Houtrib Dike Sandy Foreshore Pilot Project

Public summary

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

EcoShape

Introduction

A pilot project was conducted between 2014 and 2018 to study a sandy reinforcement for the Houtrib Dike. The aim was to develop knowledge about the application of sandy reinforcements for dikes in lakes with mild wave conditions. The thinking was that this would open the way to cost reductions in the design and construction of flood defences.

Study design

A sandy foreshore was constructed on the south side of the Houtrib Dike near Trintelhaven. The triangular trial section was 400 meters long and 150 meters wide, with the Houtrib Dike on the northern edge and a sheet piling structure on the western side that was installed at a right angle to the dike. The waterline of the sand package was at a right angle to the average wave direction in the Markermeer lake. In order to investigate the development of vegetation in different conditions, clay was mixed into the top layer in a part of the trial section. The foreshore was monitored for four years. A total of 23 surveys were conducted from September 2014 onwards and the final survey was conducted on 20 March 2018.

Trial section in 2014 soon after construction

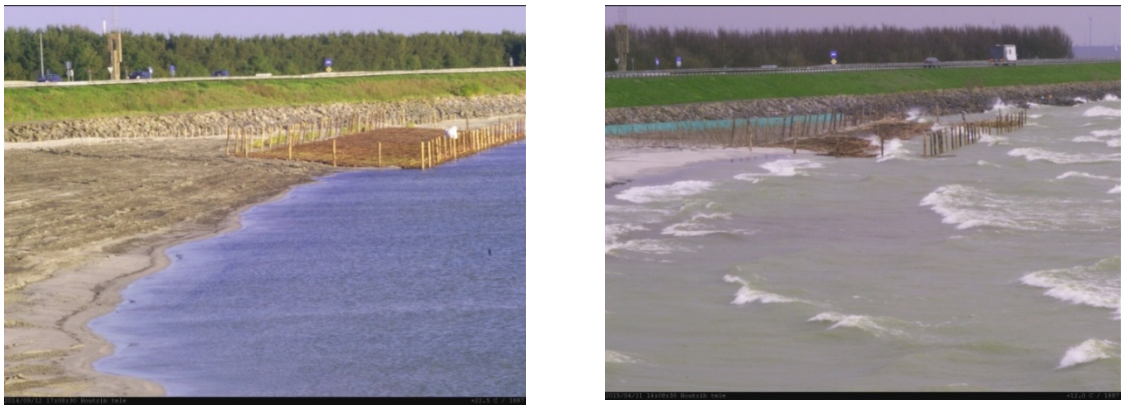
Trial section in 2016

Development of the vegetation

Vegetation on foreshores mitigates the wave impact in many cases. Moreover, vegetation limits erosion and prevents problems with drifting sand. A number of areas were set out in the trial section that included a range of combinations of vegetation and soil type. The areas differed in terms of vegetation (vegetation present or not), protection from foraging birds and the mixing of clay into the top layer. An important conclusion is that mixing in clay definitely has a major positive impact in the early stages on the growth of vegetation. Foraging birds have a clear negative impact on the vegetation.

Vegetation in an exclosure (protection from geese) in 2015 (left) and 2017 (right). The photographs clearly show that the exclosure prevents grazing by geese, allowing reeds to grow. In the surrounding areas, where reeds were planted without an exclosure, some of the reeds had been eaten away in 2015 and most of them were gone in 2017 due to grazing.

