

## Introduction

The continual increase in human activities on coasts has turned coastal erosion into a serious problem all over the world and the Yucatan coast in Mexico is not an exception. About 60km of the 245 km Yucatan coastline show significant urban, fishing and tourist development but also registered coastal erosion of ~1 m/yr-1 along some stretches over the last 10 years. (Fig.1). In order to decrease this tendency, many structures (mainly emerged groins) have been planned and constructed but most of these efforts have been unsuccessful.

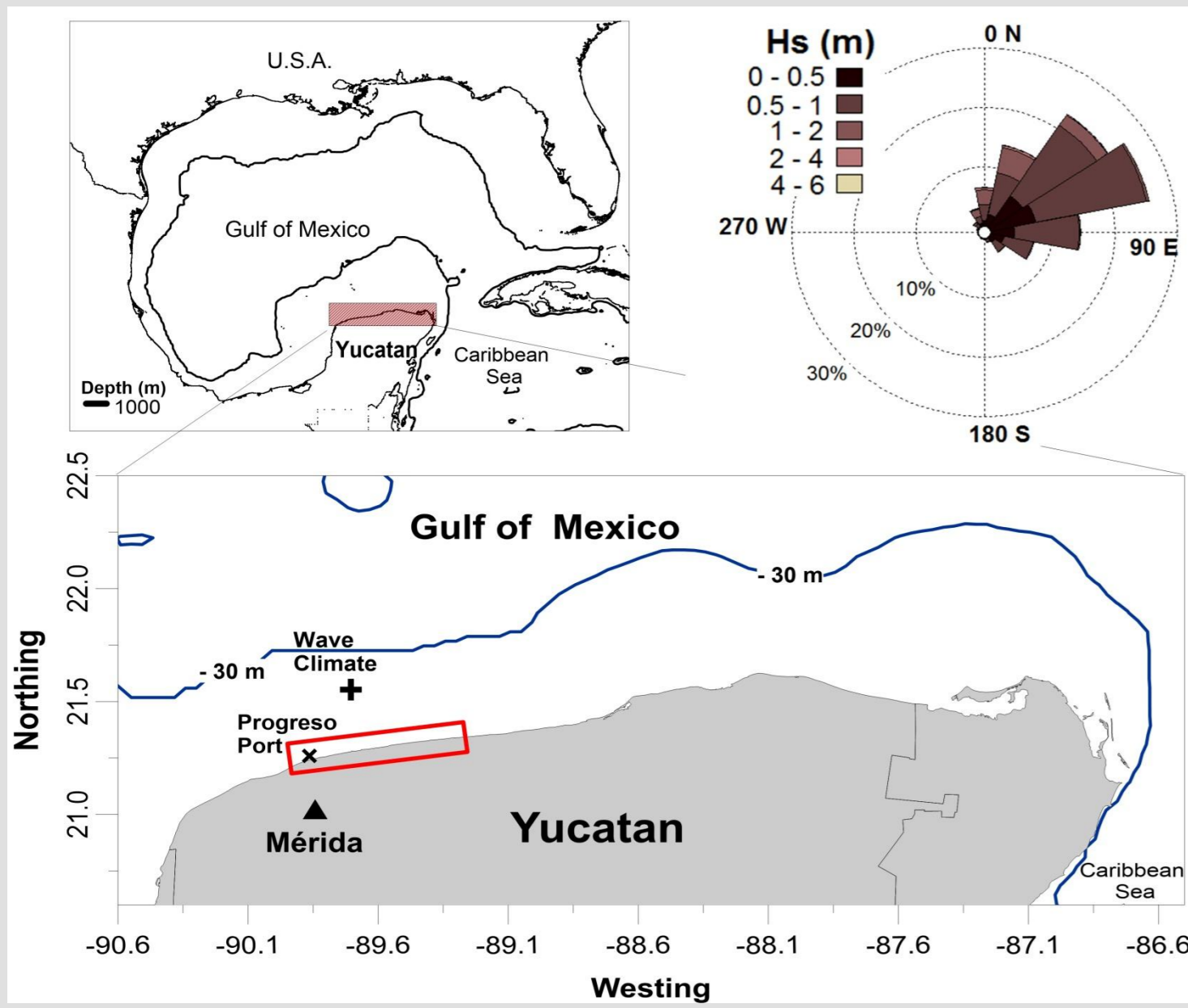


Figure 1 The Yucatan Peninsula, with the part of the coast with more shore protection structures, and the location of the wave rose (+) obtained from hindcast data.

