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A NUMERICAL MODEL FOR THE NEAR-SHORE WAVE TRANSFORMATION

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abstract

A numerical model was developed for the prediction of wave field in the near-shore area based on the mild-slope equation. Verifications of the model for one-dimensional problem revealed a good agreement with experimental data. An example of computation for the propagation of irregular waves in a two-dimensional domain is also given.

INTRODUCTION OF THE NUMERICAL MODEL

The governing equations are time-dependent mild-slope equations accounting for wave breaking, given as follows

$$\eta_t = -\nabla_h\left(\frac{CC_g^{\,*}}{g}\nabla_h\tilde{\phi}\right) + \frac{(\omega^2 - k^2CC_g)}{g}\tilde{\phi} - f_d\eta \qquad (1)$$

$$\tilde{\phi}_t = -g\eta \qquad (2)$$

where η is water surface elevation;η_t is $\partial\eta/\partial t$; $\tilde{\phi}$ velocity potential; C phase velocity; C_g group velocity; g gravitational acceleration; ω frequency; k wave number; ∇_h gradien vector in the horizontal direction; f_d an energy dissipation coefficient due to wave breaking.

According to Isobe (1987, 1994), the energy dissipation due to wave breaking is modeled as follows: if the ratio between amplitude of a wave and water depth $\gamma=a/d$ with a as wave amplitude and d water depth, is greater than a critical value γ_b, then the wave is judged to be breaking. After breaking, if γ becomes smaller than γ_r=0.135, the individual wave is judged to have recovered. γ_b is determined as $0.8\gamma_b$' with γ_b' evaluated by equation (3).

$$\gamma_b' = 0.53 - 0.3\exp(-3\sqrt{d/L_0}) + 5(\tan\beta)^{1.5}\exp[-45(\sqrt{d/L_0} - 0.1)^2] \qquad (3)$$

where L_0 is the representative wave length in deep water and $\tan\beta$ is the bottom slope.

To evaluate the spatial distribution of the energy dissipation coefficient f_d, we first determine f_{dmax} at each crest of breaking waves by using equation (4), then obtain the energy dissipation coefficient f_d by interpolating f_{dmax} linearly (Kubo et al, 1992).

$$f_{d\max} = 2.5\tan\beta\sqrt{\frac{1}{k_0 d}}\sqrt{\frac{\gamma - \gamma_s}{\gamma_s - \gamma_r}} \qquad (4)$$

where γ_s=0.4(0.57+5.3tanβ), k_0 is the representative wave number in deep water. The governing equations are solved by using a finite difference approximation with a second order accurate Crank-Nicolson scheme. At the offshore boundary, two kinds of boundary condition are applied. For the case of regular wave, the reflected wave coming from computational domain is allowed passing through the boundary freely by applying the radiation boundary condition. For the case of irregular waves, the reflected waves are assumed to be absorbed in a so-called damping layer. A random wave train is assumed arriving at the offshore boundary and the water surface elevation at this boundary is described as a superposition of a number of harmonic waves having amplitude and angular frequency determined from Bretschneider-Mitsuyasu spectrum (Goda Y, 1985)

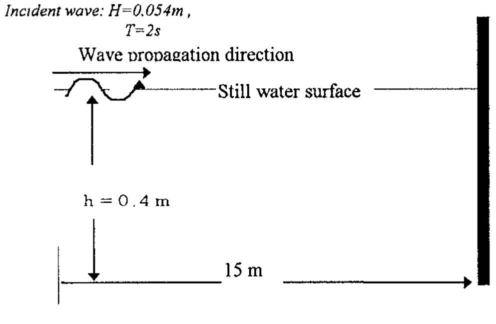

Figure 1 Computational domain for the case of a harmonic wave

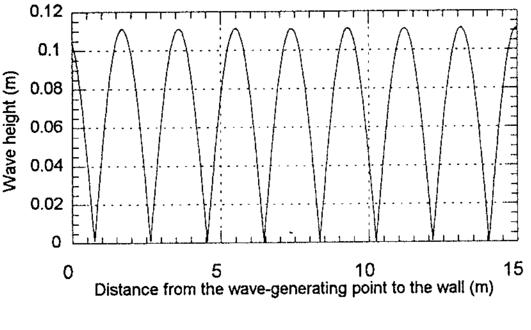

Figure 2 Distribution of wave height in case of a harmonic wave

Keywords: Mild slope equation, near-shore area, numerical model, wave propagation.

