_{11} + F_6F_{12})}{F_{11}^2 + F_{12}^2}, \quad F_6^* = \frac{-2G_1\ (F_6F_{11} - F_5F_{12})}{F_{11}^2 + F_{12}^2}$$

$$F_7^* = \frac{-4G_1G_2\ (F_3F_{11} + F_4F_{12})}{F_{11}^2 + F_{12}^2}, \quad F_8^* = \frac{-4G_1G_2(F_4F_{11} - F_3F_{12})}{F_{11}^2 + F_{12}^2}$$

$$F_9^* = \frac{-4G_1G_2\ (F_1F_{11} + F_2F_{12})}{F_{11}^2 + F_{12}^2}, \quad F_{10}^* = \frac{-4G_1G_2(F_2F_{11} - F_1F_{12})}{F_{11}^2 + F_{12}^2}$$

$$F_{11}^* = \frac{-8G_1G_2G_3F_{12}}{F_{11}^2 + F_{12}^2}, \quad F_{12}^* = \frac{-8G_1G_2G_3F_{11}}{F_{11}^2 + F_{12}^2}$$

in which

$$G_1 = \frac{\rho\omega b_1}{\mu k_0}, \quad G_2 = \frac{\rho\omega b_2}{\mu k_0}, \quad G_3 = \frac{\rho\omega b_3}{\mu k_0} \quad .....(27)$$

G_1,G_2 and G_3 are known as porous-effect parameter(Chwang 1984) for the three porous plates, respectively,

$$\begin{aligned}
F_1 &= (G_3-1)\ T_3^*\ (T_1T_2 - T_1^*T_2^*) + G_3T_3\ (T_1^*T_2 + T_1T_2^*)\\
F_2 &= G_3T_3\ (T_1T_2 - T_1^*T_2^*) - (G_3-1)\ T_3^*\ (T_1^*T_2 + T_1T_2^*)\\
F_3 &= (G_3+1)\ T_3^*\ (T_1^*T_2^* - T_1T_2) - G_3T_3\ (T_1^*T_2 + T_1T_2^*)\\
F_4 &= G_3T_3\ (T_1T_2 - T_1^*T_2^*) - (G_3+1)\ T_3^*\ (T_1^*T_2 + T_1T_2^*)\\
F_5 &= (2G_2-1)\ F_1 + (T_1^2 - T_1^{*2})\ F_3 + 2T_1T_1^*F_4\\
F_6 &= (2G_2-1)\ F_2 - 2T_1T_1^*F_3 + (T_1^2 - T_1^{*2})\ F_4\\
F_7 &= (T_1^{*2} - T_1^2)\ F_1 + 2T_1T_1^*F_2 + (2G_2+1)\ F_3\\
F_8 &= -2T_1T_1^*F_1 + (T_1^{*2} - T_1^2)\ F_2 + (2G_2+1)\ F_4\\
F_9 &= -(2G_1-1)F_5 - F_7, \quad F_{10} = -(2G_1-1)F_6 - F_8\\
F_{11} &= F_5 - (2G_1+1)F_7, \quad F_{12} = F_6 - (2G_1+1)F_8
\end{aligned}$$

$$T_1 = \cos k_0 \ell_1, \quad T_2 = \cos k_0 \ell_2, \quad T_3 = \cos k_0 \ell_3$$
$$T_1^* = \sin k_0 \ell_1, \quad T_2^* = \sin k_0 \ell_2, \quad T_3^* = \sin k_0 \ell_3$$

From equation (5),we have the free-surface equation for region (j)

$$\eta_j = -\frac{1}{g}\frac{\partial \Phi_j}{\partial t}\ (\ y=h) \qquad j=0,1,2,3 \quad ....(28)$$

