

# WAVE TRANSMISSION AND DISSIPATION BY HYBRID (VEGETATED WITH MANGROVE) BREAKWATERS

José Partida, National Autonomous University of Mexico, [jpartidar@iingen.unam.mx](mailto:jpartidar@iingen.unam.mx)  
 Edgar Mendoza, National Autonomous University of Mexico, [emendozab@iingen.unam.mx](mailto:emendozab@iingen.unam.mx)

## INTRODUCTION

In recent years a group of studies for coastal protection (Hashim & Catherine (2013), Maza et al. (2018), Tomiczek et al. (2020), among others) have been carried out to determine drag coefficients in mangrove forests due to ocean waves. Following the mangrove hybrid platform concept by Tagaki (2019), and actual projects such as the mangrove rehabilitation site in the Jakarta Fishing Port, the main objective of this study was to propose and test a hybrid structure capable of controlling wave energy via breaking and dissipation. The experimental tests focused on determining the rates of the wave energy distribution (reflection, transmission and dissipation) due to the presence of an afforested mangrove zone in the upper part of the breakwater. A fixed-bottom small-scale model was tested under normal and extreme marine regimes. The prototype dimensions of the breakwater are total height 5.70 m, crest width 10 m, seaside slope 2:1 (H:V) and leeward slope (1.5:1). The barrier is composed of a rigid bottom built of artificial elements (cubipods) and a long crown intended to be vegetated (with red mangroves, for example). The rationale behind this configuration is to provide ecosystem services by an artificially built mangrove forest protected by the rigid bottom. The experimental program consisted of 54 experiments divided into 7 groups corresponding to regular and irregular waves, mean and extreme and high and low tide conditions. Other variables of interest were the density and spatial distribution of mangroves, such as core materials.

## MATERIALS AND METHODS

The laboratory tests were conducted at the 20 x 0.4 x 0.5 m wave flume of the Engineering Institute of the National Autonomous University of Mexico. The wave flume is equipped with a piston-type wave generator that features an active wave absorber. The scale factor selected for the construction of the model was 1:25. An 8 m acrylic ramp was placed within the flume to produce a 2% slope bottom. The ramp elevation at breakwater foot was 12 cm.

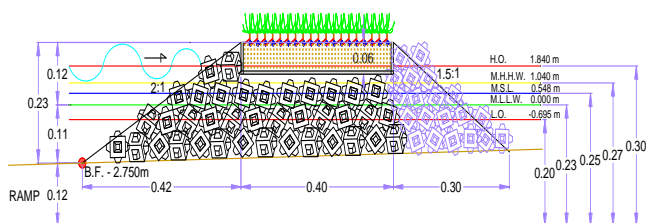


Figure 1 - Geometric design of breakwater.

For the vegetated part a 0.4 x 0.4 m acrylic box was constructed, floral foam was used intended to plant

mangroves in it. In prototype, this box represents a concrete structure filled with soil.

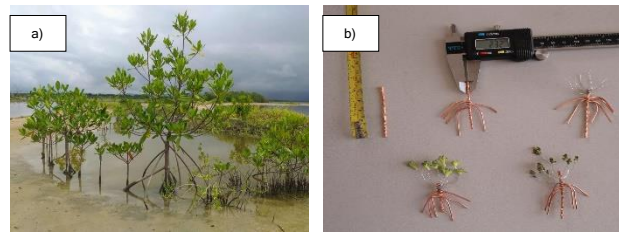


Figure 2 - Manufacture of individuals for physical model. a) Reference plant, b) Manufactured copper pieces.

The geometric characteristics of a mangrove individual located in the Sinaloa National Marshes reserve were used as a reference plant and pieces of copper wire were manufactured trying to reproduce the geometry of this plant. The dimensions of the pieces were as follows: 6 pieces of 22 gauge (0.711 mm) soft copper wire were used for the trunk. 3 pieces of soft copper wire 18 gauge (1.245 mm) were used for the roots, and 8 pieces of 29 gauge (0.356mm) soft stainless- steel wire were used for the branches.

