ON THE ASSESEMENT OF DETACHED BREAKWATERS ON A SEA-BREEZE DOMINATED BEACH

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INTRODUCTION

Sandy beaches provide habitat and natural protection to coastal areas against extreme events. Beach erosion is ubiquitous of coastlines around the world and is very important given the implications in the loss of land and infrastructure in coastal areas. This problem is particularly relevant in low-lying coasts, with shallow and extended continental shelves, considering the increasing trends on the frequency, intensity of storms (waves, currents and surges), and the sea level rise due to climate change. Mitigation measures encompass different approaches including soft and hard engineering solutions. The Yucatan coast (Mexico) has experienced beach erosion over the past decades. More recently, detached breakwaters have been constructed to mitigate beach erosion. Thus, we investigate both permeable and impermeable structures performance in this area.

STUDY AREA

The study area, located on the northern coast of the Yucatan peninsula, is characterized by intense and persistent northeasterly sea breezes. They are responsible of generating short- period and high- angle incident waves which drive a net westward littoral transport on the $\mathcal{O}(10^4)\mathrm{m}^3$/year (Appendini et al., 2012). Furthermore, storm events are often associated to cold-front passages. With coastal development triggered on early 1960s by the construction of fishing ports and summer houses along the coast (Meyer-Arendt, 2001), beach erosion has become a severe problem in most of the coast, due to the sediment transport impoundment by ports jetties and the deployment of hundreds of unauthorized small groins. More recently, impermeable and permeable detached breakwaters have been deployed at some locations where erosion was critical (Figure 1). Therefore, the aim of this work is to assess the seasonal beach variability due to the presence of such structures on this micro-tidal sea-breeze environment.

Figure 1 - Study sites location of impermeable and permeable structures in the Northern Yucatan coast. The structures are made of geotextile bags (G1 and G2) and Reef Balls (RB1 and RB2).

METHODS

The study focuses on the morphological effects caused by four detached breakwaters constructed in 2016-2017 with varying (i) materials, (ii) geometry, (iii) distance and orientation with respect to shoreline, and (iv) height of the crest of the structure with respect to the mean sea level (freeboard). Impermeable breakwaters consist of 20-m long sections of sand-filled geotextile bags (sites G1 and G2). On the other hand, permeable structures consist of 0.4 (site RB2) and 0.8 (site RB1) tons Reef Ball elements. Given the highly sensitive shoreline response to anthropogenic interferences, there is a need to investigate morphological changes behind and near these structures on a seasonal time scale.

Beach morphological changes have been measured by means of RTK-DGPS surveys with high spatial resolution. At each site, 20 to 27 cross-shore transects (Figure 2) were surveyed with a maximum alongshore resolution of 10 m between transects. The beach surveys covered an area of 300 to 400 m. Furthermore, Unmanned Aerial Vehicles (UAVs) flights were performed at 30-m height and approximately 1-km in length to generate a Digital Elevation Model (DEM) using ground control points. Wave conditions were obtained from NOAA Wave Watch III hindcast data (http://polar.ncep.noaa.gov/waves/hindcasts/).

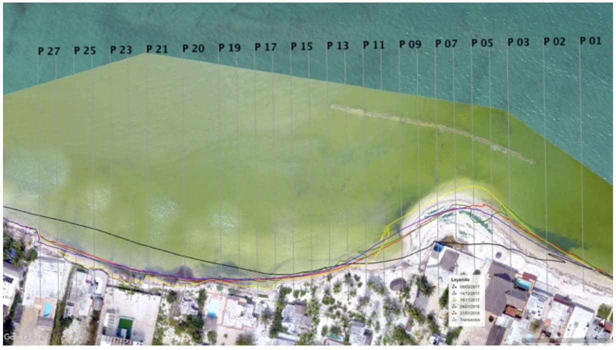

Figure 2 - Aerial picture of Punta San Miguel showing the shoreline evolution (black: 03/08/2017; blue: 12/14/2017; yellow: 11/15/2017; green: 01/24/2018; red: 01/31/2018) associated to the impermeable detached breakwaters installed at G1. The 27 beach transects employed for the topo-bathymetric surveys are also shown (gray lines).

RESULTS

We investigate the seasonal beach morphodynamics on this sea breeze dominated beach due to the presence of the structures. Field surveys were conducted before the structures' deployment in three (G1, G2, and RB1) of the four sites (see Figures 3a, 4a, and 6a). Figure 2 shows the shoreline evolution at location G1 before and after a 120-m long impermeable breakwater was installed (June 2017). The shoreline drastically grew behind the structure during sea-breeze conditions occurring in the first months (Figures 3b-3c), causing a significant erosion downdrift. During the cold-front season (winter months) the salient became more symmetrical owing to sediment bypass during storm conditions (Figure 3d) and the eroded portion of the beach partially recovered. The salient almost became a tombolo owing to the high ratio between the breakwater length and shoreline distance.