Substituting equation (16) into (28) , by using equation (19), (25) and (26),then taking the real part,we obtain the free-surface elevation, ζ_0, for region(o)

$$\zeta_0 = R_e(\eta_0) = a\,[\sin(\omega t+k_0x)+F_1{}^*\sin(\omega t-k_0x)+F_2{}^*\cos(\omega t-k_0x)] \quad \text{.................(29)}$$

in which

$$a = \frac{\omega A_0 \cosh k_0h}{g}$$

The first term on the right hand side of equation(29) represent the incident wave , and the second and third term represent the reflected wave with a wave amplitude a_r as

$$a_r = (F_1{}^{*2} + F_2{}^{*2})^{1/2}a \quad \text{..........................(30)}$$

If we define the reflection coefficient as ratio of wave amplitude of the reflected to incident wave , then we have the reflection coefficient c_r as

$$c_r = (F_1{}^{*2} + F_2{}^{*2})^{1/2} \quad \text{............................(31)}$$

The free-surface elevation for regions (1) , (2) and (3) could also be obtain in the same way. They are respectively

$$\zeta_1 = a\,[\,F_3{}^*\sin(\omega t + k_0x) + F_4{}^*\cos(\omega t + k_0x) + F_5{}^*\sin(\omega t - k_0x) + F_6{}^*\cos(\omega t - k_0x)] \quad \text{...........(32)}$$

$$\zeta_2 = a\,[\,F_7{}^*\sin(\omega t + k_0x) + F_8{}^*\cos(\omega t + k_0x) + F_9{}^*\sin(\omega t - k_0x) + F_{10}{}^*\cos(\omega t - k_0x)] \quad \text{..........(33)}$$

$$\zeta_3 = a\,\{\,F_{11}{}^*\sin\omega t\cos[k_0(x+\ell_1+\ell_2+\ell_3)] + F_{12}{}^*\cos\omega t\cos[k_0(x+\ell_1+\ell_2+\ell_3)]\,\} \quad \text{............(34)}$$

The first and second term in equation (32) , (33) represent waves progressing from right to left,with amplitude $(F_3{}^{*2}+F_4{}^{*2})^{1/2}\cdot a$ and $(F_7{}^{*2}+F_8{}^{*2})^{1/2}a$ for regions (1) and (2), respectively. The third and fourth term are waves from left to right with amplitude $(F_5{}^{*2}+F_6{}^{*2})^{1/2}a$ and $(F_9{}^{*2} + F_{10}{}^{*2})^{1/2}a$, respectively.In region (3) ,the wave is in a situation of fully standing wave , with the same wave amplitude in both directions.

Ⅲ.THEORETICAL RESULTS

Based on equation (31),the theoretical reflection coefficient is computed. Letting $\ell_2=\ell_3=0$ we obtain the theoretical reflection coefficient for a single porous plate , showing the same result as Chwang's (1984). The porous plate produces the smallest reflection coefficient if the single porous plate is located at a distance of m/4 times the wave length (m=1,3,5 ,....)in front of the end wall. Letting $\ell_3=0$ we obtain a case for two porous plates.For a constant value of $\ell_2/\lambda = 0.25$, the relationship between C_r and ℓ_1/λ is calculated and shown in Figure 2 . With four G values presented

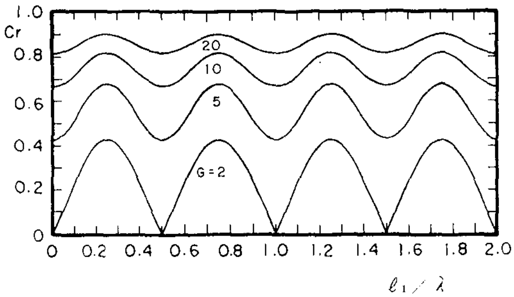

Fig.2. Reflection coefficient versus ℓ_1/λ for two porous plates with $\ell_2/\lambda=0.25$.

