

Study Dispersion Effects of Wave Propagation over Mangrove Models in Shallow Water using 2-D Hyperbolic Wave Equation

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Abstract

The aim of this research is to study dispersion effects of wave propagation over mangrove models in shallow water environments. This numerical modeling of wave propagation is using two dimensional parabolic wave equation. In this study, numerical solution of the parabolic wave equation is using finite difference method. For solving the 2nd order derivatives of the wave equation, the finite-difference method is one of several methods using discrete approximations that can be used to calculate linear combination of approximation of the function, at grid points. Second order of accuracies explicit finite-difference method are employed to simulate wave propagation.

The mangroves were modeled in order to dissipate waves propagate over them. To reduce reflections from non physical boundaries, Reynolds boundary condition method was used. A line source was used to model wave sources. Ricker wavelet is used as a line source. In the environment setup of the model, assumed the waves propagate in shallow water with the depth (d) is equal to 5 meter. Results of this research present wave propagation and dispersion effects, at location before and after the mangrove models. The results present the dispersion effects of the mangroves clearly. If results with the different scenarios or different situation are compared, where the model was using full mangroves with the narrow channel, present more dispersions and more dissipated than only using a half of the mangroves. It is concluded that wave propagation over mangroves can be modeled numerically, to study and to investigate dispersion effects of the mangroves as green breakwaters.

KEYWORDS: dispersion effects, parabolic wave equation, finite difference, mangrove

1. Introduction

Wave propagation theory was used by scientists and engineers, in particular civil engineers in developing models for wave propagation. Usually

engineers involve the theory in developing numerical models in coastal environments, of particular importance in civil engineering, while scientists develop the numerical models which are of importance in geophysical exploration. In this

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paper, the hyperbolic wave equation is used to describe free surface water wave propagation in shallow water.

Surface water wave propagation researches have been conducted in [4, 5, and 6]. The other researcher [4] has been done by using physical modeling or experimental research. Physical breakwater was modeled to study wave run-up, reflection, dissipation and dispersion effects. Wave propagation across a submerged breakwater has been modeled to investigate transmission or dispersion effects [5]. Artificial reefs have been produced by one of several reef ball foundation which having research in reef restoration and coastal protection [6].

This research was intended to study dispersion effects of mangroves which were modeled to dissipate wave propagation over them numerically. Mangroves can be used as natural or green breakwater to protect coastal zone from wave attacks.

2. Methodology

Research methodology used in this research was only using a numerical method. Using the method, cost of the research is more least if it is compared with physical modeling and field modeling researches.

In this research, wave equation used to model wave propagation over mangrove model was a two dimensional hyperbolic equation [3] as follows,

$$\frac{\partial^2 \eta}{\partial t^2} = c^2 \left\{ \frac{\partial^2 \eta}{\partial x^2} + \frac{\partial^2 \eta}{\partial y^2} \right\} \quad (1)$$

where,

η = elevation of water surface

c = wave velocity

$$c = \sqrt{g \cdot d}$$

d = water depth

A solution of the 2-D hyperbolic wave equation used in this research is explicit finite-difference method. Using this method, the equation could be approximated as follows,

$$\frac{\partial^2 \eta}{\partial t^2} = \frac{\eta_{i,j}^{n-1} - 2 \cdot \eta_{i,j}^n + \eta_{i,j}^{n+1}}{\Delta t^2} \quad (2)$$

$$\frac{\partial^2 \eta}{\partial x^2} = \frac{\eta_{i-1,j}^n - 2 \cdot \eta_{i,j}^n + \eta_{i+1,j}^n}{\Delta x^2} \quad (3)$$

$$\frac{\partial^2 \eta}{\partial y^2} = \frac{\eta_{i,j-1}^n - 2 \cdot \eta_{i,j}^n + \eta_{i,j+1}^n}{\Delta y^2} \quad (4)$$