Between 2005 and 2007, geotextile tubes were used as semi-submerged breakwaters (GT-SBW) at several sites on the Yucatan coast, 10 to 30 m away from the shoreline. The most seriously eroded part of the coast had developed a scarp height of ~1 m on the beach.

Despite the fact that geotextile tubes are less expensive and have less ecological impact on the coastal system than traditional types, if they are designed properly; it was found that in some cases shore protection and beach stabilization was achieved with the geotextile tube structure but in other places the results have been far from the expected.

Figure 2 shows two beaches after GT-SBW were installed using a basic criteria of negative freeboard ( $F_b \sim -0.3$  m referred to mean sea level).

The beach response largely depends on the relative position of the extreme ends of the structure to the orientation of the beach. The design requires a very gentle slope shoreward from the original coastline and the lack of this can turn the GT-SBW into a groin, causing a shadow effect.

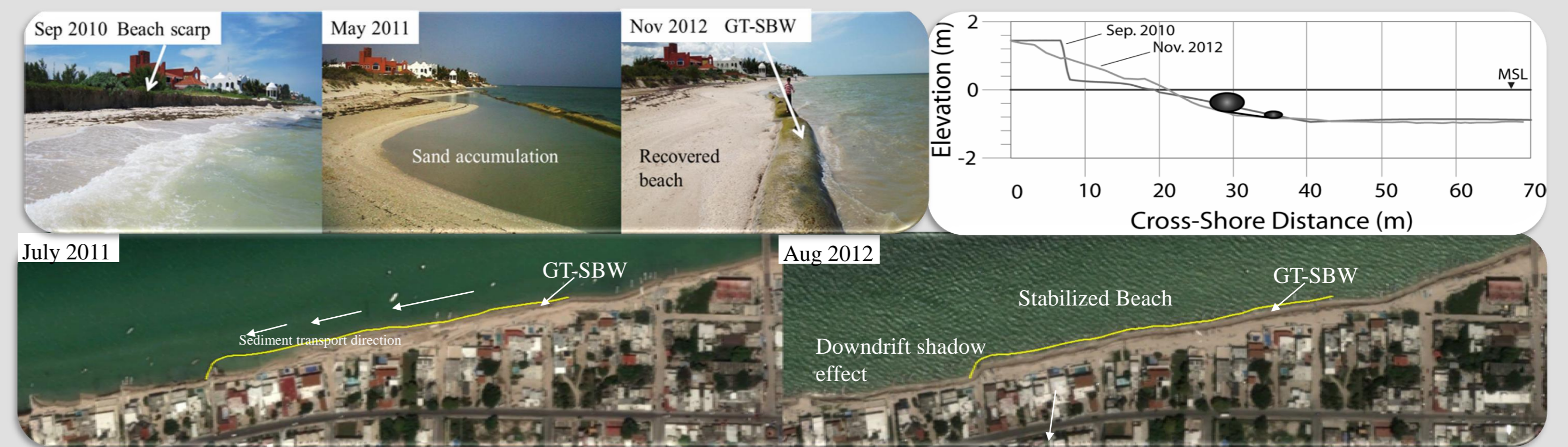


Figure 2 (a) Positive performance of GT-SBW to beach profile recover ed and shoreline advance, (b) stretch of coast stabilized after GT-SBW filled causing down-drift shadow effect

This study analyzes the results obtained through experimental tests using different physical scales and geometric configurations of geotextile tubes as a low crested breakwater or submerged breakwater (SBW).