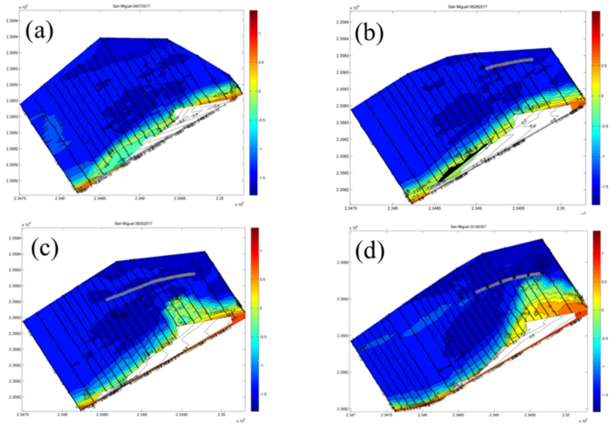

Figure 3 - Contour plots of seabed elevation (a) before (04/2017) and (b-d) after (06/2017, 08/2017; 03/07/2018) the impermeable structure deployment at location G1.

A second geotextile breakwater was deployed on a beach with straight and parallel contours at G2 (Figure 4). The shoreline presented smaller variations with respect to G1 (Figures 4b-d). The salient oscillated (Figures 4b and 4c) depending on incident wave conditions. However, freeboard variations along the structure induced unexpected sediment transport gradients behind the breakwater (Figure 4d).

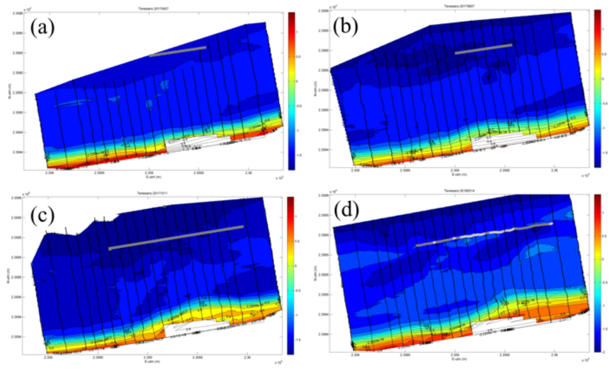

Figure 4 - Contour plots of seabed elevation (a) before (04/2017) and (b-d) after (06/2017, 10/2017; 03/2018) the structure deployment at location G2. Lighter color sections along the structure in (d) indicate lower freeboard.

Beach morphodynamics behind a permeable breakwater installed at RB1 (Figure 5), made of Reef Ball elements, presented a different behavior with respect to G1 and G2. A beach salient was observed during sea-breeze conditions (Figure 6b). However, the salient was smoothed out during the storm season (Figures 6c and 6d). Moreover, onshore sand bar generation and migration occurred between the breakwater and the shoreline (Figure 6c).

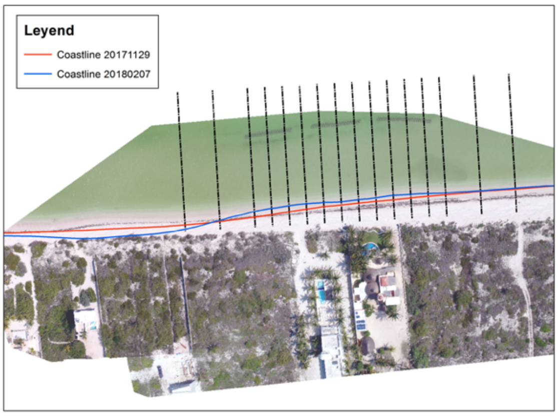

Figure 5 - Aerial picture of Faros beach (RB1) showing the beach transects and the shoreline change associated to the permeable detached breakwaters.

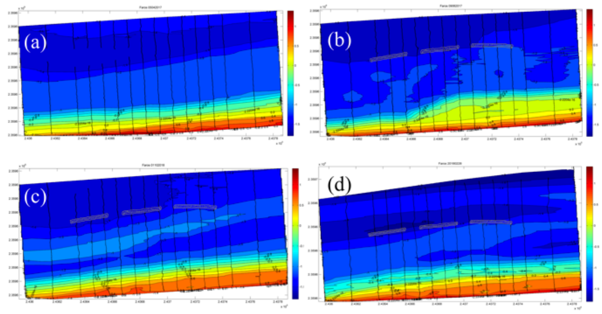

Figure 6 - Contour plots of seabed elevation (a) before (04/2017) and (c-d) after (09/2017, 01/2018, 02/2018) the breakwater deployment at RB1.

CONCLUSIONS

We investigate beach morphodynamics on a sea-breeze dominated beach under the presence of (permeable and impermeable) detached breakwaters. A distinct behavior was observed at the four sites due to difference on the structure type (geotextile or Reef Ball), design (length and distance to the shoreline), coastline orientation, and the freeboard of the breakwaters. It is shown that the combined use of high-resolution DGPS measurements and DEM derived from UAVs flights allow an assessment of the structures' performance behind the structure and in adjacent beaches. Seasonal beach variability was amplified with increasing breakwater length to shoreline distance ratio and was more drastic on beaches located behind impermeable structures. Beaches behind permeable structures presented a more stable behavior. Moreover, sandbar generation and migration were not inhibited behind such structures. However, downdrift erosion was observed in all cases regardless of the structure characteristics and shoreline orientation.

ACKNOWLEDGMENTS

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