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CEE 4350
Laboratory 3

Wave Shoaling and Breaking

Introduction

There are three classifications for types of breaking waves: spilling, plunging, and surging. The purpose of this laboratory was to compare the visual and theoretical results of wave break type as waves propagate onto a sloped beach. The Shoaling formula was used to determine the wave amplitude, which can be used until the wave breaks with the assumption that energy flux is conserved. The Iribarren number, or surf similarity parameter, was then used to determine the type of breaking. The Iribarren number is defined as:

$$\xi = \frac{s}{\sqrt{\frac{H_0}{\lambda_0}}}$$

where λ_0 is the wavelength in the constant depth region, H_0 is the corresponding wave height, and s is the beach slope.

Table 1, below, shows values of the Iribarren number that correspond to each breaking type.

Table 1: Demarcations of the Iribarren number

Iribarren Number	Type of Breaking
$\xi < 0.5$	Spilling
$0.5 < \xi < 3.3$	Plunging
$\xi > 3.3$	Surging

Experimental Setup

A wave tank with a hydraulic piston that oscillates a paddle was used to create desired waves. Four waves were generated; the experimental conditions are shown in table 2.

Table 2: Experimental conditions

Case	Stroke (mm)	Frequency (Hz)
W1	35	1.25
W2	40	0.85
W3	40	0.50
W4	30	0.50

A diagram showing the experimental setup is shown below in figure 1. Once the generated waves hit the shore, the wave height was measured at each x-position labeled on figure 1. The positions measured were x = 0.2, 0.1, 0, -0.2, -0.6, and -1.0 meters. The zero x-coordinate was determined by the still water level (SWL).

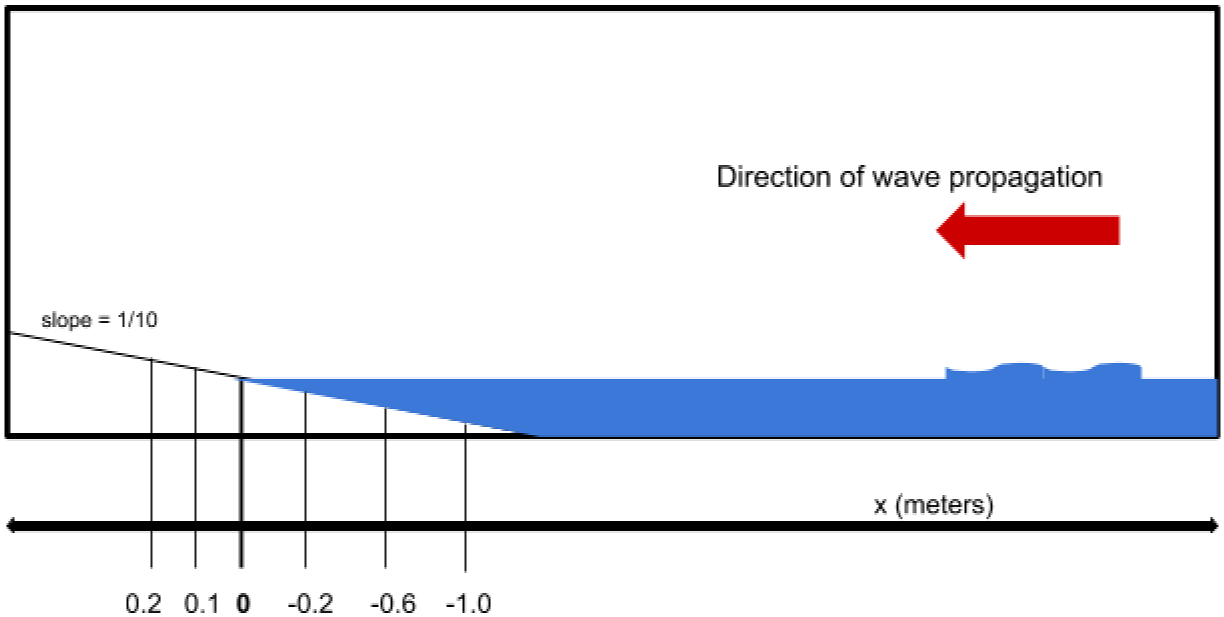

Figure 1: Experimental setup of wave tank

Wave Amplitude

Experimental data was gathered for each wave case shown in table 2. The data is shown below, in table 3. The data was analyzed and plotted using Python. All code can be found in the Appendix, attached at the end of this document.

