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Numerical simulation design of an artificial porous reef

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Numerical simulation is important tool for the study of wave interactions with coastal defenses as real-time data can be difficult to obtain and large-scale experiments can be costly to perform. A new type of artificial reef is examined in the experimental laboratory, and the results are used to effectively design and perform numerical simulations to determine the key properties of the reef.

Keywords: *CADMAS-SURF, artificial reef, numerical simulation, porous barrier*

1. INTRODUCTION

CADMAS-SURF numerical wave flume is a useful simulation tool developed for the study of advanced maritime structure design[1)]. It is easily applied to investigate and analyze complex interactions between waves and submerged artificial reef structures[2)].

The goal of this research was to design a numerical simulation using CADMAS-SURF with the best fit parameters that accurately reflected the physical phenomena that occur during large-scale hydraulic experiments in a wave flume. Using this numerical simulation, the results can be extended by running various numerical simulations of different parameters, wave conditions, and reef configurations without the expense of running multiple large-scale hydraulic experiments, both in terms of time and cost.

2. NUMERICAL SIMULATION

The dimensions of the wave flume used in the large-scale experiment and the numerical simulation are 25 meters in length, 5 meters in width, and 2 meters in height. On one end is a piston-type wave generator and on the other end is a wave damping area.

The base unit design of the reef is a new type of concrete block with a solid base on which solid cylinders sit spaced evenly in a 3x4 grid. The base dimensions are 36 cm wide, 48 cm long, and 4 cm high. Resting on the base are 12 cylinders of diameter 8 cm and height 8 cm.

The blocks were then used to construct a 3-tier reef structure, **Fig. 1a**. The bottom 2 tiers consist of blocks laid out 5 units in length (2.4 m) and 13 units in width (4.68 m). The top tier (crest) is offset by a half unit on each end, 4 units in length (1.92 m) and 13 units in width (4.6 m). The reef was positioned 11.6 meters from the wave generator to allow the wave to travel a distance of approximately one wavelength before interacting with the submerged barrier. The numerical simulation is two-dimensional, so it is not possible to replicate the blocks as is; the reef in the simulation, **Fig. 1b**, was designed to best replicate the experimental conditions using a porous calculation table. The model is made of solid bases sandwiching porous layers to replicate the effect of the cylinders. For the porous layers, several values were investigated to determine the best porosity, drag coefficient, and inertia coefficient.

Thirteen wave gauges to measure the water surface profile were placed at intervals in the flume in front of, on the crest of, and behind the barrier. Two electromagnetic current meters to record velocity were placed alongside wave gauge 3 and wave gauge 11.

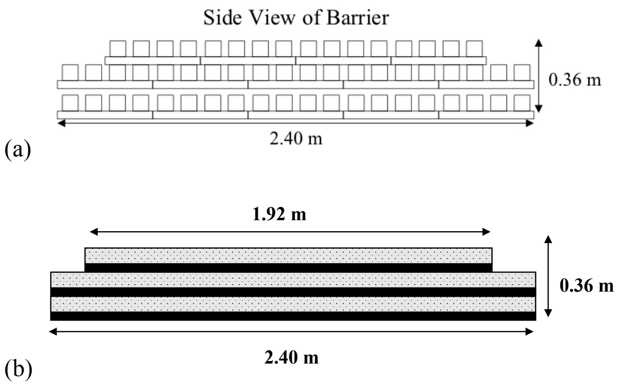

Fig. 1 (a) Concrete block unit reef used in experiment, (b) CADMAS-SURF model.

Target wave periods were between 4.8 to 5.6 seconds. Regular shallow water wave conditions (wavelength >> water depth) were used. The still water depth was 0.40 m, such that the freeboard is 0.04 m (reef is just barely submerged).

A mesh size of $\Delta x = 0.01$ m and $\Delta z = 0.01$ m was used. Referring to previous studies, a horizontal mesh size was chosen to satisfy the criteria of $L/\Delta x > 80$, where L is wavelength[3)]; in this study, the wavelength was in the range of 10 to 14 m. Additionally, the vertical mesh size satisfies $H/\Delta z > 10$ for general wave conditions; this study used an offshore wave height ranging from 10 to 20 cm.

Wave surface profile and velocity data was collected so key properties could be analyzed. Fig. 2 shows the non-dimensional wave height between the experiment and the numerical simulation for one of the cases. Fig. 3 shows the calculated reflection coefficients and Fig. 4 shows the transmission coefficients. Fig. 5 shows the non-dimensional wave setup.

