THE EFFECTS OF VEGETATION DENSITY ON WAVE PROPAGATION THROUGH EMERGENT COMMUNITIES

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In this paper we develop an analytic model for wave propagation through an emergent vegetation community to investigate the effects of vegetation density on the wave attenuation.

The model is based on the mass and momentum conservation equations with drag and inertia forces associated with the vegetation stems. After normalizing the basic equations and the corresponding boundary conditions by using representative physical variables of an incident wave, we obtain the dimensionless forms of the equations with governing parameters, including the dimensionless vegetation density $a^* d^*$, dimensionless wave amplitude of the incident wave A_0^* / d^*, and the Froude number Fr. By solving the equations with a linear approximation of the drag force, wave characteristics through the vegetation community, such as a decay rate of wave height k_ε, wave number k_θ, celerity C, group velocity C_G, and wave energy E, are derived explicitly with respect to the dimensionless governing parameters.

The k_ε and E are represented as follows;

$$k_\varepsilon = \frac{1}{\sqrt{2}}\left\{-\left(1+\overline{C_M}\frac{\pi}{4}(a^* d^*)\right)+\sqrt{\left(1+\overline{C_M}\frac{\pi}{4}(a^* d^*)\right)^2+\left(\overline{C_D}\frac{\alpha}{2\omega}(a^* d^*)\left(\frac{A_0^*}{d^*}\right)\right)^2}\right\}^{1/2},$$

$$E = \frac{1}{4}\exp[-2k_\varepsilon x]\left\{4-\frac{2C_G}{C}\left(\frac{k_\theta^2+k_\varepsilon^2-1}{k_\theta^2+k_\varepsilon^2}\right)\right\},$$

where, $\overline{C_M}, \overline{C_D}$: the inertia and drag coefficients of the vegetation community, A_0^*: the incident wave amplitude, d^*: the plant diameter, ω: the angular frequency, and α : a constant.

The result of sensitivity analysis on the two unknown coefficients $\overline{C_M}, \overline{C_D}$ shows that the drag force is more important for wave attenuation in the vegetation community compared to the inertia force. Next, Fig. 1 demonstrates the effects of the dimensionless governing parameters, i.e., the $a^* d^*$ and A_0^* / d^* on the wave decay rate k_ε. We can see that the value of k_ε becomes large as the $a^* d^*$ and/or A_0^* / d^* increase. Therefore, when waves have high energy and/or plant population is high, the decay of the wave height becomes significant. Then, we examine the wave number k_θ and wave celerity C with respect to the governing parameters. The results indicate that the drag force of the vegetation makes the wave length smaller compared with the wave length of the incident wave, and that the corresponding wave celerity becomes small with the vegetation density. Finally, the wave energy profile in the vegetation community along with the wave propagation direction x is examined as shown in Fig. 2. It shows that the wave energy E attenuates significantly when the vegetation density $a^* d^*$ becomes large.

It is obvious from the results obtained in this paper that the decay rate of the wave height and energy, wave number, and celerity are much influenced by the vegetation population density as well as the wave amplitude of the incident wave. In next research, the inertia and drag coefficients will be evaluated from laboratory experiments.

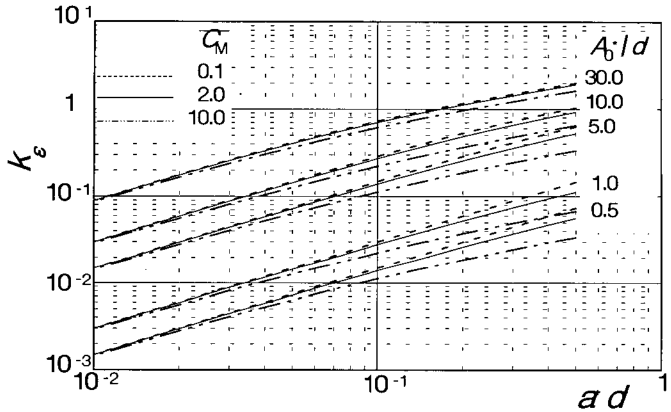

Fig. 1 The relationship between the wave decay rate k_ε and the vegetation density $a^* d^*$. ($\overline{C_D}$=1.2)

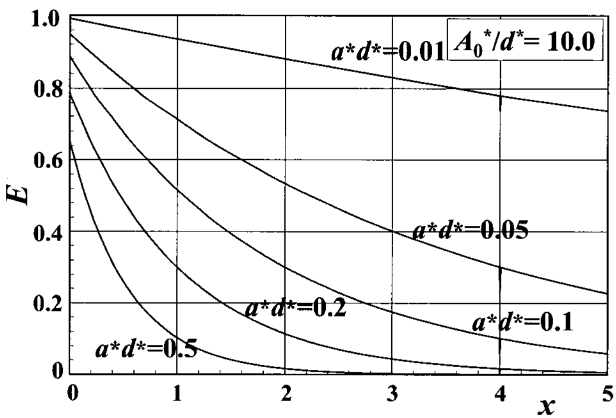

Fig. 2 The wave energy profile along with the wave propagation direction ($\overline{C_D}$=1.2, $\overline{C_M}$=2.0, $h_0 = \pi/10.0$, A_0^*/d^*= 10.0)