Using Equations (2), (3) and (4) and obtained wave velocity as $c = \sqrt{g \cdot d}$ [3], so we can rearrange a solution for the above equation as follows,

$$\frac{\eta_{ij}^{n-1} - 2 \cdot \eta_{ij}^n + \eta_{ij}^{n+1}}{\Delta t^2} = g \cdot d \cdot \left[\frac{\eta_{i-1,j}^n - 2 \cdot \eta_{ij}^n + \eta_{i+1,j}^n}{\Delta x^2} + \frac{\eta_{i,j-1}^n - 2 \cdot \eta_{ij}^n + \eta_{i,j+1}^n}{\Delta y^2} \right] \quad (5)$$

Equation (5) is an approximation solution for explicit finite-difference of the 2-D hyperbolic wave equation.

Modeled surface wave propagation is restricted by boundaries, as physically it is not real. The boundaries usually mentioned as nonphysical boundaries or open boundaries. To simulate the waves in order to be able to propagate past the nonphysical boundaries, mathematical equation is applied on the boundaries to minimize or reduce nonphysical reflection from computational array boundaries, a number of techniques have been developed, having advantages and disadvantages.

In this research, a boundary condition method which usually used in modeling of wave propagation is transparent boundary condition method. The boundary condition method is needed to reduce waves propagate through to over nonphysical boundaries. From the boundaries, reflected waves are not allowed. Equation used as open boundaries is as introduced by Reynolds in [1] as follows,

$$\frac{\partial \eta}{\partial t} + c \frac{\partial \eta}{\partial x} = 0 \quad (6)$$

Using Equation (6) above, nonphysical reflections from the boundaries are possible to be reduced. Using hyperbolic wave equation and Reynolds transparent boundary condition method, surface wave propagation could be modeled.

Using different values of the wave velocities, mangroves could be modeled. How far dispersion and dissipation effects caused the mangroves could be investigated.

3. Environment set-up

In the numerical modeling, as a source is line source. to model surface wave source, a source model of Ricker wavelet is applied as used in [3]. Source waves employed as line waves which having the same direction with the mangroves. In this research, to model wave propagation is using two scenarios (scenario A and scenario B).

For the scenario A, the mangroves are located close to the top boundary or close to the line source where having the same direction. in the center of the mangroves location is opened. It is intended as a way for the waves to propagate over and pass the mangroves model (see Figure 1)

For the scenario B, also the mangroves are located in the same direction with the scenario A, but the mangroves is located from the center of the domain through to the right boundary (see Figure 2)

Grid schemes used to model mangroves effects are such as be presented in Figure 3. Where at the positions of rectangular grid points, velocities (c) are set to zero, because at the positions, waves are not allowed to propagate or equal to zero.

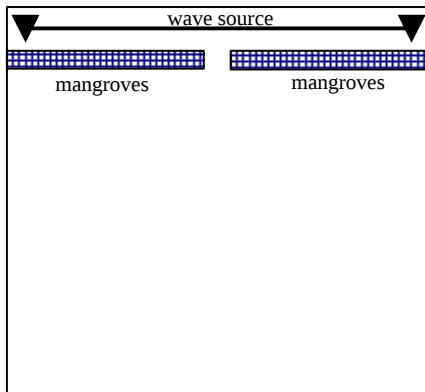


Figure 1. Environment setup for scenario A

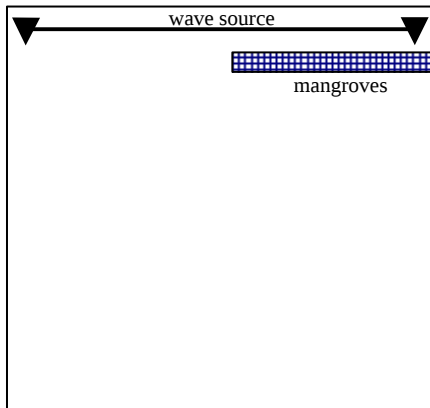


Figure 2. Environment setup for scenario B

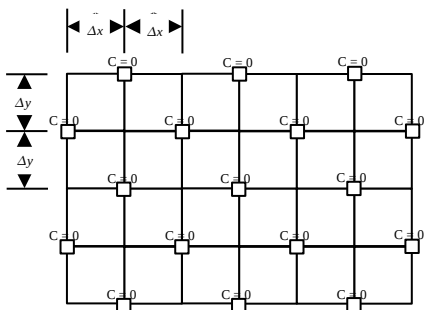


Figure 3. Grid scheme for Mangrove models.