The motivation for this study is to better understand the wave-structure interaction under sea-states representative of the coast of Yucatan in terms of the effectiveness of the structure in minimizing wave transmission ( $K_t$ ). The final goal is to define an optimal design for a submerged breakwater which acts as coastal protection for this low-energy coast.

## Experimental Set-up

The experimental tests were conducted in a wave flume at the Coastal Engineering Laboratory of the Instituto de Ingeniería at UNAM.

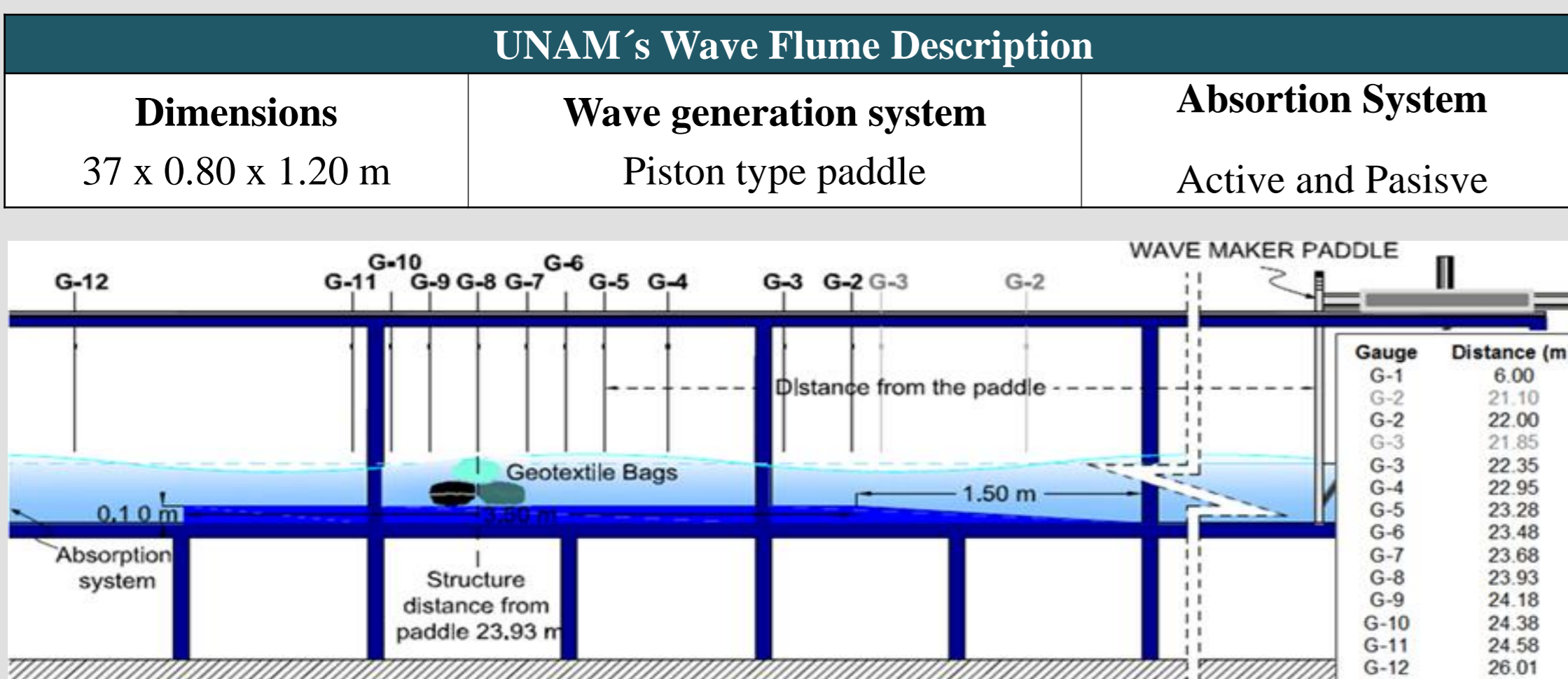


Figure 3 Set-up showing the location of 12 capacitance gauges.