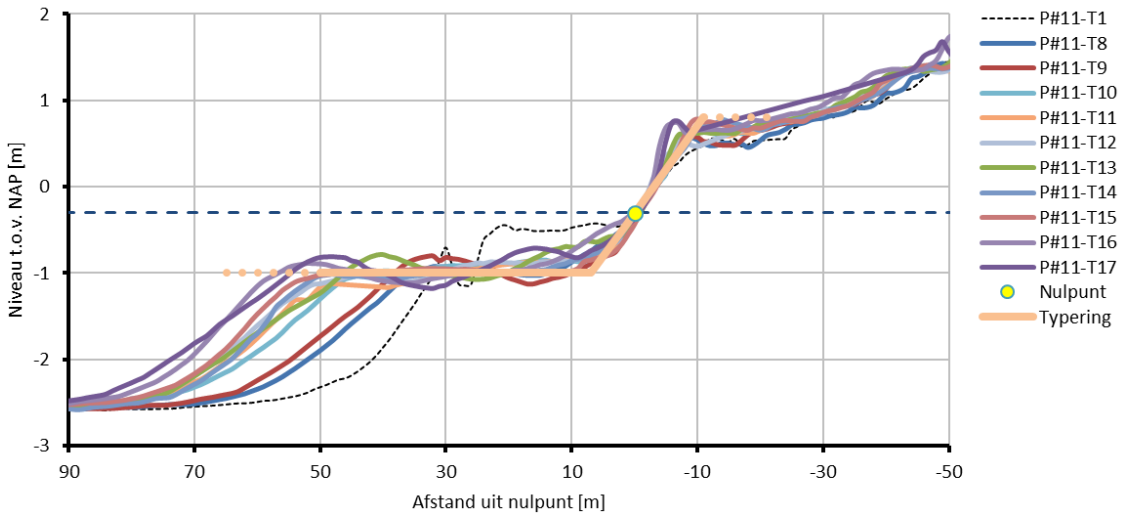
It proved to be difficult to investigate the wave-reduction effect of reed vegetation around the shoreline: the impact of the waves proved to be too much for the reeds and so they failed to grow. Several unsuccessful attempts were made. This finding is in line with information from other locations indicating that reed vegetation has difficulty in coping with waves higher than roughly 20 cm.



Photos made by the camera at the pilot location on 12 September 2014, with the first reeds on a braided brushwood mattress (left), and on 11 April 2015, showing a marked effect of the waves on the braided brushwood mattresses (right). Parts of the braided brushwood mattresses were washed away during the winter of 2014-2015. The planted reeds can be seen behind the mattresses.

Sand volume development and form of the trial section

The amount of sand has remained almost the same despite the sometimes severe storm conditions with waves up to 1.2 meters high. A stable sandy solution in a lake environment is therefore possible.
The form of the trial section did change during the pilot study. The cross-section has developed: the foreshore is now lower and there is a steeper section around the waterline.



Schematic representation of the cross-section in the central part of the trial section with respect to the intersection at NAP-0.3 m.

The steeper, higher part (slope angle of approximately 1 : 10) moves in line with the prevailing wave directions. For example, a period with more south-easterly winds led to a clockwise rotation of the higher part and the growth of the coastline at the location of the sheet pile structure. The outer contour of the lower part of the profile (below NAP-1 m) did not behave in this way and it acquired a plateau shape.

Function and effect of plateau

On the basis of the observations, it did not prove possible to explain the function and effect of this plateau satisfactorily. It was therefore decided to study this area in mid-2017. This additional research included two components:

- physical measurements on the plateau of factors such as wave height and flow velocity;
- monitoring the effect of digging away the plateau locally to investigate how the plateau worked.

The analysis of these data resulted in improvements to the XBeach morphological model that designers use to make calculations for coastal reinforcements. Another important result is that a calculation module has been added to this model that can be used to simulate the steep profile around the waterline much better.

Installation of instruments for measuring the localised digging

The monitoring work generated insights into how the plateau works. If the plateau had been protecting the part around the waterline, the partial digging away of this plateau would have led almost immediately to local erosion. However, the observations showed there was no major impact on the area around the waterline. The new 'hole' filled up mainly on either side as a result of the flow along the trial section and not from the higher part as a result of the water flow and waves at a right angle to the trial section. The conclusion is that the plateau does not clearly protect the upper part of the foreshore. The formation of the wide plateau would appear to be caused in part by the sheet piling and dike. This can be deduced from the fact that, as the research was being conducted, there were extreme hydraulic conditions with the highest wind speed, the highest water level and wave heights up to over 1 m. Even then, there was no significant effect on the waterline.