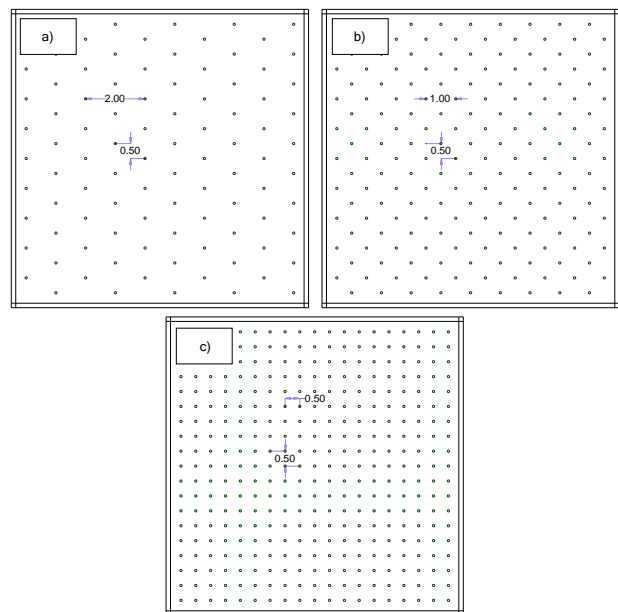


Figure 3 - Mangrove scenarios changing tree density and distribution. From left to right. a) Box 2, b) Box 3, c) Box 4.

Densities and spatial distributions of mangrove trees were as follow:

- Box 1 (without mangrove).
- Box 2 (95 trees, 3 trees/m<sup>2</sup>) separated 2 m in the x coordinate and 0.5 m in the y coordinate, placed staggered.
- Box 3 (180 trees, 5 trees/m<sup>2</sup>) separated 1 m in the x coordinate and 0.5 m in the y coordinate, placed staggered.
- Box 4 (361 trees, 9 trees/m<sup>2</sup>) separated 0.5 m in the x coordinate and 0.5 m in the y coordinate, placed in reticular order.

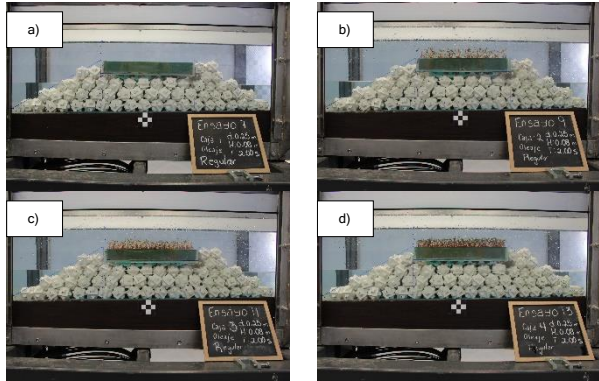


Figure 4 - Examples of scenarios in model a) Box 1 (test #7), b) Box 2 (test #9), c) Box 3 (test #11), d) Box 4 (test #13).

Tested conditions were a combination of wave heights (4 cm, 8 cm and 11 cm), wave periods (1.6 s, 2 s and 2.4 s), and water depths as a result from the addition of tide levels and storm surge elevation (23 cm, 25 cm, 27 cm, 29 cm and 31 cm).

Depth in prototype (m)	Tide level (m)	Storm surge (m)	Total depth (m)	Wave height in prototype (m)	Wave period in prototype (s)	Depth in model (m)	Wave height in model (m)	Period in model (s)
Normal waves in low tide (tests 3-4)								
2.75	0.00	0.00	2.75	1.00	8.00	0.23	0.04	1.60
Storm waves in low tide (case I) (tests 7-14)								
2.75	0.00	0.50	3.25	2.00	10.00	0.25	0.08	2.00
Storm waves in low tide (case II) (tests 17-24)								
2.75	0.00	1.00	3.75	2.80	12.00	0.27	0.11	2.40
Normal waves in high tide (tests 27-28)								
2.75	1.00	0.00	3.75	1.00	8.00	0.27	0.04	1.60
Storm waves in high tide (case I) (tests 31-38)								
2.75	1.00	0.50	4.25	2.00	10.00	0.29	0.08	2.00
Storm waves in high tide (case II) (tests 41-48)								
2.75	1.00	1.00	4.75	2.80	12.00	0.31	0.11	2.40
Additional cases- Changing core materials (tests 49-54)								
2.75	0.00	0.50	3.25	2.00	10.00	0.25	0.08	2.00

For reduction in transmission percentages and increase in dissipation percentages of the incident wave through the

core of the structure analysis, three different scenarios were proposed with different core materials using the same conditions of waves and tides from tests #13 and #14 (d:25 cm, H:8 cm and T:2 s, regular and irregular waves, Box 4), and were directly compared using these tests as reference.