## Test Conditions

The dominant incoming wave characteristics for the Yucatan coast were chosen following the statistical analysis of hindcast data generated by Silva et al. (2008). The wave characteristics used during the tests are representative of normal ( $H = 1$  m) and storm conditions ( $H > 1$  m) for the Yucatan coast. With this information the combinations of incident regular waves were established.

Experimental Setting for wave-structure interaction						
Experimental scales	Structure Geometries	Model Structure Dimensions	Wave flume instrumentation	Wave conditions	Criteria to eliminate	Coefficients
1:05		0.25 x 0.50 m	12 capacitance gauges installed to record water surface elevations Wave Gauge 1 (G1) close to paddle		wave breaking before the structure and non-linear conditions (Ursell > 40).	Transmission and Reflected Coefficients Mansard and Funke's, 1980 separation method $K_t = \frac{H_T}{H_I}$ $K_R = \frac{H_R}{H_I}$
1:10		0.15 x 0.25 m	Wave Gauges 6 or 7 (G6, G7) before GT-SBW Wave Gauges 10-12 (G10-G12) after GT-SBW			

## Measured variables and Coefficients Calculated

To characterize the performance of the wave-structure interaction 12 capacitance wave gauges recorded water surface elevations, the transmission coefficient,  $K_t$  was evaluated as:

$$K_t = \frac{H_T}{H_I} \quad (1)$$

where  $H_I$  = incident wave height and  $H_T$  = transmitted wave height.

Before calculating wave-structure interaction coefficients, a separation was made of the reflected from the incident wave, according to the Mansard and Funke's (1980) method. The reflected and transmission coefficients ( $K_R$ ) is defined as:

$$K_R = \frac{H_R}{H_I} \quad (2)$$

To calculate using Equation 1 it was necessary to determine the transmitted wave height ( $H_t$ ). For that reason and to remove the reflected waves, which the passive absorption system does not dissipate, a second separation incident/reflected wave on the lee side was carried out using the gauges G-10, G-11 and G-12.

Figure 4 clearly illustrates the transformation in the free surface during the modeling: The first gauge (G-1) indicates the generated wave height (offshore), the second gauge (G-6 or G-7) recorded, in some cases, increase of the wave amplitude due to the shoaling effect caused by the platform and the last gauge (G-12 or G-10) shows a decreased wave height induced by the protection of the structure.

