

QUANTIFYING WAVE-INDUCED PRESSURES ON A SALTMARSH CLIFF: AN EXPERIMENTAL STUDY

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INCLUDING SALTMARSH IN COASTAL DEFENCE

Increased forcings on existing coastal flood defences due to sea level rise and an increase in storminess leads to a current challenge to reinforce coastal flood defences, such as coastal sea dikes. Conventionally, these structures are reinforced by increasing their height and thereby the total width of the structure. Aside an increase in costs, it reduces either landward usable area or seaward area, where intertidal mudflats and vegetated saltmarshes provide vital ecosystem services. An alternative can be found in actively including these foreshore/saltmarsh systems in the coastal protection scheme. During storm conditions, the inundated vegetation leads to higher energy dissipation than non-vegetated foreshores (Möller et al., 2014), while the induced shallower conditions also contribute to reduce the wave height at the toe of the dike. Hence, reducing the need for increasing the height of the dike itself.

The wave attenuation capacity is related to the cross-shore length of the saltmarsh and reduces when the saltmarsh laterally erodes. A hotspot for lateral erosion is at the transition between the mudflat and the vegetated saltmarsh. Due to the offset in vertical erosion between the bare mudflat and the saltmarsh, this transition is often depicted by a cliff with typical heights around 0.5 m (Figure 1).



Figure 1 - Saltmarsh cliff with a height of 0.8 m near Wierum, The Netherlands (taken by P. Willemsen, 2022).

In order to actively include the saltmarsh within a long-term coastal protection system, the saltmarsh should be stable during various storm conditions. However, erosion at the saltmarsh cliff is not well understood. Wave-induced forcing at the cliff leads to failure of the exposed cliff, but a clear quantification of the complex, near-cliff flow and pressure distribution is lacking as well as a complete understanding of the underlying triggered failure mechanisms. In this research, we present high-resolution measurements of

wave-induced hydrodynamics and local pressures at a saltmarsh cliff performed in a scaled wave flume experiment.

METHODS

A series of experiments was performed in the 39 m long, 0.8 m wide and 1.0 m deep wave flume at the Hydraulic Engineering Laboratory at Delft University of Technology. The generated waves propagate over a saltmarsh, consisting of a 5 m foreshore, a varying cliff height with a maximum of 0.12 m, 7 m saltmarsh and dike with a slope of 1:3.6. The experiments are designed according to a Froude scaling of 1:10. Target vegetation was *Spartina Alterniflora*, a common pioneering species in Dutch saltmarshes. The vegetation is modelled by elastic cylinders, scaled according to Cauchy similitude, with a height of 0.09 m and density of 8100 stems/m². Monochromatic waves are generated offshore at water depths ranging from 0.3 to 0.7 m with wave heights between 0.05 to 0.15 m. Water levels were measured by 7 wave gauges and 2 laser scanners. Wave-induced pressures at the saltmarsh cliff were also measured by 12 pressure transducers, mounted around the cliff (Figure 2). Particle Image Velocimetry (PIV) was used to quantify near-cliff velocities and patterns over the full water depth and cliff length in a non-intrusive way. An inhouse developed LED line light (Bakker et al., 2021) was used as a light source. To ensure uniform illumination of the water column, the light was emitted from below the wave flume, directed upward through a transparent bottom (Figure 2).

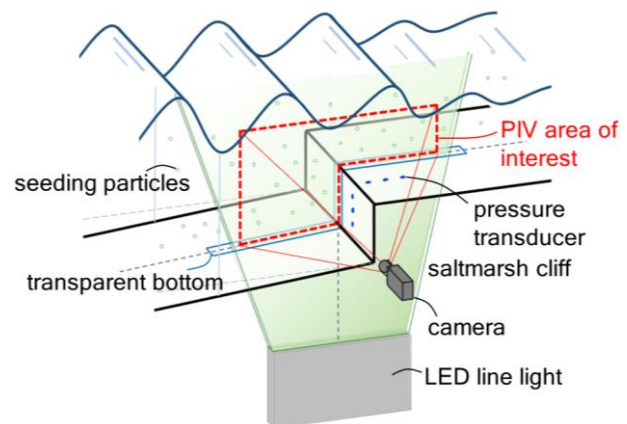


Figure 2 - Schematic overview of the PIV and pressure transducers setup around the saltmarsh cliff.

