FIELD MEASUREMENT OF IMPACT PRESSURES ON A VERTICAL STRUCTURE GENERATED BY OVERTOPPING WAVES ON A SHALLOW FORESHORE.

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CONTEXT

The vulnerability of coastal areas to the impact of overtopping storm waves has increased in the last decades and should intensify in the future as a result of both heavy anthropisation and climate change effects, notably the mean sea level rise (IPCC Report (2021)). A better knowledge is required of the physical processes that lead to wave overtopping and their impact on upper beach infrastructures. In particular, the quantification and prediction of overtopping wave loading are strategic for designing defense structures and implementing adaptation strategies to improve the resilience of coastal communities faced to the effects of climate change.

PROBLEMATIC

Shallow foreshore configurations with an upper beach sea dike topped with a promenade and backed by buildings are common in many coastal cities worldwide (Altomare (2020)). Hydrodynamic processes that cause wave overtopping and the associated impacts on infrastructures in such configurations have been documented during the last decade based on a series of laboratory measurements (e.g. Chen (2016), Streicher (2019)). From these reduced-scale experiments, empirical formulas have been proposed to predict the maximum impact force exerted by overtopping waves on a vertical wall (EUROTOP (2018), Streicher (2018)). However, field studies in comparable real configurations are very scarce because of the difficulty of carrying out similar measurements under storm conditions. Consequently, the accuracy and applicability of established empirical formulas in realistic cases remain uncertain because of possible scale effects, in particular due to dissimilarities in air entrainment in bores before impact.

In this context, the present study provides a new dataset collected in the field to complement the knowledge acquired in laboratory studies. This unique dataset is analysed to characterize the impact generated by overtopping waves on a vertical structure located on top of a sea dike in a real shallow foreshore beach configuration. Then, the performances of existing formulas to estimate the maximum impact force are assessed and discussed.

METHODOLOGY

This study presents the first field deployment of a new measuring device: a Wave Impact Pressure (WIP) station specifically designed to evaluate the hydrodynamic loads exerted by overtopping waves on a vertical wall in field conditions. The first part of the work consisted in developing and testing the different components of the WIP station to ensure its robustness and suitability to be operated remotely. The second part of the work was devoted to the deployment of the WIP station on the waterfront of the urbanized embayed beach of Biarritz (France) during a storm event that generated a series of overtopping of the upper beach sea dike (Figure 1).

Figure 1 – Overview of the Wave Impact Pressure (WIP) station deployed at the Grande Plage of Biarritz (France) during a storm event in fall 2023.

This deployment was completed with the installation of an array of pressure sensors (RBR), a current meter (ADV), video cameras (GoPro®) and a runup videometry station, as well as the conduct of topo-bathymetric surveys. These additional data are used to characterize the hydrodynamic conditions in the surf and swash zone up to the WIP station installed on top of the sea dike.

RESULTS

The first result of the study is the validation of the acquisition chain specifically developed for the WIP station, which includes a CompactRIO controller and a tailored supervision solution (SCADA). The validation is based on the reproduction of the dam break experiment carried out by Lobovsky (2014). This laboratory experiment represents a bore propagating over a dry bed and impacting a vertical structure equipped with pressure sensors. The analysis of the results shows that our system accurately captures the various impact phases including the impulsive pressure impact at the lowest pressure sensor, followed by a quasi-static pressure impact measured with all the sensors. Once validated, the acquisition and supervision systems were then integrated into our WIP station, which is composed of a 1.7 m high, and 0.6 m wide marine aluminium plate mounted with 9 piezoresistive pressure sensors Keller pr-25y (frequency sampling up to 10 kHz). The WIP station was deployed on Biarritz study site for 2 days during a storm characterized by maximum incident significant wave height and peak period of 6 m and 15 s respectively. The station was installed on the promenade located on top of the upper beach impermeable dike (Figure 1). At high tide, the WIP station was exposed to several overtopping wave impacts and measured time series of pressure evolution at the different sensor locations (Figure 2).

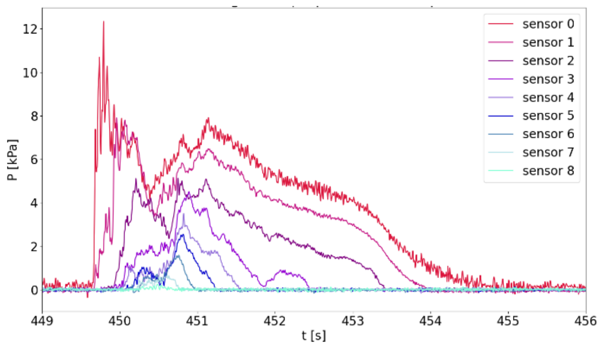

Figure 2 – Pressure records at different elevations above the upper beach dike measured during one of the overtopping wave impacts. Sensors are numbered in crescentic order from the bottom to the top of the WIP station.

The analysis of the pressure measurements coupled with the processing of video images at the time of impact, provide an unprecedented field characterisation of overtopping wave impact in real conditions. The general hydrodynamic features of the overtopping wave and the shape of the measured force time series are comparable to the ones presented in Streicher (2019) for the smallest impacts of their laboratory dataset. For the largest impacts, the dynamic differs and seems controlled by stronger infragravity waves. Same differences between smaller and larger impacts are observed in the assessment of the performance of existing empirical formulas currently used to predict the maximum impact force. For smallest impacts, most of the formulas provide a fair estimation of the force magnitude, while important divergences are observed for most energetic overtopping events observed in the field.

CONCLUSION

This study presents a new measuring device, the “WIP station”, designed to provide measurements of impact pressure generated by overtopping waves on a vertical structure in field conditions. The deployment of this device on top of a real sea dike fronted by a shallow foreshore allowed to collect a unique dataset in storm regime. Data analysis provides a first characterization of overtopping wave impact loads on the study site configuration. The dataset was then used to assess the performance of existing empirical formulas to predict the maximum impact force. It is shown that the prediction performance decreases with increasing impact intensity. Future work will be carried out to investigate the relationship between foreshore hydrodynamics and the overtopping bore loading.

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