SALT MARSH AND EXTREME CONDITIONS: A LARGE SCALE EXPERIMENT

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INTRODUCTION

In densely populated coastal regions across the globe, hard sea defenses have been widely used to guarantee the safety of the population and exposed assets. However, the efficacy of these hard structures has come under scrutiny in recent times due to the expected impacts of climate change and the claimed inappropriate behavior due to their static nature. In 1925, A.G. Verhoeven (Verhoeven, 1938) introduced the concept of man-made salt marshes for land reclamation purpose. He transplanted around 40,000 Spartina Townsendii plants from their native southern UK habitat to Zeeland, the coastal southernmost region of the Netherlands. In doing so, Verhoeven inadvertently played a pioneering role in the early development of the 'Building with Nature' concept. Since then, several decades of dedicated research showed the potential use of salt marshes as low environmental impact structures (Maza et al., 2015) as an opportunity to be quantitatively investigated, Willemsen et al., 2020, Vuik et al. 2019, Borsje et al., 2011; Gedan et al., 2010; Costanza et al., 1997; Chapman VJ., 1974. Nevertheless, a comprehensive understanding of wave attenuation by salt marsh and its survivability remains limited, with only a few experimental studies addressing this topic under mild hydrodynamic conditions (Ghodoosipour et al., 2022; Maza et al., 2015; Möller et al., 2014). As a result of this knowledge gap, salt marshes have been excluded from technical consideration within coastal flood protection systems and the underlying risk quantification, thereby allowing for speculative claims regarding their efficacy in mitigating coastal flooding, both in the Netherlands and internationally. This contribution aims to present the first worldwide large-scale test dedicated to quantitatively describe the response and survivability of a salt marsh under extreme hydrodynamic conditions while also providing a complete overview of the complex background activities required for such a unique experiment.

METHOD

One month test series is planned to start during mid-February 2024 in Deltares' Delta flume (291 m long, 5 m wide and 9.5 m high). The laboratory set-up is composed of a salt marsh spanning 71 meters, comprising two sections constructed from 33 vegetated clay blocks each and a smooth concrete dike at the shore-most edge, Figure 1a and 1b. The initial 8 blocks at the beginning (Figure 1d), and the 2 blocks before the intersection between the dike and the marsh (Figure 1c) measure 2.0 meters in width, 2.0 meters in length, and 0.7 meters in height. These blocks are positioned at the salt marsh's edges which are anticipated to experience the most intense hydrodynamic load. The remaining 25 blocks are squared with the side equal to 2.2 m and 0.4 m high. The offshore salt marsh edge is made of a 0.6 m step to reproduce the seaward cliff usually resulting from the horizontal gradients in sediment deposition and consolidation, (Colosimo et al., 2023). A 40.5 m long foreshore made of sand and thin concrete cover layer is built offshore the salt marsh cliff with a steepness of 1:45, while 12.5 m steeper slope (i.e. 1:9) is realized to allow a smooth bottom transition, natural wave propagation and to save construction material.

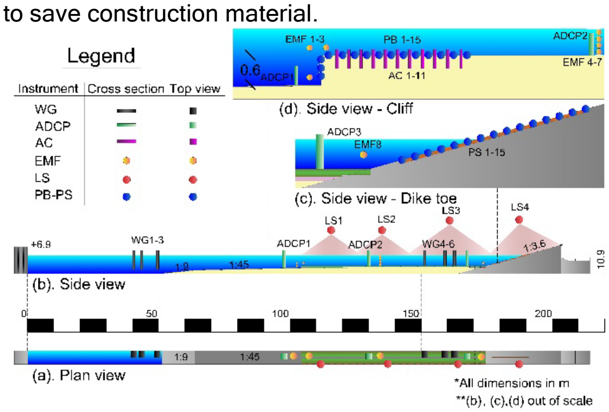

Figure 1 – Laboratory layout set-up.