3. CONCLUSIONS

Several numerical simulations were performed for many cases to vary the porosity and drag/inertia coefficients; the results show that the best fit porosity condition for this reef was 85%, with values of 1.0 for coefficients of inertia and drag. This porous condition is somewhat higher than the calculated value for the 3-D experimental reef, however it is determined that in 2-D simulations these values show the most accurate models. CADMAS-SURF is demonstrated to be a useful numerical simulation tool for the study of wave interaction with submerged reefs.

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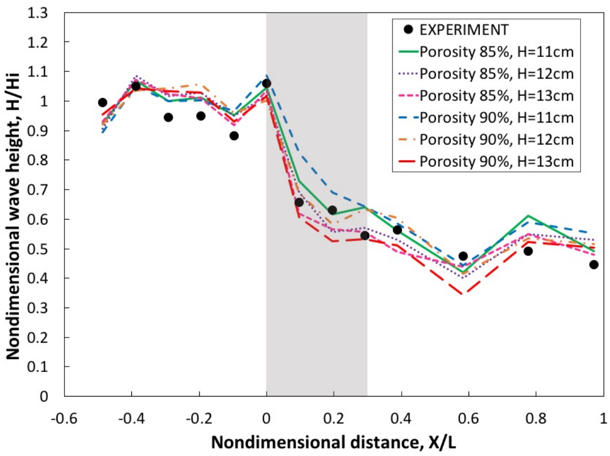

Fig. 2 Non-dimensional wave height distribution for T=5.2 s.

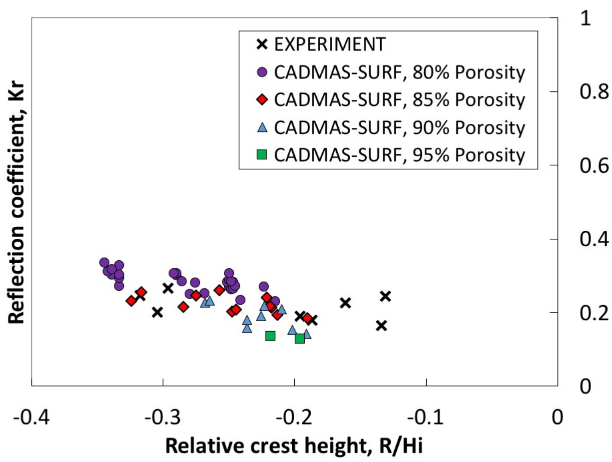

Fig. 3 Reflection coefficient.

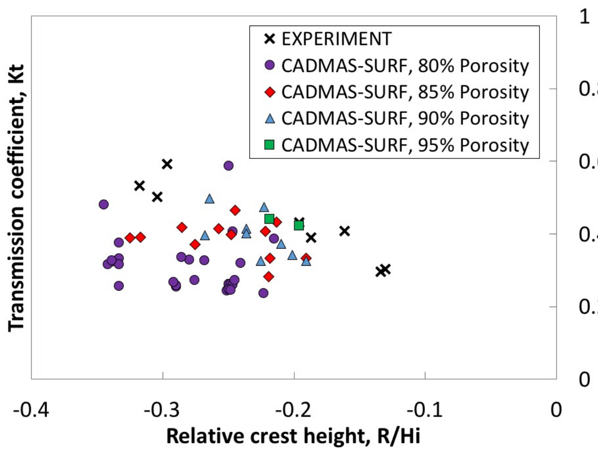

Fig. 4 Transmission coefficient.

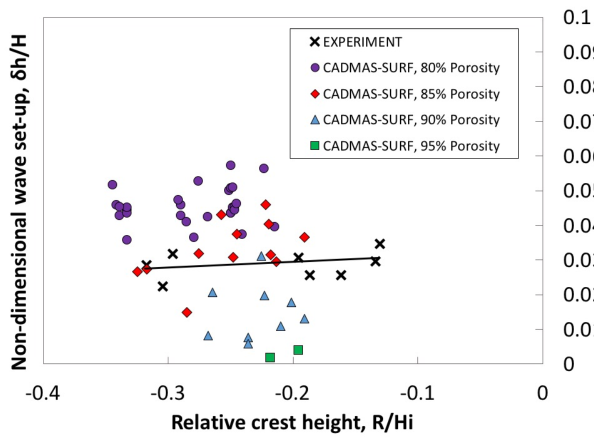

Fig. 5 Non-dimensional wave setup.