, it shows that the two porous plates produce the smallest reflection coefficient if the distance between the two porous plates is maintained at a distance of a multiple of half wave length.For G=2 a zero reflection coefficient can be reached.In the case of three porous plates,letting $\ell_3/\lambda=0.25$ and $\ell_2/\lambda=0.5$ the relationship between C_r and ℓ_1/λ is presented in Figure 3. Again ,it is found that as long as the distance between the first and second plate is maintained at a multiple of half wave length , the best wave absorption can be observed. For G=3 , a zero reflection coefficient can be obtained. From the above-mentioned cases, it is concluded that the best wave absorption could be achieved by locating every porous plate at a position where a clapotis node may occur . Both porous plates in Figure 2 ,or three porous plates in Figure 3 , have a uniform G value for each solution curve.Now,

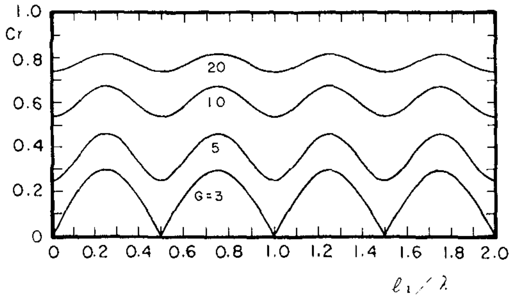

Fig.3. Reflection coefficient versus ℓ_1/λ for three porous plates with $\ell_2/\lambda=0.5$, $\ell_3/\lambda=0.25$.

we shall see what would happen if we use different G values for the two or three porous plates . Firstly , each plate of the two-porous-plate wave absorber is placed at where a alapotis node may occur.And two cases are calculated. One of them is that the first plate has a G value twice as large as that of the second plate. The other case has a reverse arrangement. Their results are shown in Figure 4 by the curve indicating C_r versus G. It is easily seen that for two porous plates with different G values , whether the first or the second plate has a larger porous - effect parameter does not have any effect on the reflection coefficient , if each

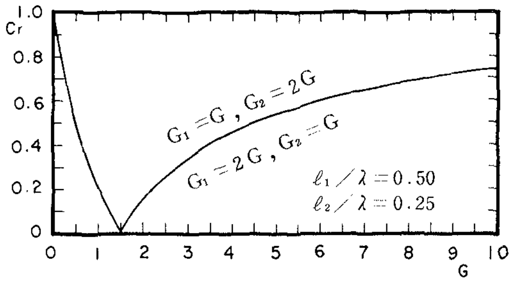

Fig.4. Comparison of reflection coefficient between two arrangements of two porous plates.

plate is located at a position where a clapotis node may occur. However ,if one of the plates is not located at such a position, a different phenomenon happens.This can be seen in Figure 5,in which the first porous plate is not located at such a position . It is indicated that the two-porous-plate wave absorber with a larger G value for the first porous plate than for the second porous plate always give a lower reflection coefficient than the one with reverse G values . The same phenomenon also happens in the three-porous-plate wave absorber.Figure 6 shows the case of three porous plates having each plate located at a position where a clapotis node would occur.And it is observed that whether the porous plates have an increasing order or decreasing order of G values from the front to the back of the wave absorber does not have any effect on the reflection coefficient. But in Figure 7, in which only one

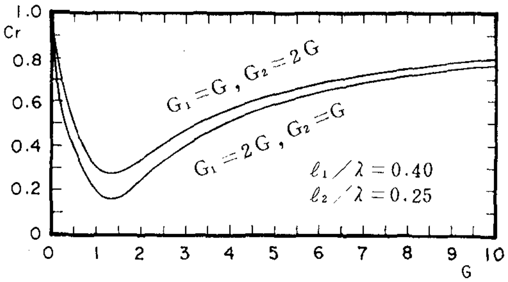

Fig.5. Comparison of reflection coefficient between two arrangements of two porous plates.