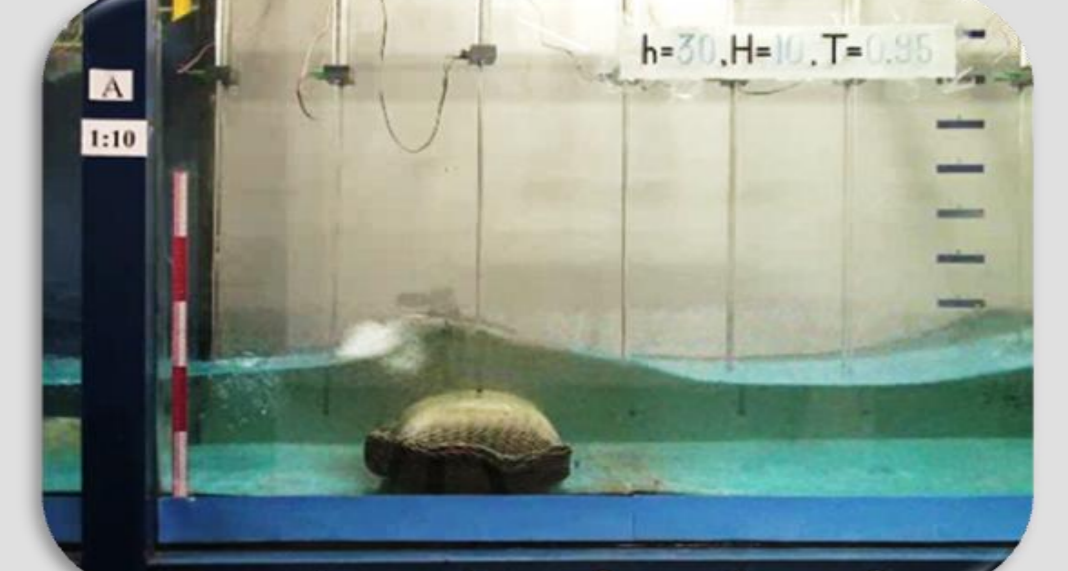
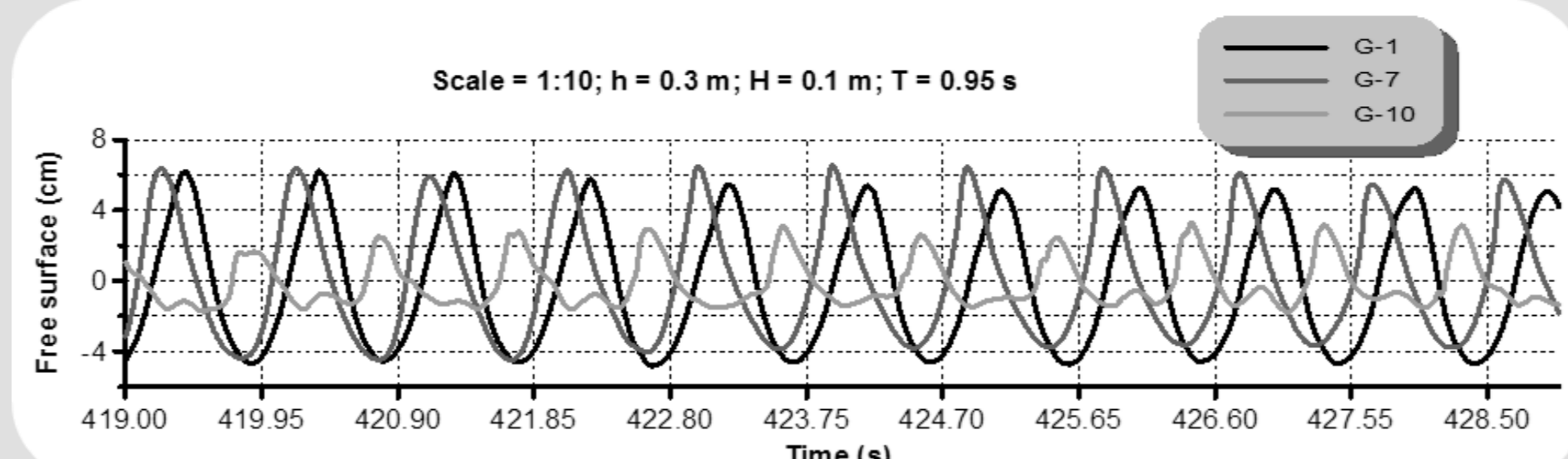
