LARGE-SCALE PHYSICAL MODELING OF COASTAL PROTECTION PROVIDED BY A MODEL RHIZOPHORA MANGROVE FOREST

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INTRODUCTION

Mangrove forests exist in intertidal areas of tropical zones and most are characterized by their complex root systems, which attenuates flow energy. Among the mangrove species, Rhizophora species is the most common one, representing approximately 90% of the world mangrove distribution (Ohira et al., 2013). In addition, this species is used in the majority of restoration projects. Rhizophora plants are characterized by their aerial roots, which form a network above the substrate. Although several studies have been performed in the last decade to characterize flow interaction with mangrove trees (e.g.: Zhang et al., 2015), there is still a lack of knowledge of the forces exerted on the trees and the attenuation produced under waves, currents and waves and currents flowing simultaneously action.

EXPERIMENTAL SET-UP

Experiments are run in the Cantabria wave-current-tsunami flume (COCOTSU) at IHCantabria. Model trees where built based on Ohira et al. (2013). They provide a detailed three-dimensional geometric model of stilt root morphology based on a collection of field measurements. The geometry of the root system depends on the diameter of main trunk at breast height (DBH), which is also an indication of tree age. In this study, we consider mature mangroves for which DBH = 0.20 m. For this DBH, the highest root attaches to the trunk at HRmax = 2.012 m, and the number of roots is N = 24. The diameter of these roots range from 0.033 to 0.042 m. The roots are distributed around the trunk at 8 different angles leading to a three-dimensional layout. The model forest scale, 1:6, was chosen based on the facility dimensions. 140 trees were built leading to a mangrove forest 25 m long, representing 150 m at real scale. To avoid preferable channels next to the flume walls (Figure 1), 56 of these trees where half trees. Trees were distributed following a staggered arrangement. This distribution led to a mangrove forest density equal to 625 trees/ha at real scale.

Three water depths were tested: 0.17, 0.33 and 0.50 m, that is one below HRmax, one exactly at HRmax and one above that location. Regular and random waves with wave heights ranging from 0.04 to 0.15 m and wave periods from 1.2 to 2.2 s were tested. Several of these wave trains were also tested join to a unidirectional current ranging from 0.12 to 0.48 m/s. These unidirectional flow conditions were also tested alone. All flow conditions were set considering Reynolds and Froude similarity.

Free surface was measured at 23 locations along the flume including 3 gauges offshore the forest and 3 onshore. Flow exerted forces on the mangroves were recorded at 9 mangroves located at the first half part of the forest. Velocity was measured offshore and onshore the forest and velocity profiles were recorded in front of the 9 mangroves were forces were measured.

In addition to all these tests, and to analyze the influence of mangrove forest density, two smaller densities, i.e. 10 and 20% smaller than the original one, were also tested.

RESULTS

Free surface measurements reveal wave height attenuations up to 55% of the incident wave height for the smallest water depth (e.g. Figure 2) and a free surface gradient up to 200% for the same water depth and the highest unidirectional flow velocity. Flow attenuation strongly depends on water depth, highlighting the importance of the variable frontal area characteristic of this type of mangroves. Forces exerted on the mangroves exhibit the highest values at the first 5 rows and they are dependent of frontal area variability in agreement to Maza et al. (2017).

Figure 1 - Model mangrove forest (top and left bottom panel) and real mangrove forest (right bottom panel).

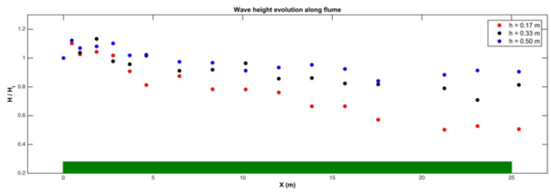

Figure 2 - Wave height evolution for regular waves (H = 0.06 m, T = 1.2 s) over h = 0.17, 0.33 and 0.50 m.

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