of the three porous plates is located at the particular position mentioned above,the reflection coefficient is quite different. The wave absorber with decresing order of G values for those plates along the incident wave direction tends to give a lower reflection coefficient in comparison with the increasing order case.According to the previous statement , we know that it is the most efficient way to locate each porous plate at a position where a clapotis node may occur,if a number of porous plates are adopted.However,in actual situation it is impractical to maintain a porous plate at such a position because of the variable incident wave length . The nondimensional parameter ℓ_s/λ is evidently a variable rather than

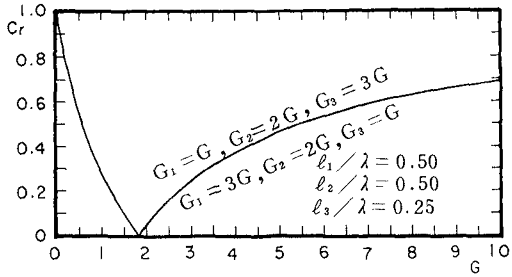

Fig.6. Comparison of reflection coefficient between two arrangements of three porous plates.

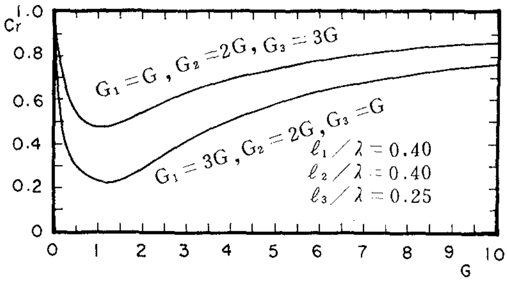

Fig.7. Comparison of reflection coefficient between two arrangements of three porous plates.

a constant. Therefore, a value of another dimensionless parameter ℓ_s/h is more suitable to be sought in an attempt to find a proper spacing among those plates.For incident waves corresponding to the range $0.095 < \omega^2 h/g < 3.13$,the reflection coefficient of the wave absorber has been calculated for various values of ℓ_s/h from 0.05 to 1.0. And it is found that whether it contains one, two or three porous plate(s) , the wave absorber gives a more homogenuous lower reflection coefficient as $\ell_s/h=0.88$.The reflection coefficient of these cases at this particular value of ℓ_s/h will be shown later in section (IV) and compared with the experimental results.

IV.EXPERIMENTAL TESTS

Three kinds of porous plates with different G values have been used for the model tests . They are (i) Plate No.1 : a stainless steel screen with 7 strings per cm , (ii) Plate No.2 : four layers of plate No.1 attached together, (iii) Plate No.3 : a layer of sponge of one cm in thickness and a plate No.1 attached together. To determe the material constant b of the porous plates , a water tank with a water head of 3 cm is used. The porous plate is placed at the outlet of the water tank , and the flow velocity passing through the porous outlet is measured. From eguation (12) or (13), (14) ,we have.

$$\frac{W}{\gamma} = \frac{b}{\mu} \left(\frac{\Delta p}{\gamma} \right) \qquad \cdots\cdots(35)$$

in which $\frac{\triangle p}{\gamma}$ represents the water head in tank . Based on equation (35) , with μ , γ , $\frac{\triangle p}{\gamma}$ and W being known, the material constant can be calculated.The material constant thus obtained for the porous plates is as follows:(i)porous plate No.1:$b=1.49\times10^{-6}$m , (ii) porous plate No.2:$b=1.01\times10^{-6}$m ,(iii) porous plate No.3:$b=3.25\times10^{-7}$m . Substituting the material constant for these porous plates into equation (27),the porous-effect parameter is abtained. And based on this , the theoretical reflection coefficient is computed. Finally , several comparisons between the theoretical solution and the experimental result are made.