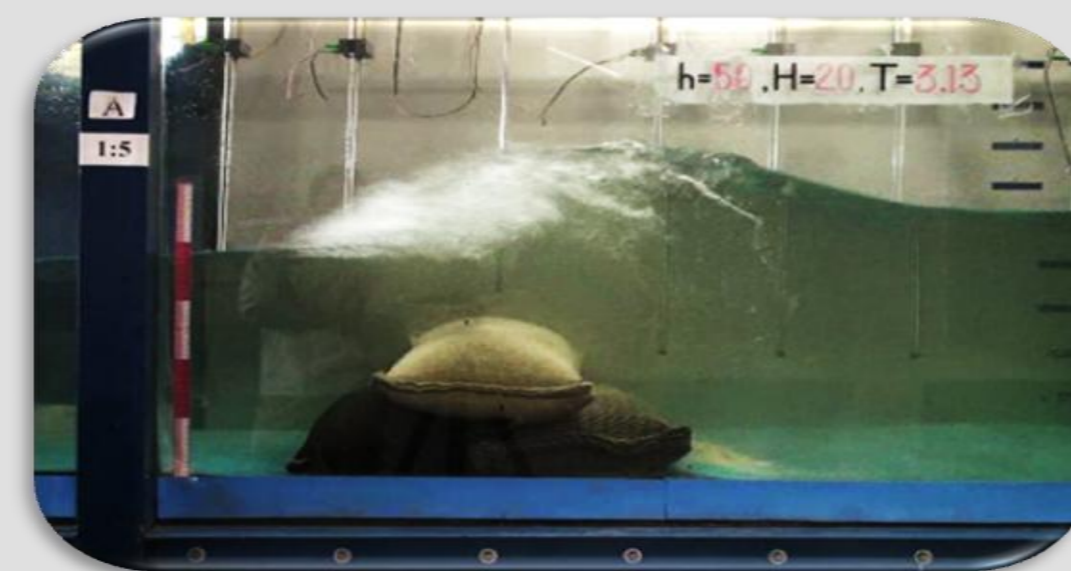
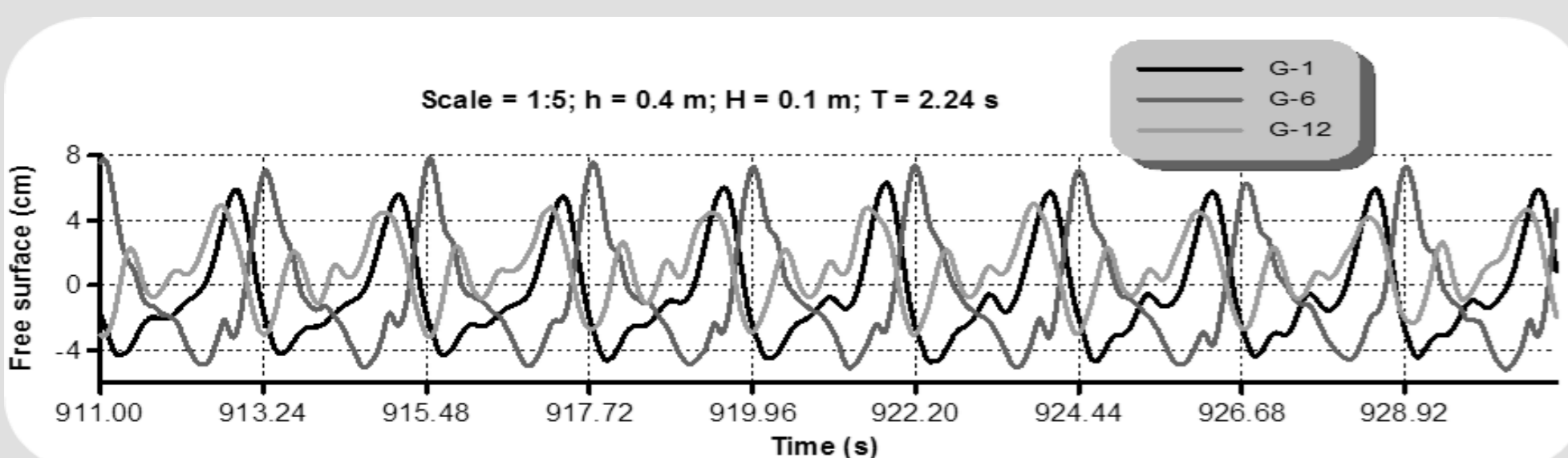


