Experiment 4: "Wave reflection from a partial vertical barrier"

1. Background theory

As water waves propagate toward a vertical partially submerged barrier (Figure 1) part of the incident wave energy will be reflected and part will be transmitted beneath the vertical barrier. Assuming that no energy is lost in the reflection process,

$$H_r^2 + H_t^2 = H_i^2, \tag{1}$$

where H_r is the reflected wave height, H_t is the transmitted wave height, and H_i is the incident wave height. The transmission coefficient, κ_t, is defined as,

$$\kappa_t = \frac{H_t}{H_i} \tag{2}$$

where $\kappa_r^2 + \kappa_t^2 = 1$; and κ_r is the reflection coefficient defined as $\kappa_r = H_r/H_i$.

Different wave theories have been developed to predict regular wave transmission past vertical barriers. Wiegel (1960) power transmission theory states that to determine the wave height of the transmitted wave component, we can assume that all the incident wave power propagated below the lower edge of the barrier is transmitted. The wave power is depth-integrated from the bottom at $z = -h$ to the lower edge of the barrier at $z = -h + \Delta$ and time averaged over one wave period T,

$$\frac{1}{T}\int_0^T \int_{-h}^{-h+\Delta} p_i\, u_i dzdt = \frac{1}{T}\int_0^T \int_{-h}^{0} p_t\, u_t dzdt \tag{3}$$

where p is the wave-induced dynamic pressure and u is the wave-induced horizontal velocity and subscripts i and t refer to the incident and transmitted components, respectively. Assuming linear wave theory, Wiegel (1960) obtained,

$$k_t = T_F^{1/2}, \tag{4}$$

where the transmission function, T_F, is given by,

$$T_F = \frac{2k\Delta + \sinh 2k\Delta}{2kh + \sinh 2kh}. \tag{5}$$

This theory was modified by Kriebel and Bollmann (1996) to account for the wave reflection effects on the pressure and the horizontal fluid velocity below the barrier that results on a greater pressure $p_i + p_r$ and a reduced velocity $u_i - u_r$ (subscript *r* refers to reflected). For the modified power transmission theory, the pressure and horizontal velocity in the left-hand side of equation (3) was replaced with the total contribution from the incident and reflected wave components finding,

$$\kappa_t = \frac{2T_F}{1+T_F} \,. \tag{6}$$

These two theories, based on linear wave theory, have been widely employed as an engineering solution despite their limitations. The aim of this experiment is to employ an approximate theory to predict the transmission coefficient and compare it with numerical experiments conducted in the virtual wave flume.

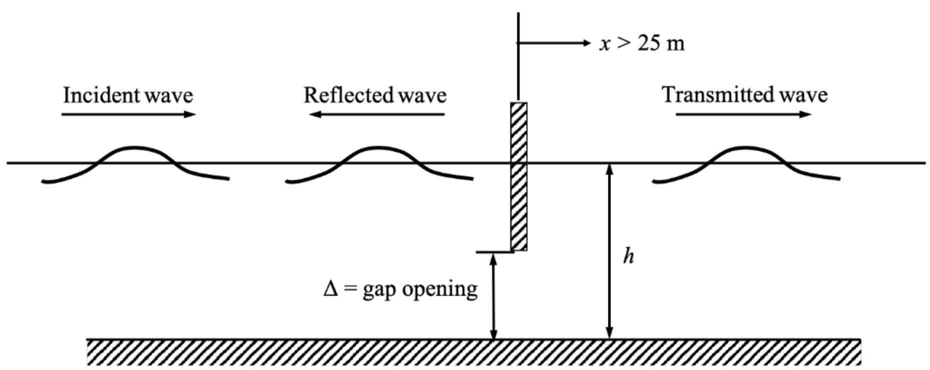

Fig. 1. Wave interaction with a partial vertical barrier problem. Adapted from Dean and Dalrymple (1991).

2. Objective

To measure wave reflection and transmission from a partial vertical barrier and to compare with approximate theory.

3. Instructions

- Use the virtual wave flume to conduct a series of experiments considering different wave periods (Table 1) for a fixed water depth h = 0.6 m and a fixed barrier gap Δ = 0.3 m.
- For each test, measure the wave envelope for x < 25 m by moving a wave cart sensor along the wave flume over a distance of at least one wave length.
- From the wave envelope determine the incident and reflected wave height to compute the reflection coefficient as explained in the wave reflection experiment (see Experiment 3, Supplementary material).
- Use a fixed sensor to measure the transmitted wave and determine the transmission coefficient.

Table 1.- Simulated cases for the wave interaction with a partial vertical barrier

Case	H (m)	T (sec)	h (m)	Δ (m)
1	0.10	1	0.60	0.30
2	0.10	1.5	0.60	0.30
3	0.10	2	0.60	0.30
4	0.10	3	0.60	0.30
5	0.10	4	0.60	0.30
6	0.10	5	0.60	0.30

4. Assignment

For each test, plot κ_t as a function of kh using the approximate theory and also plot the experimental results. Compute the differences between wave flume data and theory and discuss.

References:

Dean, R.G., and Dalrymple, R.A., 1991. Water wave mechanics for engineers and scientists. Advanced Series in Ocean Engineering, vol.2. World Scientific, 353 pp.

Kriebel, D. L., & Bollmann, C. A. (1996). Wave transmission past vertical wave barriers. Coastal Engineering Proceedings, 1(25). https://doi.org/10.9753/icce.v25.%p

Wiegel, R.L. (1960). Transmission of waves past a rigid vertical thin barrier. J.of the Waterways and Harbors Division, ASCE, 86 (WW1), 1-12.