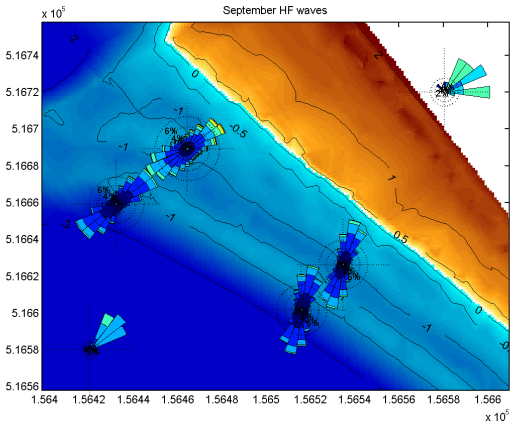


Image of measured 'intra-wave flow patterns' for the four instruments in the water in front of the trial section on 8 September 2017. The compass at the bottom left shows the measured wave direction for the shore; the compass at the top right shows the wind direction.

Difference between a lake and an open coastline

The main difference between the foreshore in this pilot study and a foreshore on the coast was the steep profile around the waterline and an almost horizontal plateau below the surface. This is because there are no tides in a lake. However, there is a strong correlation between water level and wave height in a lake: the wind not only pushes up the water level, it also drives the incoming wave impact. A higher wave impact is accompanied by a higher water level. The level of the flat plateau would appear to coincide with the level at which the waves can effectively work on the foreshore in different combinations of water levels and wave heights.

Results and conclusions of the pilot study

The main conclusions of the pilot study are:

Vegetation

- Strong waves prevent the growth of vegetation on the waterline
- Mixing clay into the sand has a positive impact on vegetation growth in the early stages
- Foraging birds have a negative effect on the vegetation

Morphology

- The foreshore stayed in place well and there is little sand loss
- A plateau formed unexpectedly in front of the foreshore (on the side of the lake)
- However, this plateau does not clearly protect the foreshore
- The XBeach model has been validated and extended on the basis of the data relating to the formation of the plateau
- The sheet piling and dike have, as an enclosure structure, had an effect on the shape of the sand package and the shape of the plateau.

The trial section in 2017

Lessons Learned and Guidelines

One of the aims of the pilot study was to produce design guidelines for future sandy foreshores and to record the lessons learned. Documents containing guidelines and lessons learned have been produced for permits and construction, and there are guidelines for the management and maintenance and design of dike foreshore systems. There is also a business case document with other possible locations for sandy foreshores. The documents are freely available on the EcoShape website. The main points in those documents are:

Permits

- The fastest way to obtain the necessary permits in a Natura2000 area

- Requirements relating to obtaining permits and how to apply those requirements in the design

Construction
- Experiences during construction and analysis of actual settlement and sand loss
- The extent to which the design was actually implemented in terms of geometry
- Guidance for the cost-effective construction of larger-scale foreshore solutions

Design and assessment of dike foreshore systems
- An overview of the technical obstacles to assessing the design?
  These result from the lack of concrete computing rules. The document therefore also includes:
- Initial suggestions for the development of concrete computing rules for the design of sandy foreshores
- Useful rules for the design and assessment of foreshore solutions for new and existing dikes
- Useful rules for the integrated assessment of the integrity of the hybrid flood defence

Management and maintenance
- The stability of a sandy foreshore depends in part on the decisions made in the design phase. This is because the profile and soil structure are also included in the design. These factors have a major impact on the morphological development of the foreshore itself and on vegetation development.
- Smart decisions in the design phase make it possible to adapt to the conditions that will actually be found in practice and to management and maintenance requirements.

Finally, the Business Case document explores the possibilities for the construction of foreshore solutions at other types of location.

The summary of each report was translated. These can be found on the Houtrib Dike project page.

Contribution to other projects and follow-up research

One of the main objectives of the pilot study was to apply the results in both ongoing and upcoming HWBP (High Water Protection Programme) projects. The knowledge generated by the pilot study has now been used to determine the dimensions for the sandy reinforcement of the Houtrib Dike and the sandy outer edges of the Marker Wadden. Furthermore, the insights from the pilot study have also been applied to the upgrading of the Markermeer dikes between Hoorn and Edam, the lakeside dike.
The pilot study contributed to projects in and around the Markermeer lake even as it was being conducted.

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