1. INTRODUCTION

Breakwaters are designed to protect coastal infrastructure by dissipating wave energy, partially due to wave reflection. A submerged, horizontal deck located beneath free surface can be used as a breakwater. Some benefits include:
- Less dependent on seabed topography for foundation
- Neutral effect on coastal currents or currents in coastal regions
- Does not restrict natural circulation of water and sediment transport
- Is simple geometry, and easy to construct and maintain

Submerged partially is act as breakwaters by reflecting part of the wave due to the fluid-solid-fluid interaction, while the remaining wave energy is transferred above and below the plate.

Many studies have been conducted on a submerged breakwater using linear deep water or intermediate water waves. We will study the effects of a submerged breakwater as a breakwater using the Green-Naghdi (GN) nonlinear, shallow water wave equation.

2. SUBMERGED BREAKWATER

Figure 1 shows a schematic of submerged horizontal plate as a breakwater. It is plate length, is water depth, h0 is submerged depth from the still water level (SWL), is the plate vertical location from the seabed, (the combined reflected and incident waves upstream of the plate, and h0 and h is the transmitted waves downstream.

3. METHODOLOGY

The Level 1 Green-Naghdi (GN) equations originally developed by Green and Naghdi (1976a, b) are used to solve the propagation of an inviscid and incompressible fluid over a submerged plate. The GN equations are given by the mass and combined momentum equations. Equations (1) and (2) are the water surface free surface, p is the fluid's mass density, the superposed dot is the two-dimensional material time derivative, and g is the gravitational acceleration. See Hatanaka and Enomoto (2015) for details on applying the GN equations to the problem of flow of an inviscid and incompressible fluid over a submerged plate.

The equations are numerically solved for a submerged plate by using reflection and transmission coefficients to describe wave scattering. A method similar to the two-point method for nonlinear waves given by Green (1992) is applied to closely estimate scattered wave amplitudes. In this method, we use the dimension relation of the linearized GN solution, given by Green and Naghdi (1974) as:

\[ \omega^2 = \frac{-g}{\Delta} \left[ \frac{1}{2} + \frac{1}{\Delta} \left( \frac{1}{2} - \frac{1}{\Delta} \right) \right] \]

where \( \omega \) is the angular frequency, and \( K \) is the wave number.

We discus the reflected wave amplitude, \( \alpha_r \), incident wave amplitude, \( \alpha_i \), and transmitted wave amplitude, \( \alpha_t \), by performing a Fourier transform on the surface elevation time series recorded at the gauges and performing the method and analysis by given by Green (1992).

The reflection coefficient, \( C_r \), is the ratio of \( \alpha_r \) to \( \alpha_i \), given by:

\[ C_r = \frac{\alpha_r}{\alpha_i} \approx \frac{\alpha_r}{\alpha_i} \]

The transmission coefficient, \( C_t \), is the ratio of \( \alpha_t \) to \( \alpha_i \), given by:

\[ C_t = \frac{\alpha_t}{\alpha_i} \]

Further details obtaining \( C_r \) and \( C_t \) can be found in Green (1992).

4. RESULTS AND DISCUSSION

a) Snapshot of the Numerical Wave Tank

In Fig. 1, a snapshot of the GN wave tank with a submerged plate is shown. The vertical axis is the dimensionless surface elevation \( \eta \), and the horizontal axis is the dimensionless positive axis. Coastal waves travelling from the left to right hand side of the figure are seen scattering above the submerged plate, resulting in the combined reflected and incident waves upstream from the plate, and transmitted waves travelling downstream from the plate. It is clear that the transmitted wave amplitude is considerably less than the combined incident and reflected waves amplitudes.

b) Surface Elevation Comparisons

Here, the surface elevations (q) calculated by the GN equations are compared with existing data. Figure 3 shows GN comparisons with Experimental Fluid Dynamics (CFD) and wave plate measurements given by Hayatdavoodi et al. (2015). Figure 4 shows GN comparisons with the Desingularized Boundary Integral Equation Method (DBIBM) and measurements given by Lou (2009), and a curve fit to model the GN surface elevation recordings for use in Grue’s (1992) method. The results of GN compare well with the observations.

5. CASE STUDY: HURRICANE IKE (2008)

Here, we explore the possibility of wave scattering due to a submerged plate on incident shallow-water waves generated by Hurricane Ike (2008) off the Bolivar Peninsula coast, just north of Galveston Island. Figure 7 shows surface elevations of the waves, with and without the presence of a submerged plate.

The wave data is given by Blinder et al. (2011) who obtained the data through a buoy at a depth of h = 9.48m. The peak wave height, H = 5.49 m, and peak wave period, T = 11.75 s. We choose \( h_0 = 0.5 \) and L/B = 5 from the coefficient and transmission coefficient results to possibly produce significant reflection and small transmission without wave breaking. We compare the surface elevation of a simulated non-scattered transmitted wave when the submerged plate is absent, and the surface elevation of a simulated scattered transmitted wave with the presence of the plate during Hurricane Ike.

6. CONCLUSION

Scattering of waves by a submerged horizontal plate is studied by use of the GN equation. A submerged horizontal plate is shown to be very effective in reflecting a significant portion of wave energy, while allowing some transport. Close agreement can be observed between GN equations and existing measurements and data. GN equations can be used for nonlinear wave scattering in shallow water conditions, \( C_r \) and \( C_t \) are shown to be significant due to a submerged plate, hence it can be used as a very simple and effective breakwater. A case study shows that the severity of damage due to waves generated by Hurricane Ike could be reduced by a submerged breakwater.

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8. REFERENCES


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