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# DIGITAL PROFILER BASED ON A LOW-COST 3D-SCANNER TO EVALUATE THE HYDRAULIC PERFORMANCE OF HOMOGENEOUS LOW-CRESTED STRUCTURES

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## 1 INTRODUCTION

In order to evaluate the hydraulic performance of breakwaters, mechanical profilers were first used in wave flumes. Vertical bars and rolling wheels have been used to track the breakwater shape. Once surveyed, useful hydraulic parameters were able to be measured (e.g., envelope shape and eroded area). Nevertheless, the methodologies based on mechanical profilers have some limitations: they are intrusive, require specific equipment and are time-consuming. On the other hand, non-intrusive laser scanners can also be used; recent studies proved the feasibility of non-intrusive fast methods of surveying with 3D-scanning, (see Musumeci et al., 2018). These instruments are fast and reliable at capturing the shape of the breakwater in real-time. However, this method did not consider the distortion caused by light refraction. Laser scanners usually require to measure models in dry conditions, which is not efficient in time and resources. Regardless of the drawbacks when using non-intrusive laser scanners as digital profilers, the distortion can be corrected. The data suits for the usage of Neural Networks (NN) that can be trained to correct distortion.

This study is focused on Homogeneous Low-Crested Structures (HLCS) which is a new typology of Low-Crested Structures (LCS), made out large quarry stones or concrete armor units that are suitable to reduce shoreline erosion on degraded coastlines and natural environments. HLCS can be classified as reef-type breakwaters and are considered an environmentally-friendly solution that fulfils two purposes: to protect beaches nearby and to enhance coral regeneration and marine colonization, (see Medina et at., 2020). For the correct design of HLCS or conventional LCS, it is required to evaluate both the hydraulic stability and wave transmission (see van der Meer and Daemen, 1994). HLCS are structures without core which may erode under intense wave attack. Breakwater damage and crest freeboard must be estimated depending on incident wave conditions. The breakwater envelope evolves and finds an equilibrium state related to the incident wave conditions in which the crest freeboard and the transmitted wave energy levels may change.

The goal of this study is to provide a low-cost non-intrusive methodology based on 3D-scanning to study the hydraulic performance of mound breakwaters, specifically for Cubipod HLCS. This surveying procedure allows to obtain the real-magnitude shape of the envelope of the HLCS, even with a certain water level. The methodology mimics previous surveying techniques and provides relevant hydraulic and structural parameters (crest freeboard, damage, envelope shape, etc.) that can be then used to study the hydraulic performance of breakwaters.

## 2 MATERIALS AND METHODS

### 2.1 Small-scale tests on wave flume with Cubipod HLCS

A total of 15 tests are carried out (five crest freeboards, RC, and three wave steepness, $s_{0p}$) for a HLCS model geometry (see Figure 1). The 3D-scanner laser used in this study is the cheap and easy-access Microsoft Kinect. It is an RGB-D scanner that works at 30Hz with VGA resolution (640x480 pixels). The Microsoft Kinect is placed on top (vertically orientated) and the breakwater models are scanned after each test is finished (see Figure 1a). The scans are cloud points that can be exported as *X-Y-Z* coordinates. For each cloud point obtained *X-Y-Z*, relevant hydraulic and structural parameters can be measured after



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the light refraction distortion is corrected. To correct distortion, a NN methodology is proposed in this study. It requires some dry scans that can be obtained without disturbing the usual program of tests in wave flume, therefore saving time and resources.

### 2.2 Obtaining undistorted scans to study the hydraulic performance of Cubipod HLCS

The NN architecture is defined by three input neurons $X$-$Y$-$Z_{sub}$, a single hidden layer and one output neuron $Z_{dry}$. The samples used to train are a total of four scans, i. e., two pairs of dry and submerged scans: a first pair at the start and a second pair at the end of tests. In addition, only for the purpose of this study, another dry scan is obtained at an intermediate stage to have an independent sample $X$-$Y$-$Z_{sub}$-$Z_{dry}$ to validate the performance of the NN. All required scans to train the NN are obtained without interrupting the program of tests.

The methodology is divided in three steps: Firstly, all raw scans are pre-processed with an algorithm that mimics a physical profiler to obtain envelopes. It clears and transforms the raw data into proper inputs and outputs for training the NN. Secondly, the NN architecture is prepared and trained. The data to be trained is subdivided in three random samples (train, validation and test) which uses an early stopping algorithm to prevent overfitting. Thirdly, the NN is fed forward to obtain the real-magnitude counterpart $Z_{dry}$ for the remaining tests $Z_{sub}$. Thus, the same analysis approach, previously used with physical profilers, can be then used to study the hydraulic performance of Cubipod HLCS.

## 3 RESULTS

A good agreement is found between predictions and observations. For instance, Figure 1b shows the observed $Z_{dry,observed}$ (black) against the predicted $Z_{sub,corrected}$ (blue) given by the NN for an arbitrary sample $Z_{sub,observed}$ (red); the indicators measured are $RMSE$=0.48cm, $R^2$=0.990 and $r$=0.995. The proposed method allows to measure the damage and crest freeboard evolution as if it were a conventional physical profiler with the presence of water. Moreover, this digital profiler with a laser scan presents advantages: it is quick, cheap and non-intrusive.

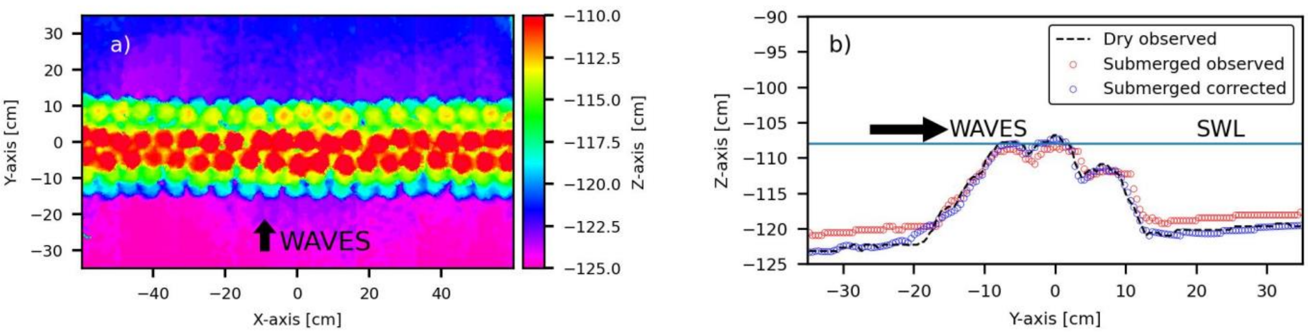


**Figure 1. a) Heightmap of a scanned HLCS model, and b) its corresponding corrected cross-section (plane X=0 cm).**

## 4 CONCLUSIONS

A non-instrussive methodology using the cheap and easy-access Microsoft Kinect 3D-scanner is proposed to capture the real-magnitude shape of the envelope of partially or fully submerged Cubipod HLCS. It easy to implement and allows to remove the distortions caused by light refraction; the required dry-wet scans can be obtained without modifying the usual hydraulic stability test procedures. This methodology is valuable to evaluate their hydraulic performance. Additionally, since the inputs and outputs are X-Y-Z coordinates, this methodology can be potentially generalized for rubble mound breakwaters. At the congress, the details about the method and their possibilities will be presented.

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