Table 3: Experimental Results for Amplitude

Case	H_0	**a @ x = -1.0 m (mm)**	**a @ x = -0.6 m (mm)**	**a @ x = -0.2 m (mm)**	**a @ x = 0 m (mm)**	**a @ x = 0.1 m (mm)**	**a @ x = 0.2 m (mm)**
W1	60	45	15	12	7.5	2.5	1
W2	74	40	30	26	14	11	9
W3	34	21	19	20	9	5	3
W4	25	16	15	13.5	7	4	2

The amplitudes gathered were non-dimensionalized and plotted versus the non-dimensionalized wave height. The wave height was non-dimensionalized by diving each wave height by the initial wave height, h_0, which was the SWL. Amplitude was non-dimensionalized using the initial amplitude, a_0, which was the value H_0 in table 3 divided by two. The plot is shown below, in figure 2.

<u>Figure 2:</u> Non-dimensionalized Amplitude vs Water Depth for Experimental Data

To find the theoretical values for amplitude using the given data in table 2, a series of equations were used. To find k, the wavenumber, the dispersion relationship was used with the assumption that the waves were linear.

$$\sigma = \frac{2\pi}{T}$$

$$\sigma^2 = g * k * tanh(kh)$$

where h is the water height from the bed, and g is gravity. Then, that was used to find the wave phase speed, which allowed for the calculation of wave group velocity, and ultimately, the non-dimensionalized amplitude.

$$C_p = \frac{\sigma}{T}$$

$$n = \frac{1}{2} * [1 + \frac{2kh}{sinh(kh)}]$$

$$C_g = n * C_p$$

$$\frac{a(x)}{a_0} = \sqrt{\frac{C_{g,0}}{n * \sqrt{gh}}}$$

where a_0 is the initial amplitude, and $C_{g,0}$ is the initial group velocity, both found using the SWL.

The results using the theoretical values obtained are shown below, in figure 3.

A plot comparing the theoretical values and experimental data is shown below in figure 4.

Figure 3: Non-dimensionalized Amplitude vs Water Depth for Theoretical Values

Figure 4: Comparison of theoretical values and experimental data

Wave Breaker Types

Wave breaker types were determined both visually and computationally. To determine it visually, the following graphic was used, figure 5. Computationally, the formula for the Iribarren number was used and determined using the demarcations in table 1. The comparison between visual and computational results is shown below in table 4.

It was difficult to determine the wave breaker types visually; on such a small scale it was difficult to differentiate different curves and characteristics of each wave. The predictions of the Iribarren number were slightly different than those calculated.

This lab group neglected to measure the experimental wavelength, so it was calculated using the following formula, instead:

$$\lambda = C_p * T$$

where λ_0 can be found using $C_{p,0}$, and then used to calculate the Iribarren number.

Figure 5: Wave Breaking Types Diagram

Table 4: Results for Breaker Type

Case	λ_0 (m)	ξ	Observed Breaker Type	Actual Breaker Type
W1	0.88	0.38	Surging	Spilling
W2	1.48	0.45	Plunging	Spilling
W3	2.69	0.89	Spilling	Plunging
W4	2.69	1.03	Spilling	Plunging

Experimental results for breaker locations are shown below in table 5. Data from another group was used, as this group did not collect breaker location data during the experiment.

Table 5: Experimental Results for Breaker Location

Case	h_b (cm)	H_b (cm)	$\frac{H_b}{h_b}$
W1	7.5	4.9	0.653
W2	6.4	5.7	0.891
W3	4.9	4	0.816
W4	3.5	3.5	1

Discussion

As slope becomes steeper, the Iribarren number will become larger. This is due to the increase in slope, which is in the numerator of the Iribarren equation. Additionally, the initial wavelength will increase, also causing the Iribarren number to become larger. With a steep bed slope, the wave breaker type will almost always be surging, due to the demarcations in table 1. There is just not the amount of land area needed to allow for the waves to spill or plunge onto shore.

The shoaling formula is not valid after a wave breaks. This is because the formula is based on the assumption that wave energy is conserved. When a wave breaks, energy within is dissipated and therefore cannot be conserved. Typically, as wavelength decreases or water depth decreases, amplitude would increase in order to keep the conservation of mass. This is shown in the theoretical data, where the amplitude spiked at the non-dimensional zero water height and asymptotically tapered off. But, because of the dissipated wave energy, the of the wave can decrease after the break.