4. Results and Discussion

Results of this research are presented in two scenarios, scenario A and scenario B. For results of the scenario A are presented in Figure 4, Figure 5, Figure 6, and Figure 7. For results of the scenario B are presented in Figure 8, Figure 9, Figure 10, and Figure 11 as follow,

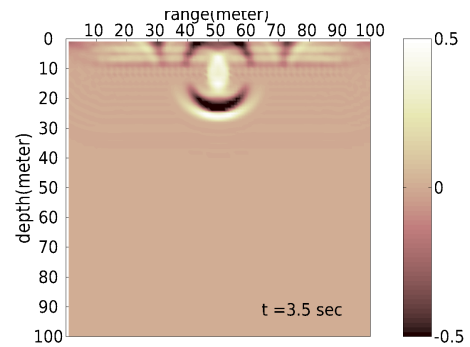


Figure 4. Snapshot of wave propagation at t = 3,5 sec (scene A)

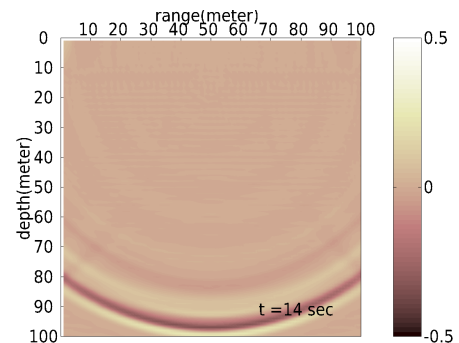
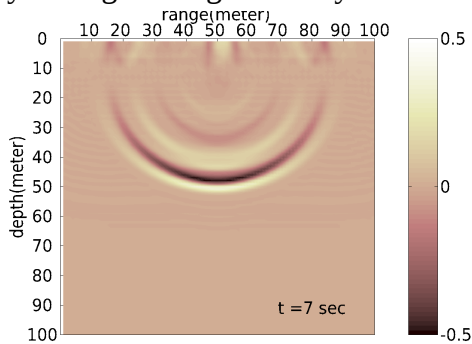
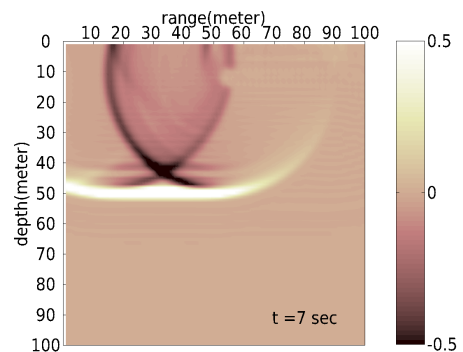


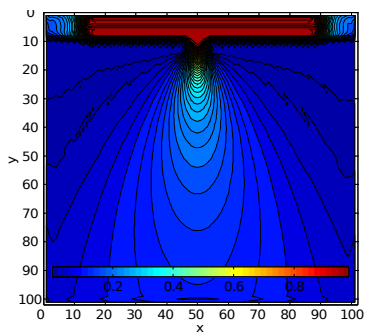
Figure 5. Snapshot of wave propagation at t = 7 sec (scene A)



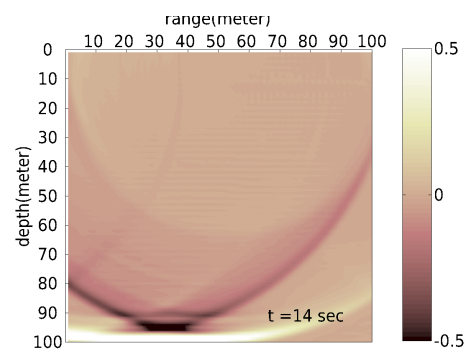
**Figure 6. Snapshot of wave propagation
 at t = 14 sec (scene A)**