Experiments for the wave reflection by the wave absorber are conducted in a 75 m long wave flume with a cross section of $1.2^{m}\times 1.0^{m}$. Two wave gauges are located in front of the wave absorber at proper positions suggested by Goda . Then the experimental reflection coefficients are calculated by Goda's method for separation of the incident and reflected waves. The advantage of Goda's method is that there is no need to adjust the positions of the two wave gauges whenever the wave period changes . Let $\triangle \ell$ be the distance between the two wave gauges and X_1 the distsnce between the first porous plate and its nearst wave gauge . Goda suggests

$$X_1 \geqq 0.1\lambda_{max}$$
$$0.05\ \lambda_{max} < \triangle \ell < 0.45\ \lambda_{min}$$

In the experimental test a water depth of 50 cm is adopted. Wave period varies from 0.85 to 3 secs and the wave length varies from 112.0 to 639.6 cm. Hence, X_1=120cm and $\triangle \ell$=40cm used here are both within the Goda's suggested range . In measuring the reflection coefficient two different ways have been conducted. One of them is fixing the wave period at a constant , 2 secs, and then varing the distance between the porous plate and the end wall.This is conducted for a case of single porous plate . The ℓ / λ value has been changed from 0.5 to 1.5 with an interval of 0.05 and its result is shown in Fig 8 . Whereas the other is fixing ℓ/h at a

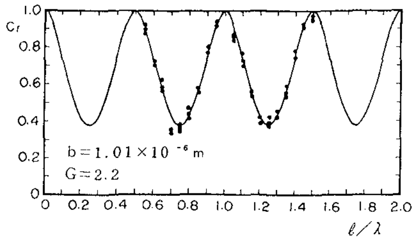

Fig.8. Reflection coefficient versus ℓ / λ for single porous plate with wave period=2S.

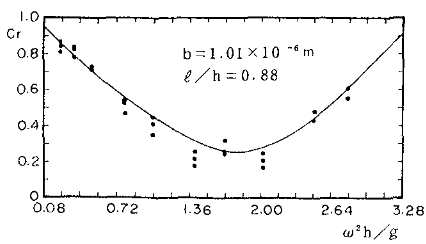

Fig.9. Reflection coefficient versus ω^2h/g for single porous plate.

constant and then changing the wave period during the experiment and its results are shown in Figure 9 to 13.In all these figures the theoretical value is presented by curve and the experimental result by dot. Figure 8 shows the reflection coefficient in terms of ℓ/λ for a single porous plate with material constant b= 1.01 $\times 10^{-6}$m. It is found that the experimental data agree very well with the theoretical solution . The wave absorber gives the lowest reflection coefficient if the porous plate is located at where the clapotis node may take place,i.e. ℓ/λ=1/4,3/4,5/4,7/4,....Figure 9 to 13 show the reflection coefficient in terms of ω^2h/g with ℓ_s/h=0.88 , which is the proper spacing found after series of calculation . Figure 9 ,10 ,11 are the results for single porous plate,two porous plates and three porous plates,respectively, with the same material constant , b=1.01$\times 10^{-6}$m , for all these porous plates . Good agreement is found between the theoretical solution and the experimental result . It is observed that a three-porous-plate wave absorber is more effective in damping wave than a two-porous-plate one , and the two-porous plate wave absorber is also more effective than the single-porous-plate one. Figure 12 shows the reflection coefficient for a two-porous-plate wave absorber with different material constants for the plates,one with b=1.01 $\times 10^{-6}$m, the other with b=3.25$\times 10^{-7}$m . Two arrangements have been performed, one with the larger b value for the front porous plate and the smaller b value for the back one , the other with the reverse order.Results of this two arrangements have been presented in this figure. It is shown, both theoretically and experimentally ,that an arrangement with a larger b value for the front porous plate and a smaller b value for the back plate tends to give a lower reflection coefficient than the arrangement with a reverse order does . For a three-porous-plate wave absorber, a similar phenomenon can be found by referring to Figure 13.Their material constants are 1.49$\times 10^{-6}$m, 1.01$\times 10^{-6}$m, 3.25$\times 10^{-7}$m , respectively . It is also found that the case that has a decreasing order of material constant for the porous plates gives a lower reflection coefficient, thus works better in wave absorption, than the other case does.In general speaking, theoretical curves in Figure 12 and 13 agree well with the experimental results.But the agreement is not as good as that in previous figures.This is because the present wave absorbers contain a porous plate No.3 each ,with material

