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ENERGY DISSIPATION IN A NONLINEAR MODEL FOR SURF ZONE WAVES

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1 Introduction

Up to now, the Boussinesq-type equations have been successfully applied to simulate non-breaking waves. However, their application for modelling nonlinear waves in the surf zone is still limited due to the complexity of wave transformation after breaking. It is well-known that behind the breaking point, an energy dissipation process takes place over the whole surf zone and as a result, the wave height decreases from $H = H_b$ at breaking to $H = 0$ at the shoreline. This dissipation process can be regarded mainly as the result of the turbulent diffusion originated from two sources: (1) the effect of surface rollers accompanying with the wave front due to breaking waves and (2) the friction effect at the bottom boundary layer. Based on the Boussinesq-type equations, this paper presents a nonlinear wave model for the surf zone, in which the energy dissipation caused by the above two effects can be simulated by modifying the momentum equation.

2 Governing Equations

The effects of surface rollers and bottom friction on the energy dissipation of surf zone waves are included in the modified Boussinesq equations as follows

$$\frac{\partial \eta}{\partial t} + \frac{\partial p}{\partial x} = 0 \quad (1)$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + gh\frac{\partial \eta}{\partial x} - \frac{D^3}{3}\frac{\partial^3 p}{\partial x^2 \partial t} + \frac{D^2 p}{3h}\frac{\partial^3 \eta}{\partial x^2 \partial t} + \frac{\partial R}{\partial x} + \frac{gn^2 \mid p \mid p}{h^{7/3}} = 0 \quad (2)$$

where η is the water surface elevation, D is the mean water depth, h is the total water depth, p is the flow rate, and n is the Manning's roughness coefficient. The last two terms on the left side of Eq. (2) simulate the energy dissipations due to surface rollers and bottom friction respectively.

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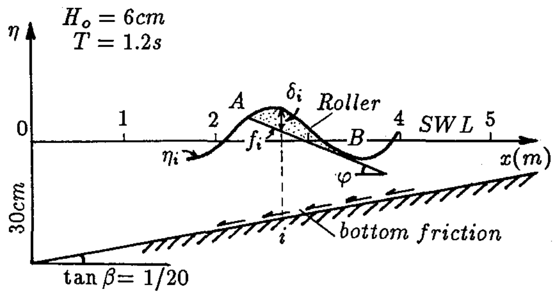

Figure 1: Definitions

Using the same assumption for velocity profile of a breaking wave as Schäffer et al. (1992), the contribution from the surface roller to the momentum flux, R, is

$$R = \delta\frac{(c - p/h)^2}{1 - \delta/h} \quad (3)$$

where δ is the thickness of the roller (see Fig. 1). The parameter δ is a function of space and time and can be determined as the vertical distance between the instantaneous wave profile and its tangent line AB with slope $\tan\varphi$.

The Manning's roughness coefficient n for large rivers with sand bed is about 0.020 to 0.040. An average value of 0.03 is used here to simulate bottom friction in the surf zone.

3 Computational Method

The governing equations are solved by using a central finite difference scheme, in which one sided differences are applied to the boundary points.

At the beginning of each time step of computation, an approximate solution for the water surface profile at time $n+1$ is obtained by applying the continuity equation (1) in the explicit finite difference form

$$\eta_i^{n+1} = \eta_i^n - \frac{\Delta t}{2\Delta x}(p_{i+1}{}^n - p_{i-1}{}^n) \qquad (4)$$

From η_i^{n+1}, the roller thickness is computed as

$$\begin{aligned} \delta_i^{n+1} &= \eta_i^{n+1} - f_i^{n+1} \\ &= \eta_i^{n+1} - \tan\varphi(x_B - x_i) - \eta_B \qquad (5) \end{aligned}$$

The function f is the equation of the tangent line AB. It is known that the value of $\tan\varphi$ decreases as wave propagates shoreward. However, the variation of φ along the surf zone still has not been investigated quantitatively. In this model, it is assumed that the value of $\tan\varphi$ for each wave front depends on the local slopes of the wave front profile and is determined as

$$\tan\varphi = 0.50(k_{min} + k_{max}) \qquad (6)$$

where k_{min} and k_{max} are the local minimum and maximum slopes of the considered wave front profile respectively.

Using the values of δ_i^{n+1} obtained from Eq. (5) and with appropriate boundary conditions, Eqs. (1) and (2) are solved implicitly in the matrix form to determine p_i^{n+1} and η_i^{n+1}.

4 Simulation Results

The results of wave transformation in the surf zone computed by the numerical model are shown in Fig. 2 and Fig. 3. In Fig. 2, it can be seen from the time history of water surface fluctuations at various sections that there exists a large deformation of the wave shape around the breaking point (x=3.8 m). The wave front becomes steeper as wave approaches the breaking point and due to the effect of the dissipation terms in Eq. (2), the wave energy (or wave height) is dissipated throughout the surf zone. From the time history of water surface at various sections, the wave height distribution is determined and compared with measured data of Nagayama (1983) as shown in Fig. 3.

5 Conclusion

The energy dissipations and wave transformations in the surf zone are well simulated by a nonlinear wave model, in which the effects of surface rollers and bottom friction on the wave height decay behind breaking point are considered in the wave computation. A good agreement is obtained between

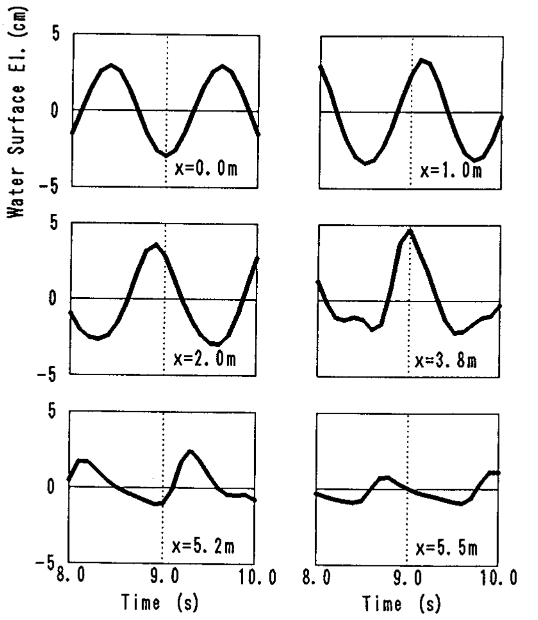

Figure 2: Time series of water surface elevation

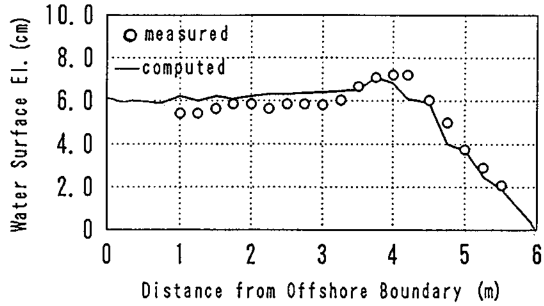

Figure 3: Wave height variation

the computed and measured wave height variations. The evolution of the magnitude order of energy dissipations due to the above two effects will be presented at the Conference.

6 References

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