Figure 4. Free surface time series recorded by 3 wave gauges for the two scales employed and snap-shot of wave flume essays.

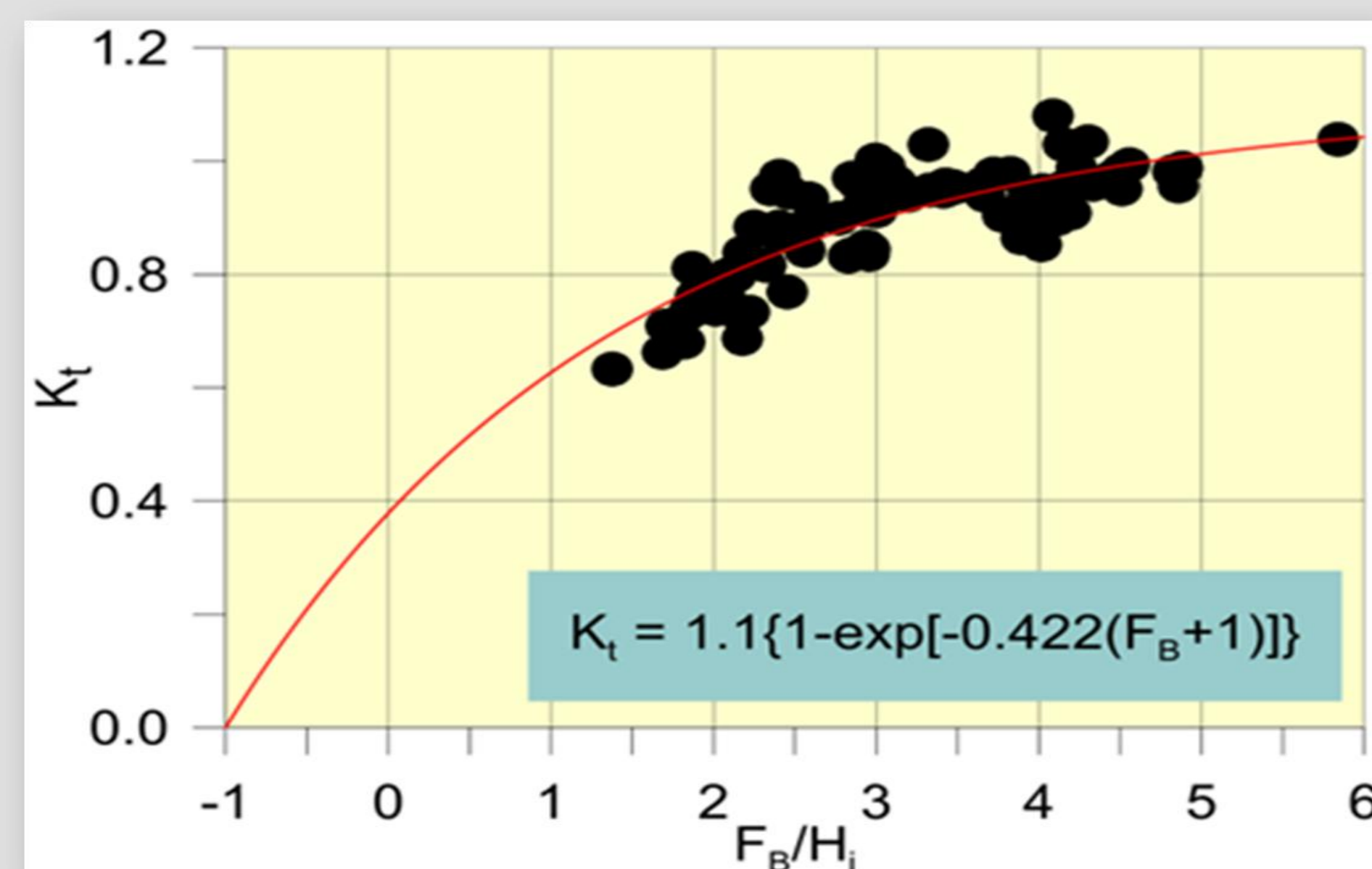
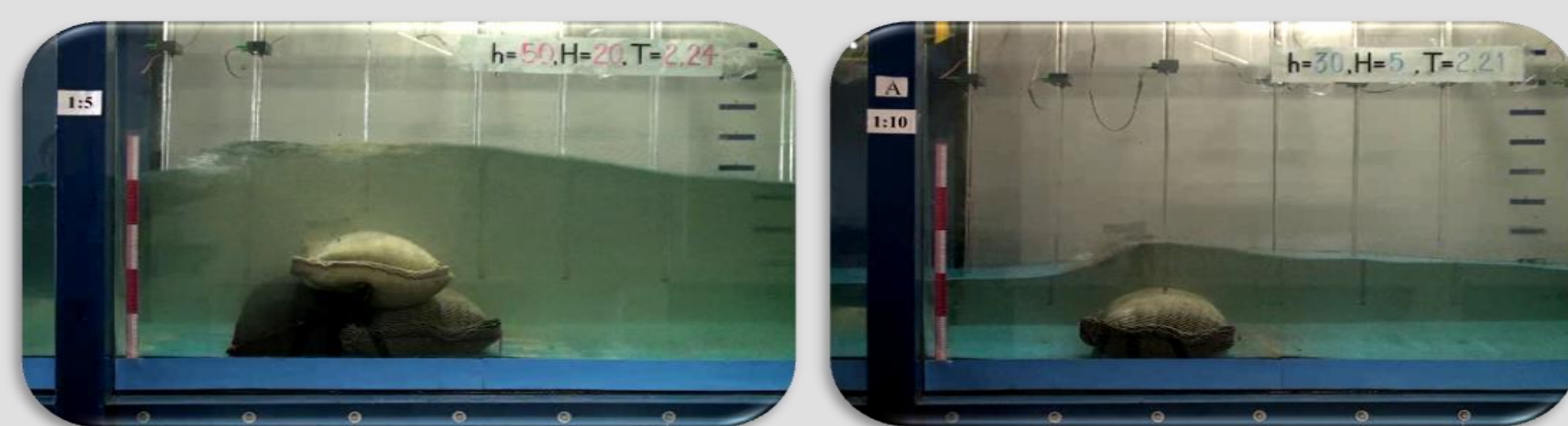