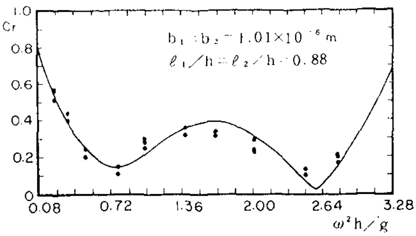

Fig.10. Comparison between the theoretical solution and the experimental result for two porous plates.

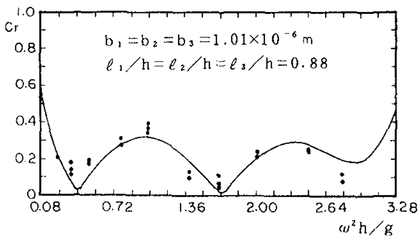

Fig.11. Comparison between the theoretical solution and the experimental result for three porous plates.

constant b= 3.25×10^{-7}m , which is a sponge attached together with a steel screen . This porous plate bends as the waves pass through .And this bending motion causes a discrepancy from the theoretical assumption that these porous plates are fixed in place ,thus leading to a little worse agreement between the experimental data and the theoretical value.

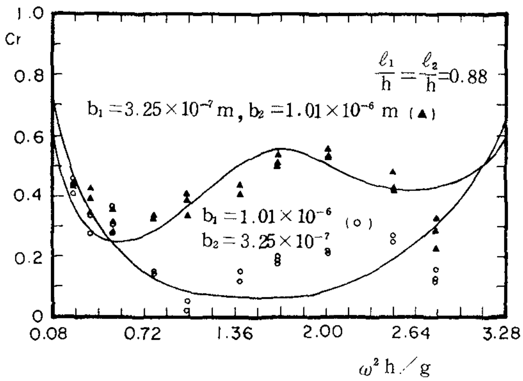

Fig.12. Comparison between the theoretical solution and the experimental result for two arrangements of two porous plates.

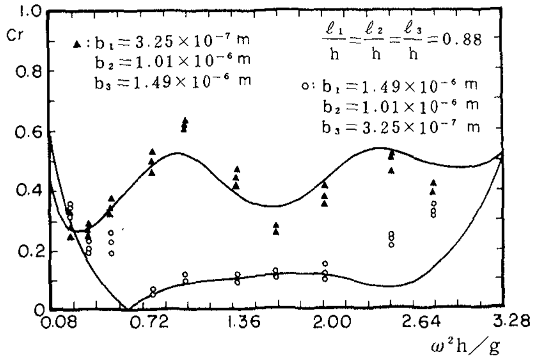

Fig.13. Comparison between the theoretical solution and the experimental result for two arrangements of three porous plates.

V.CONCLUSIONS

To damp wave by porous plate structure, the locations and the number of porous plates and the arrangement of material constant all play an important role in estimating the reflected waves from the structure.According to theoretical analysis ,the best location for a porous plate is a position where a clapotis node may take place . This measure could be applied to a wave absorber containg more than one porous plate . But in practical consideration ,it is much unlikely to choose a clapotis-node location for a porous plate because of the variable wave length.In this situation it is preferable to take a distance of 0.88 times the water depth for the space between any two adjoining porous plates,and between the end wall and its nearst one . In water areas with waves of varied wave periods,more than one porous plate would be more effective in wave damping than a single porous plate as long as the locations of the plates are properly selected . Likewise , a wave absorber containing more than two porous plates would be more effective than that containing only two porous plates . Furthermore, if more than two porous plates are adopted and an arrangement is used such that the material constants for these porous plates are in a decreasing order from the front to the back of the wave absorber, it would give a very low reflection coefficient.

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