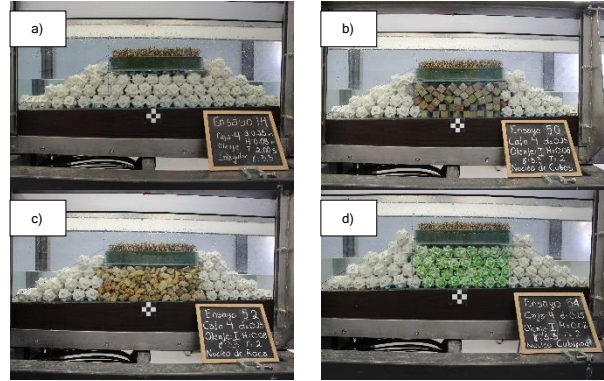


Figure 5 - Images of the breakwater with different core materials within the wave flume. a) Big cubipods (reference test #14), b) Concrete cubs (test #50), c) Rock (test #52), d) Small cubipods (test #54).

## RESULTS

The reflection coefficient is directly proportional to the tide level, storm surge elevation, wave height, and mangrove density in our experiments. Also, the reflection is between 1% and 4% higher for the cases with mangroves.

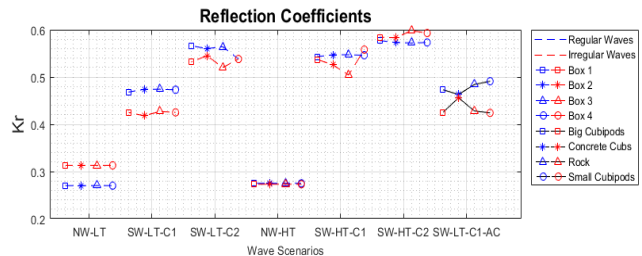


Figure 6 - Reflection coefficients.

The transmission coefficient is inversely proportional to the number of trees. This value is up to 30% lesser for regular waves and 38% for irregular waves when mangroves are present.

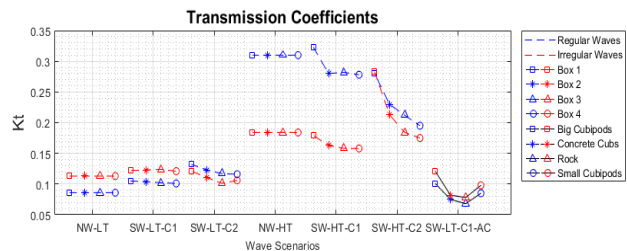


Figure 7 - Transmission coefficients.

The dissipation coefficients are 8% higher for regular waves and up to 7% with irregular waves than for non-mangrove cases.

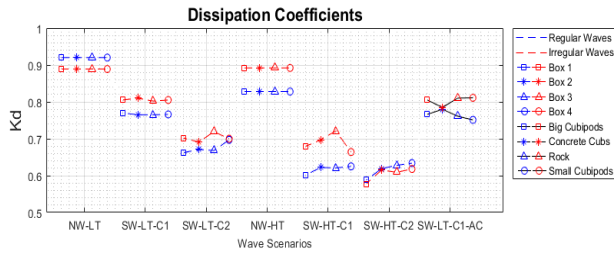


Figure 8 - Dissipation coefficients.

For the cases where core materials were changed and with regular waves, compared to the original structure an increase of up to 4% (core with small cubipods) in the reflection coefficient in front of the structure was observed. Transmission reduced by up to an additional 33% (Rock Core) and an additional 2% (Concrete Cube Core) of incident wave energy was dissipated.

For irregular waves a reduction of up to 21% (core with small cubipods) was observed in the reflection in front of the structure. Transmission reduced by 26% (Core with rock in irregular waves) and dissipated up to an additional 15% (Core with rock in irregular waves) respecting to the originally proposed structure.

### CONCLUSIONS

A hybrid structure that integrates a mangrove forest on its top was proposed and tested. It dissipates a more significant percentage of the energy of the incident waves in normal and extreme regimes. It was found as a general tendency that the greater the number of planted mangrove trees, the greater the reflection and the lower the transmission and dissipation generated by the proposed structure were. In addition, the structure's performance was improved by reducing the size of the materials in its core.

### REFERENCES

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