The effectiveness of breakwater shape: Fluid particle behavior simulation

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**Abstract.** The simulation of physical phenomena between fluid and its boundary is a fascinating study because of its application in various fields of engineering. In this simulation, we analyze how fluids are arranged as granular particles with certain conditions interacting with the wall. The walls are varied as the characters that represent the shape of the breakwater building. This simulation compares the effectiveness of commonly used wave barriers. Wave barriers are used to hold the waves from reaching the land. In this, the simulation used two types of wave holders in the form of tetrapod and cubic, which are placed on a sloping surface. Next, an analysis of the farthest distances from the variations in the speed of the waves and the types of waves holds. Simulation results show that tetrapods are able to withstand wave speeds better than cubic.

1. Introduction

The wind, ocean waves, season changes, and water level are the driving force that creates temporal the beach topography [1]. Ocean waves with energy carried have a different character when heading for the beach. Indonesia, with an island nation, the topic of research on ocean waves is crucial. Previous research has been able to show a study of simulations and numerical analyzes of breakwater layout interactions on Tidal Wave in Jember Indonesia [2]. Different studies still in Indonesian have been produced analyzes and simulations about the wave patterns around breakwater buildings in Bengkalis [3]. It shows the simulation of ocean waves is very characteristic, depending on the place.

Variations in the place of the study also make researchers use variations of tools and methods, for example, research on breakwater using OpenFOAM software [4]. The difference and optimization of breakwater forms are also interesting objects of simulation. Previous studies have produced simulations of how to impact variable steepness on the breakwater [5], floating breakwater [6], and form optimization analysis [7].

Wave analysis, aside from treating it as fluid, it can also be analyzed using a granular approach. Research on granular characters is widespread as it can represent different physical systems with different initial and different settings. In the previous study, the various simulations were used to analyze wave interaction to the wall in slope [8] and vertical [5,9]. The simulation can provide a good representation of the breaking wave process and can be a useful tool for evaluating how effective breakwater is [10]. In the wave analysis generally focused on the analysis of the measured force, the hydrodynamic force extracted, and the dynamic amplification factor reach the highest value, e.g., the
furthest achievement [8,11]. The sea waves that have the character of fluid are then approached with analysis of particles that act like fluids. This study uses tools from Unity, namely Obi Fluid [12], which can display the visualization of fluid interactions as particles with boundary walls. In this case, boundary walls are set as a breakwater.

Breakwater as a wave energy breaker [13] in this study will be carried out on two types of breakers, namely in the form of tetrapod and cubic, by analyzing the maximum range of waves. In previous studies, interactions between maritime emerging breakwaters and waves were carried out by Dentale and concluded that the breaker was proven to be able to withstand the wave rate [14]. This study aims to look at the micro-interaction between granular like sea waves of the form of the breakwater that has been used by the engineering field. To get conclusions from granular interactions as waves against wave breakers, an effect of breaker type on maximum height in 2-dimensions granular simulations were analyzed. The result of this work is used for setting parameters in the future work, in terms of scale and other variable variations.

2. Simulation methods

In this simulation, the initial velocity of particles on one side is set by two values of velocity. As a result, the ocean wave crest generally curls over and generates vortices at the water surface. The dissipation rate depends on the size and strength of these vortices [15]. The turbulence on the spilling breaker, qualitatively, is similar to a bore and can be treated as a traveling hydraulic jump shown in Figure 1a. The dissipation for a breaking wave can be calculated as follows [16].

\[
D_b = \frac{1}{4} \rho g f_p \left(\frac{BH}{h}\right)^2
\]  

To obtain the average bore energy dissipation for the distribution of irregular waves, Equation (1) needs to be multiplied by the number of breaking waves in the distribution. The main difference between the various models rises from determining the fraction of breaking waves in an irregular sea wave state. Figure 1b illustrates the waveform formed in the simulation carried out and crashes into the wall of the wave barrier.

Figure 1. a) Schematic sketch of energy dissipation associated with a bore [17], b) Wave simulation.

The waveforms in the simulation consist of two types that are commonly used, namely tetrapod (Figure 2a) and cubic (Figure 2b).

Figure 2. The wavebreak type: a) Cubic b) Tetrapod.
3. Results
We generate and increment the initial velocity for each particle in two different wall boundaries. Figure 3 shows the condition in breakwater when generating a velocity of 10 m/s. The final condition of these forms of the breakwater can show in this simulation.

![Figure 3](image)

**Figure 3.** Figure 3a-3c show the flow of 10 m/s wave to collide the cubic breaker; Figure 3d-3f show the flow of 10 m/s wave to collide the tetrapod breaker.

The simulation results on the 10 m/s wave indicate that there are differences in the attainment of the maximum height of the cubic and tetrapod barrier types. The results are shown in Figure 4.

![Figure 4](image)

**Figure 4.** Interaction between 10 m/s wave to a) Cubic Breaker, b) Tetrapod breaker.

Figure 5 shows the condition in breakwater when generating a velocity of 20 m/s. The final condition of these breakwater shapes can show in this simulation.
Figure 5a-5c show the flow of 20 m/s wave to collide the cubic breaker; Figure 5d-5f show the flow of 20 m/s wave to collide the tetrapod breaker.

The simulation results on the 20 m/s wave indicate that there are differences in the attainment of the maximum height of the cubic and tetrapod barrier type. The results are shown in Figure 6.

Figure 6. Interaction between 20 m/s wave to a) Cubic breaker, b) Tetrapod breaker.

The simulation results can show the difference between the ability of the breakwater. The results of the simulation are shown in Table 1 below.

Table 1. Comparison of wave heights at wave holders.

| No | v (m/s) | Tetrapod | $h_{max}$ (m) |
|----|---------|----------|---------------|
| 1  | 10      | 2.5      | 3.2           |
| 2  | 20      | 3.0      | 3.6           |
On the tetrapod anchor, it can be concluded that the tetrapod can withstand the rate of waves more than the cubic. A comparison of the results of breaking waves by a wave breaker is shown in Figure 7.

![Figure 7. The Comparison between 2 walls of breaker when collide by wave a) 10 m/s, and b) 20 m/s.](image)

**4. Summary**

As a summary, we succeed in simulating granular particles in a wave breaker using Obi Fluid tools. We will use a set of the type of tetrapod breaker for future work because it can hold the fluid to get the further reach.

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