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OVERTOPPING FLOW VELOCITY CHARACTERISATION OF FOCUSED WAVES ON PROMENADES USING THE BUBBLE IMAGE VELOCIMETRY TECHNIQUE

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1 INTRODUCTION

This study characterises the flow velocity of individual extreme waves that overtop promenades using the bubble image velocimetry (BIV) technique (Ryu et al., 2005). Experimental tests were carried out in the small-scale wave flume CIEMito, at the Marine Engineering Laboratory (LIM) of the Universitat Politècnica de Catalunya – BarcelonaTech (UPC), and the obtained images were post-processed to calculate the flow velocities. The ultimate objective of the experimental campaign is to develop more precise models for forecasting wave overtopping of structures with an emergent toe, commonly found on sandy beaches and frequently utilized as promenades or waterfronts in most urbanized coastal environments. The NewWave theory (Tromans et al., 1991) was used to simulate the extreme individual wave overtopping in a real random sea state. The NewWave theory establishes a correlation between the expected form of a large wave in a linear sea state and the bulk characteristics of the sea state. Using focused wave groups instead of long-duration irregular wave time series offers several benefits. It improves the ability to repeat experiments and enhances measurement capabilities by providing greater temporal resolution in models used to investigate significant wave interactions (Hofland et al., 2014). Additionally, due to the compactness of focused wave groups, wave absorption becomes unnecessary. The research identifies two distinct case studies with varying wave forcing, tidal regimes and coastal layouts. This work presents a case study of a typical Mediterranean Sea configuration, which is a micro-tidal environment with steep and relatively short foreshores and pocket beaches. The study aims to characterize the overtopping flow velocity on the selected structure, and the feasibility of non-intrusive measurements such as a BIV technique has been investigated. The work includes preliminary results.

2 EXPERIMENTAL CAMPAIGN

CIEMito flume is 18 m long and 0.38 m wide. A piston-type wavemaker is employed to generate waves. A 1:50 scale model was used. The model was made of plywood and comprised a sloping beach composed of a 1:15 slope starting at 7.2 m from the wave generation and followed by a steeper 1:6 slope reaching the toe of the dike/promenade. The structure was designed with different geometries: a vertical wall, sloping dikes with slope equal to 1:2, 1:1 and 2:1, respectively. In all cases, the height of the dike was 0.04 m. The dike was placed either at the end of the 1:6 beach or at a 0.05 m distance, creating a layout with a horizontal emerged berm at the dike toe. The water depth used was shallower than the structural toe, resulting in the dikes always being exposed. Resistive wave gauges were placed along the flume to measure water surface elevation. An overtopping tank, equipped with an ultrasonic proximity sensor, was used to measure the volume of overtopping. BIV was used to characterise the velocity of the overtopping flow. The BIV method combines the shadowgraph technique, which illuminates the fluid background to show the flow pattern, with the PIV (Particle Image Velocimetry) technique, which correlates consecutive images to determine velocity. The velocity is calculated via cross-correlating the images obtained from shadowgraph technique with the bubble structure in the images as tracers. The BIV system normally consist of the following components (Rivillas-Ospina et al, 2012): high speed camera, lights, PIV data processing software, computer for image data process. Images were recorded using a IDS UI–31800CP–M–GL video–camera with a resolution of 5.1 megapixels, shooting at a sampling frequency of about 118 fps. The video camera was located at one side of the wave flume facing the measuring window. The lens was calibrated to focus on a point at a distance from the center of focal plane equal to 0.97m. Each image was taken with a resolution of 1280x520 pixels. The illumination system consisted of high power light-emitting diode (LED) lamp built in-house using five lines of high power LED lamps located on a mobile frame on top of the flume walls. The video images were recorded using the Norpix StreamPix 7 high speed digital recording software.

Figure 1. Photos of the 1:6 beach and 2:1 dike layout with berm (left) and detail of the IDS UI–31800CP–M–GL video–camera

3 PRELIMINARY RESULTS AND CONCLUSIONS

Significant wave height H_s=0.08 m, peak period T_p= 1.6 s, focused location x=9.58 m and phase equal to 270° were employed to generate the focused wave group (target H_{max}=0.14m), which was repeated 20 times, so that accuracy of the analysis (mean error and standard deviation) and repeatability were checked. Measured individual volumes ranged between 1,500 and 16,000 l/m (in prototype scale), depending on the structure. Using an in-house Matlab script, the acquired images were treated: colour was inverted to obtain white field and black dots (=bubbles), and contours of the flow were identified in order to apply a mask to each picture and remove possible background noise for further analysis (Figure 2, left). Finally, the PIVlab Matlab tool was employed to analyse all frames and characterise the flow velocity (Figure 2, right).

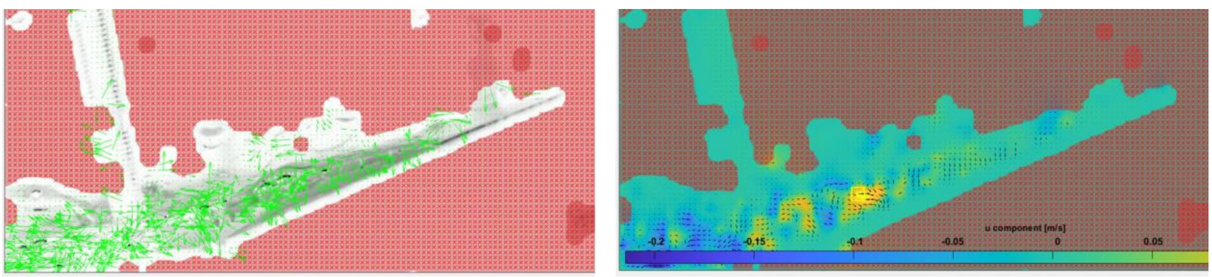

Figure 2. Left: inverted and masked image for 1:2 sloping dike. Right: reconstructed velocity field using PIVLab from Matlab.

The results show that wave grouping, dike slope, and berm presence significantly affect overtopping flow velocities. Maximum velocities exceeding 3 m/s were measured at the prototype scale. These data offer valuable insights for enhancing promenade designs and developing effective coastal defence structures (Van der Meer et al., 2022). The conference will feature detailed results for each dike configuration, including measured maximum velocities for structural layout, scale effects, and measurement accuracy. The outcomes of the present research will be compared with the ones from Raby et al. (2019), who previously applied BIV to characterise individual violent wave-overtopping events of breaking waves.

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