Figure 5. Transmission coefficient as a function of the relative freeboard

## Experimental Results

After investigating the transmission coefficient, it is concluded that the only dimensionless parameter that governs the wave transmission is the ratio of the submergence depth to the incident wave height.

- The experimental results and an empirical formula are presented in Figure 5.
- The results obtained have very important implications for the structure design, which should be taken into consideration: Depending on the amount of protection and in function of the design wave height, the most appropriate freeboard is selected. Once the design freeboard is selected, the fact that the smallest wave heights will have the highest transmission coefficients must be considered. However, higher wave heights will have smaller transmission coefficients, or, in other words, greater protection.
- In microtidal environments the hydrodynamic behavior of the geotextile structures will be the same. However, in areas where the amplitude of the tides is important, the least favorable design condition, spring tide conditions, must be considered.
- Under extreme meteorological conditions it is possible that the effect of storm surge arises. This should be analyzed and taken into account in defining freeboard of the structures.

In this study the structures were analyzed as living parallel to the coast. To define its distance from the shore it is necessary to make an estimation of the currents generated by the waves.

## CONCLUDING REMARKS

From the results obtained in the laboratory the following can be established:

- The effect of structures made of geotextiles is very similar to that of impermeable concrete structures.
- Although geotextile structures are able to reflect waves, if they are crowned well below the mean water level, the waves steepen and break more violently.
- The maximum recommended freeboard should not be more than twice the dominant wave height of the area requiring protection.
- The relative width of the crown is a parameter which can help wave dissipation. The higher this is, the better the coastal protection. However, the results show that for real dimensions it is sufficient to characterize the protection level in function of the ratio of the submergence depth to the incident wave height.

## ACKNOWLEDGEMENTS

Thanks to the Instituto de Ingeniería UNAM facilities, especially to Xavier Chávez, Rodolfo Silva and Edgar Mendoza.

Funding was kindly given through PEI-CONACYT Project: C0003-2012-01-01177371.