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Wave attenuation by salt marsh vegetation

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Keywords: salt marsh, vegetation, wave attenuation, estuaries

Abstract

Salt marshes are a characteristic feature of estuaries and coastal seas. They are found in the upper coastal intertidal zones between land and water, which are regularly flooded by tides and surges. They are covered with salt-tolerant vegetation types, such as herbs and grasses. Sheltering from continuous intense hydrodynamic forcing by waves and currents and sufficient supply of (fine) sediment are the two main requirements for salt marsh development. The presence of vegetation accelerates the sediment settlement by reducing the wave forces on the bed material. Additionally, the roots of the plants stabilize the accumulated sediments and amplify the process of subsoil drainage, consolidation and compaction. Salt marshes and the intertidal flats in front form a coherent system with many mutual dependencies.

Coastal flood risk reduction by creating and restoring ecosystems is increasingly seen as a promising supplement to conventional coastal engineering methods. Salt marshes, mangrove forests and reed fields can act as a vegetated foreshore in front of a coastal dike. In such a combined dike-foreshore system, the foreshore plays a role in attenuating storm waves, whereas the dike retains the surge and the remaining wave energy. The current study focuses on the process of wave attenuation by vegetation and, vice versa, the process of breakage of vegetation due to wave action.



Figure 1 – Examples of salt marshes in the Wadden Sea (left) and Western Scheldt (right) in the Netherlands

Wave propagation over salt marshes has been measured on several salt marshes in the Netherlands, from the autumn of 2014 till present. The measurements include storm conditions with high water depths (up to 2 m above the salt marsh surface) and the largest wave heights reported in literature so far for field measurements on salt marshes (up to 0.8 m significant wave height). The data has been used for calibrating and validating numerical models (SWAN, XBeach) to reproduce the wave energy dissipation on vegetated foreshores. Vuik et al. (2016) explain how depth induced wave breaking and wave dissipation by vegetation lead to a rapid reduction of the wave energy as soon as the orbital motion under the waves is affected by the presence of the elevated salt marsh platform with vegetation. Under storm conditions with relatively small wave height to water depth ratios, depth-induced wave breaking on the foreshore is limited, whereas wave attenuation by vegetation can already be substantial. For larger wave height to water depth ratios, the presence of vegetation prevents intense wave breaking to occur, since the wave energy is dissipated more gradually. The absence of intense wave breaking might contribute to the stable character of the salt marsh sediments.

The wave attenuation over salt marshes has been measured with four wave gauges in a transect with a total length of 50 m. Figure 2 shows the reduction in significant wave height between the first and last sensor on salt marsh Hellegat in the Western Scheldt. The reduction percentage $(H_{m0,1} - H_{m0,4})/H_{m0,1}$ is shown, dependent on the incident wave height $H_{m0,1}$ (horizontal axis) and the water depth h_1 at the first sensor, just in front of the salt marsh edge (vertical axis). The bed level at sensor 4 is 1.25 m higher than at sensor 1. Therefore, almost 100% wave height reduction is found for water depths below 1.5 m. The left figure shows the measured wave height reduction with the vegetation in summer state (July-September 2015), and the right figure for the late winter state (January-March 2015). It is clearly visible that the

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wave attenuation in summer is much higher than in winter. For example, the reduction of waves with a significant wave height of 0.25 m at a water depth of 2.0 m is approximately 35% in winter, and 65% in summer. In autumn, the vegetation becomes fragile, and will partly break due to wave action. This stem breakage process continues during winter. In spring, new shoots appear, and the total wave attenuating biomass increases again.

