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Run-up and overtopping video analysis using Timestack methodology

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ABSTRACT

This work evaluated a video camera-based technique for measuring wave run-up and identifying overtopping events in three-dimensional physical scale models of rubble-mound breakwaters. Run-up elevations inferred by the *Timestack* methodology were compared with the traditional measurements obtained by a resistive wave gauge. For both frontal and oblique incident waves, run-up statistical parameters returned by *Timestack* analysis agreed with the instrument measurements. Moreover, overtopping events were correctly identified. Overall, results indicated the feasibility of a non-intrusive video camera-based technique for hydraulic measurements in physical models.

1. Introduction

The determination of run-up and overtopping events in physical models is traditionally carried out using a resistive wave gauge placed along the slope of the structure. An alternative approach consists in the use of video cameras and image processing techniques, such as the *Timestack* methodology, proposed by Andriolo et al. (2016). At LNEC, promising results of wave run-up parameters were obtained on 2D physical models by using a common video camera and following the methodology *Timestack*, Lemos et al. (2023).

The objective of this work is to evaluate the performance of *Timestacks* in three-dimensional tests, in which the run-up that reaches the slope varies significantly along the structure, given the influence of the obliquity of the wave. With this new technique, based on videos obtained during tests on a physical model, it becomes possible to quantify, a posteriori, the run-up in any area of the breakwater, by defining the transect on the area of interest, as a virtual wave gauge. Another application of the technique is its use in identifying overtopping and determining the distance reached by the overtopping event.

2. Materials and methods

Tests were conducted in the wave tank of the Hydraulics and Environment Department of the Portuguese Laboratory for Civil Engineering (LNEC). The tank is 43 m long, 25 m wide and 1.5 m high. The model was built and operated at a 1:58.9 scale, according to Froud similarity law. Tests were conducted with both frontal and oblique wave incidence with an angle of attack of 70°. A video camera, with a frame rate of 25 frames/s, was positioned in front of the breakwater section. Tests were conducted with significant wave heights (Hs) of 6 and 8 m, associated with peak periods (Tp) of 16, 20 and 22 s and three different water levels: 0.0 m(CD); +1.8 m(CD) and +3.0 m(CD). These water levels correspond to low-water level (LWL), high-water level (HWL) and high-water level associated with sea level rising (HWLS), respectively.

The *TimeStack* methodology consists in the application of three MatLab algorithms for extracting the pixels array along a pre-defined image segment (transect). This extraction results in an image (the *TimeStack*), where is possible to identify, manually, the run-up crests, and to obtain a time series in pixel values which will then be converted into metric values, enabling to estimate the statistical parameters Ru_{max}, Ru_{min}, Ru_{med} and $Ru_{2\%}$.

To evaluate the application of *TimeStack* methodology, the run-up values obtained by video analysis were compared with those obtained in a resistive wave gauge placed along the slope of the breakwater. Figure 1 shows the three-dimensional model, as well as an example of a transect, located along the breakwater crest, to identify overtopping events and a transect defined to determine the run-up values. Figure 2 shows segments of two *TimeStack* images for identifying overtopping (left) and run-up events (right).

Fig. 1. Three-dimensional model and location of transects (red lines) to retrieve pixel array for Timestack production. Lines are chosen to identify overtopping (left) and run-up events (right).

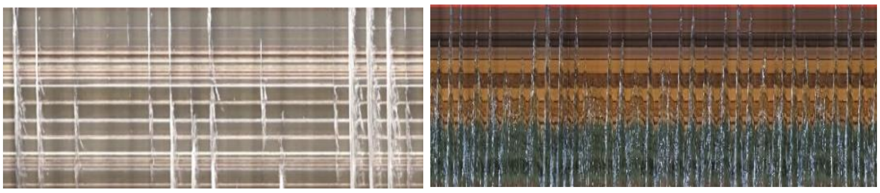

Fig. 2. *TimeStack* images for identifying overtopping (left) and run-up events (right).

3. Results and discussion

Table **1** summarizes the results obtained with both methodologies for tests conducted with a frontal wave direction (T1 and T2) and tests conducted with obliquity (T3 and T4).

Table 1. $Ru_{2\%}$ and Ru_{max} obtained with the video analysis and with the wave gauge time series

Test	Methodology	$Ru_{2\%}$	Ru_{max}
T1_S35E_Tp22_Hs8_HWL	Video	8.45	8.74
	Wave gauge	8.01	8.09
T2_S35E_Tp20_Hs6_HWLS	Video	7.87	7.87
	Wave gauge	7.13	7.23
T3_E20N_Tp16_Hs6_LWL	Video	9.61	9.97
	Wave gauge	9.00	9.49
T4_E20N_Tp16_Hs6_ HWL	Video	8.71	8.81
	Wave gauge	7.79	8.94

The differences identified were, in part, due to the manual selection of the crests on the *Timestack* image, which can lead to a loss of run-up events. An automatic crest identification algorithm is currently being developed to improve the methodology. The definition of the slope geometry is also of an utmost importance, and, unlike in 2D models, the profile geometry in 3D models cannot be verified from the side. Thus, the design profile geometry should be confirmed by model surveying, as very small differences in the model can lead to important differences in prototype values. The analysis of the overtopping detection is undergoing.

4. Conclusions

The comparison of the results obtained with the video technique with the measurements of a wave gauge placed on the breakwater armour layer confirmed that the video technique is a viable alternative to measure the run-up on 3D physical models. It also allows the creation of "virtual wave gauges" (the transects), with the possibility of placing a practically unlimited number of transects enabling the run-up analysis in any part of the model. This asset is very useful in 3D scale model tests, where the run-up varies due to the wave obliquity.

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References

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