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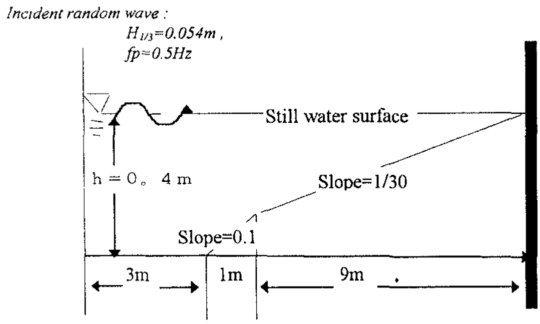

Figure 3 Computational domain for the case of random waves

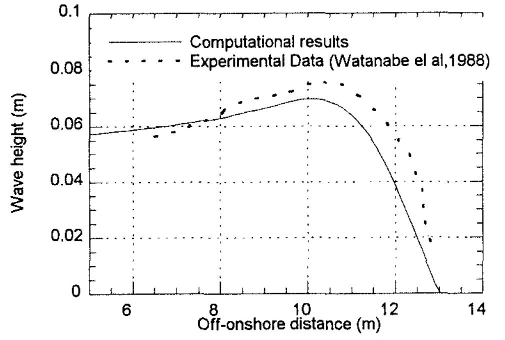

Figure 4 Comparison between computational results and experimental data for random waves. $H_{1/3}$=0.054m,fp=0.5Hz

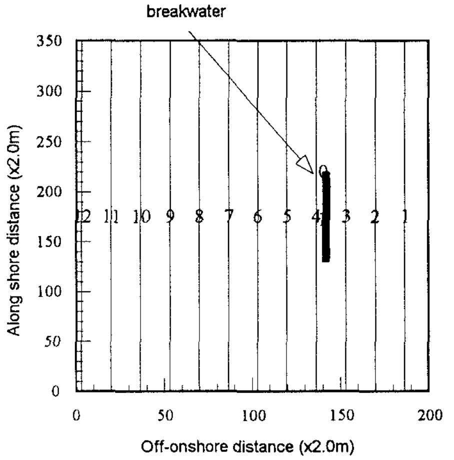

Figure 5. Distribution of depth of the computational domain (m)

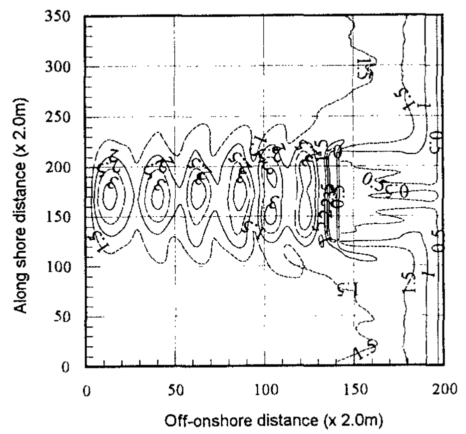

Figure 6. Distribution of computed significant wave height (m)

VERIFICATION OF THE MODEL

The verifications of the model for one-dimensional problems were carried out for regular and irregular waves. For the case of regular wave, a harmonic wave is assumed arriving at the open boundary, traveling over the computational domain with a uniform depth as depicted in Figure 1. The computational results of wave height for this case are shown in Figure 2. It is clear that the incident waves and the reflected waves from the wall interact with each other creating a system of node and anti-node in front of the wall. For the case of irregular waves, computational conditions depicted in Figure 3 are the same as those of the experiment by Watanabe et al (1988). Figure 4 shows the comparison between the results of this computation and the experimental data. The peak frequency f_p and significant wave height $H_{1/3}$ of the incident waves for this case are 0.5 Hz and 5.4 cm, respectively. The computational results show that the computed wave height distribution agrees satisfactorily with the experimental data. A small difference between computed and observed data may be due to the nonlinear nature of wave propagation on shallow water, which this model can not account for.

Two-dimensional computation was carried out to investigate the propagation of irregular waves in the near-shore area. The computational conditions are depicted in Figure 5. The incident waves were assumed as a superposition of 110 wave components, which were determined from Bretschneider-Mitsuyasu spectrum (Goda Y. 1985) with a significant wave height $H_{1/3}$=1.0m and period $T_{1/3}$=11s. The computation domain is illustrated in Figure 5. The computational results for this case are shown in Figure 6.

CONCLUSION

Results of the computation by the numerical model show that the model can satisfactorily simulates the propagation of regular and irregular waves in near-shore area.

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