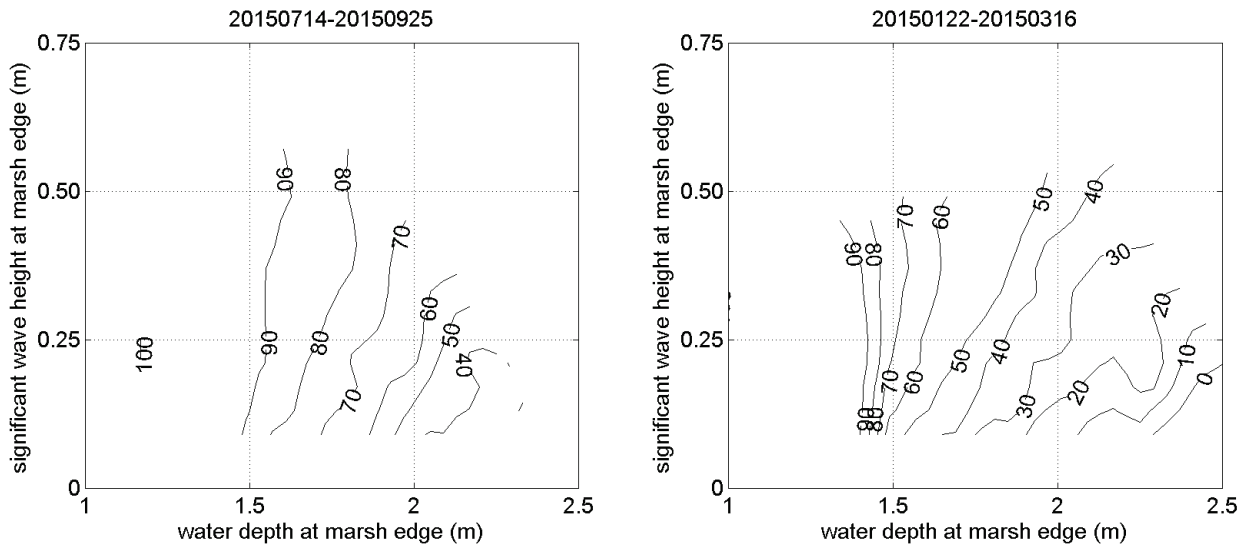


Figure 2 – Wave height reduction percentage over a transect at salt marsh Hellegat in the Western Scheldt, the Netherlands for summer state of the vegetation (left) and winter state of the vegetation (right)

An important question for coastal risk reduction is if the added wave attenuating capability by vegetation can be taken into account in the safety assessment of the flood defences. Therefore, the stem breakage process is crucial. Under design conditions for the dike, exceptional high water depths and wave heights will occur, and the biomass loss will be higher than observed in regular storm conditions. To predict the stem breakage for higher wave heights than observed, the maximum flexure stress that the vegetation can withstand is determined using a three point bending test (Figure 3). The maximum flexure stress will be translated to wave-induced flexure stresses in field conditions, to determine the maximum wave conditions that the plants can withstand.

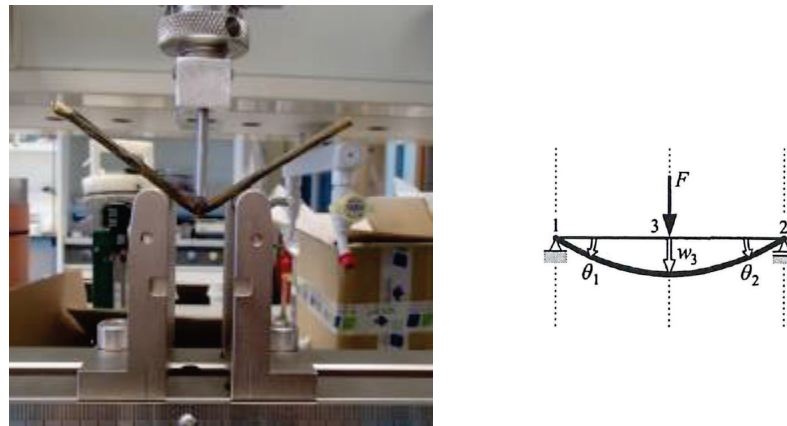


Figure 3 – Three point bending test to determine the maximum flexure stress that a stem can withstand

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