An extensive series of measurements are planned during the test and they are aimed to capture the hydrodynamic variables such as wave field development before and above the marsh (6 wave gauges (WG) and 4 lasers scanner (LS)), the water velocity at the cliff, in the middle of the marsh and at the dike toe (8 Electromagnetic flowmeters (EMF) and 3 ADCP), the pore water pressure inside the cliff blocks (15 pressure sensors (PB)), the wave pressure on the dike (15 pressure sensors (PS)), the vibration of the cliff blocks (20 accelerometers (AC)), the run-up and the overtopping. A 3D laser scanner will also be used to assess the soil erosion between tests. Offshore significant wave height (H_{S0}) between 0.8 and 2 m will be tested according to the depth limited condition imposed by the three planned water depths, i.e. 4.4, 5.4 and 6.9 m at the wave maker, respectively 1.5, 2.5 and 4.0 m above the salt marsh. Offshore wave steepness (s_{op}) ranging from 2.8 to 5% will then also be accounted for during the experiments. The experimental campaign is structured into three distinct phases, each corresponding to varying vegetation conditions: good, intermediate, and completely broken. In each phase, the six hydrodynamic conditions mentioned above are tested so that the results can be contrasted and the effect of the vegetation on the investigated variables identified and quantified. After each test with good and intermediate vegetation conditions the removed biomass will be collected and the status of the vegetation monitored.

The blocks constituting the salt marsh were collected in September 2023 from the Peazemerlannen Nature Reserve, situated in Friesland in the northern part of the Netherlands. A civil contractor collected the blocks in the field, Figure 2.a, b, c, that afterwards were moved close to the Delta flume, where they are stored and maintained through ongoing watering and drainage procedures involving both fresh and saltwater to reproduce the saline water content in the field.

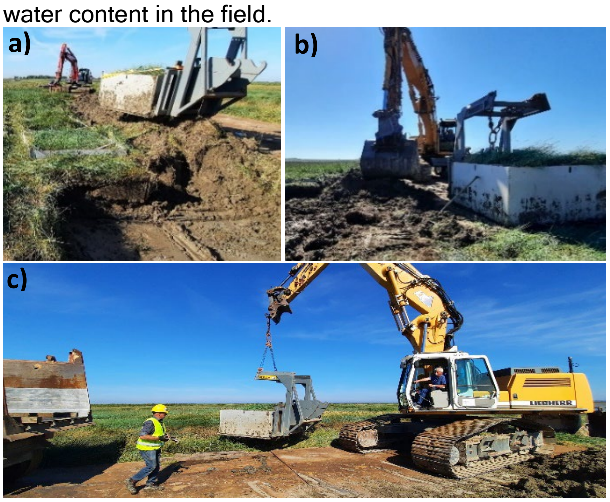

Figure 3 – The sequence of blocks harvesting process

Two locations (seaward and landward in Figure 4) along the natural marsh were selected to collect blocks characterized by different soil compositions (Table 1) and equal vegetation. The selection of these two locations was mainly based on the presence of a rather undisturbed high salt marsh with the locally dominant climax vegetation species *Elymus athericus* mixed with *Atriplex spp.* and *Aster tripolium*.

Table 1 – Soil characteristics of the blocks collection areas

	Seaward			Landward	
Gravel	2 mm - 63 mm	-	**Gravel**	2 mm - 63 mm	-
Sand	63 µm - 2 mm	37%	**Sand**	63 µm - 2 mm	1%
Silt	2 µm - 63 µm	43.40%	**Silt**	2 µm - 63 µm	53.40%
Clay	< 2 µm	19.70%	**Clay**	< 2 µm	45.30%

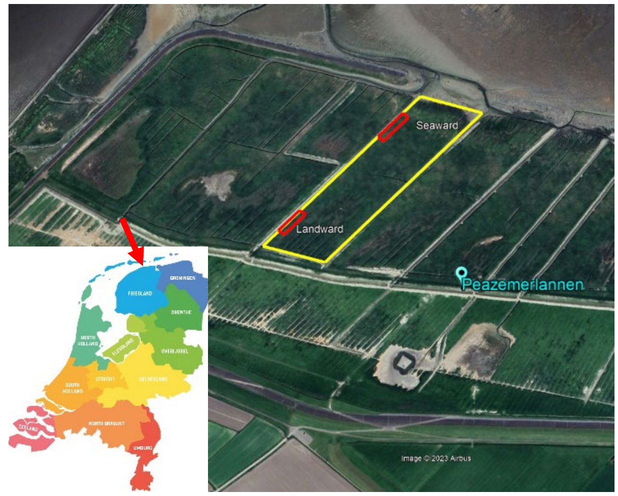

Figure 3 – Locations of the blocks collection area.

EXPECTED RESULTS
At the conference, the experimental design and specific challenges resulting from the use of real salt marsh vegetation will be discussed. The first results on wave attenuation under extreme hydrodynamic conditions and the salt-marsh response in terms of erosion, pore pressure build-up and biomass evolution will furthermore be presented.

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