RESULTS

The validation of the velocity measurements obtained by PIV shows a good agreement with multiple Acoustic Doppler Velocimeter (ADV) measurements, with RMSE smaller than 0.08 m/s and 0.02 m/s respectively for the test with and without the cliff. Similar to Suzuki and Klaassen (2011), the formation of vortices has been observed in front of the cliff along the trough of a wave (Figure 3 and 4, top panels). The presence of a vortex is detected and linked to the occurrence of pressure gradients through its intensity and quantified via the swirl strength (λ_{ci}) eq.1.(Adrian et al., 2000):

$$\lambda_{ci}^2 = \max \left[0, -4 \frac{\partial u}{\partial z} \frac{\partial w}{\partial x} + 2 \frac{\partial u}{\partial x} \frac{\partial w}{\partial z} + \frac{\partial u^2}{\partial x} + \frac{\partial w^2}{\partial z} \right] \quad (1)$$

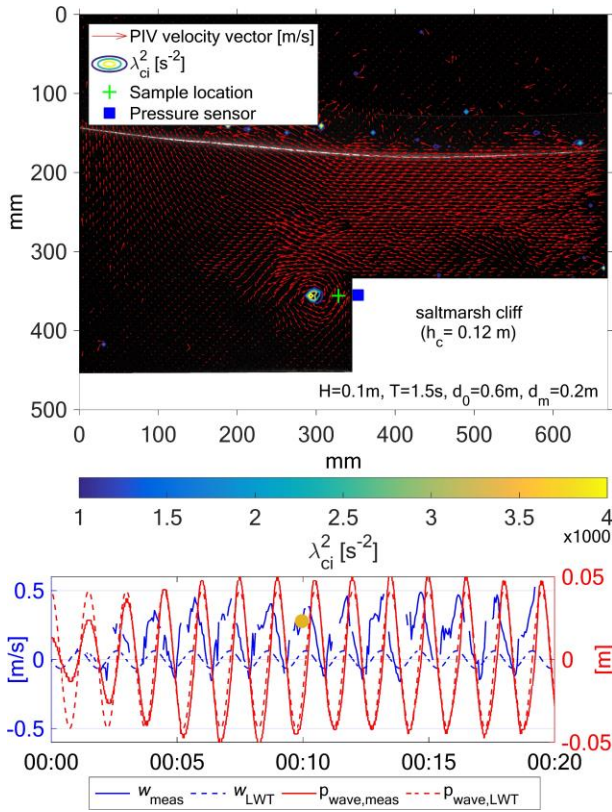


Figure 3 - Instantaneous flow velocity field (top panel) and timeseries of vertical velocity (w) and dynamic pressure (p) (lower panel) for a case with a cliff height of 0.12 m and no vegetation. Moment of the velocity field is indicated with the orange marker in the bottom panel.

Comparison between the measurements and the linear wave theory (LWT) shows higher measured vertical velocities, indicating the upward jet due to the detachment of the flow at the edge of the cliff. Further analysis will focus on the relation between the vortex and pressure fluctuations and the comparison between the experiments with and without vegetation. These will be treated in more detail during the conference.

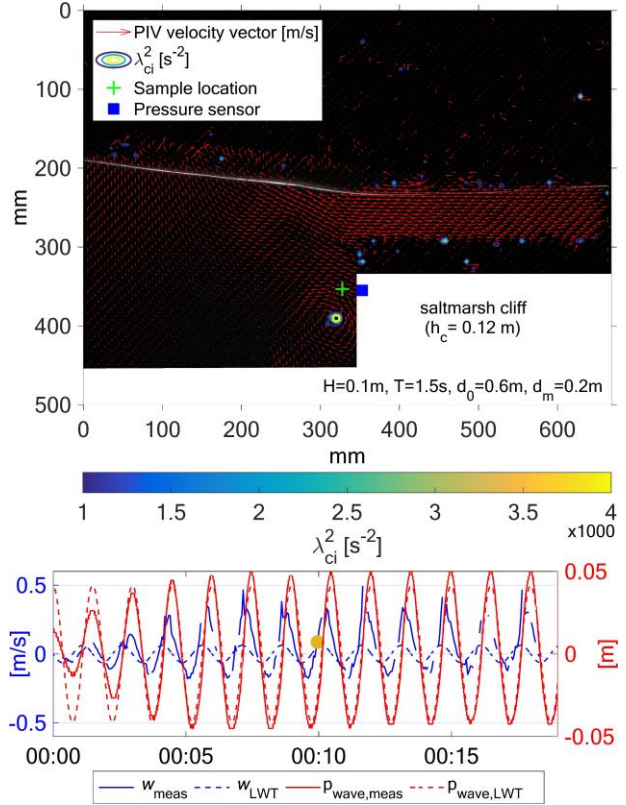


Figure 4 - Instantaneous flow velocity field (top panel) and timeseries of vertical velocity (w) and dynamic pressure (p) (lower panel) for a case with a cliff height of 0.12 m and vegetation. Moment of the velocity field is indicated with the orange marker in the bottom panel.

ACKNOWLEDGEMENTS

This work is part of the 'Living Dikes - Realising resilient and climate-proof coastal protection' project NWA.1292.19.257, funded by the Netherlands Organisation for Scientific Research (NWO). The authors want to thank P. van der Gaag, A. Doorn and A. van der Vlies for their help in the design and construction of the physical model. Furthermore, the support during the PIV experiments by W. Bakker, P. Faber, C. Willems and F. Kalkman is greatly acknowledged.

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