**Figure 9. Snapshot of wave propagation
 at t = 7.0 sec (scene B)**

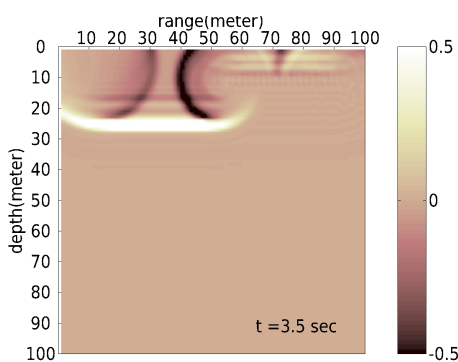


**Figure 7. Contour plot diffraction effects
 of the mangrove model (scene A)**

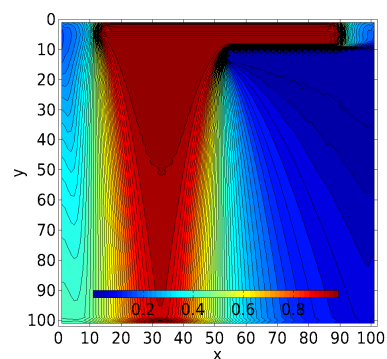


**Figure 10. Snapshot of wave propagation
 at t = 14 sec (scene B)**

For results of the scenario B are presented as follow,



**Figure 8. Snapshot of wave propagation
 at t = 3.5 sec (scene B)**



**Figure 11. Contour plot diffraction effects
 of the mangrove model (scene B)**

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To generate and simulate wave propagation such as presented above, 101 times 101 grid points are used. The grid spaces Δx equal to Δy used in this model are 1 meter. The depth (h) which used in the numerical domain is 5 meters. The grid time Δt in this model is 0.01 second. So numerically, the model is stable, because Δt is less than $\Delta x / \sqrt{gh}$.

Second order of accuracies finite difference method are used to approximate the second order derivatives of the hyperbolic wave equation.

Snapshot results of scenario A can be compared with snapshot results of scenario B. In the scenario A, the wave propagation is completely dissipated, and the waves only propagate by the opened location in the mangrove model. the Waves propagate in the domain clearly dispersed. In the scenario B, the waves fully propagate from

References

- [1] A. C. Reynold, Boundary conditions for the numerical solution of wave propagation problems, *Geophysics* 43(6), pp 1099-1110, 1978.
- [2] D. K. Mihardja, S. Hadi, Model matematika numerik untuk simulasi gerak pasang-surut, Pusat Penelitian dan Pengembangan Oceanografi LIPI, Jakarta, 1989.
- [3] Ahmad Zakaria, Numerical modelling of wave propagation using higher order finite-difference formulas, Thesis (Ph.D), Curtin University of Technology, Perth, W.A., 2003.

the left side position without mangroves and at the right side position, the waves almost dissipated by the mangroves (see Figure 4, 5, 6, 8, 9, and 10). Dispersion effects of the mangroves also can be studied from Figure 7 and Figure 11. For the scenario A, the waves almost dissipated significantly, and waves only propagate by a narrow channel of the mangrove model. For the scenario B, the waves is only dissipated from the right side where the location having mangroves.

4. Conclusions

Based on the results of this research concluded that mangroves can be modelled numerically to study and to investigate dispersion effects of mangroves as green breakwater.

- [4] S. Nelamani and B.V. Sumalatha, Wave reflection, run-up, run-down and pressure on seawalls defended by an offshore breakwater, *J. Indian Inst. Sci*, 86, pp 15-31, 2006.
- [5] Wamsly, Hans Hanson, and Nicholas C. Kraus, Wave transmission at detached breakwaters for shoreline response modeling, U.S. Army Corps of Engineers, ERDC/CHL CHETN-II-45, March 2002.
- [6] Lee E. Harris and Todd Barber, Artificial reefs for beach and reef restoration, FIT Department of Marine & Environmental Systems and Reff Ball Foundation.