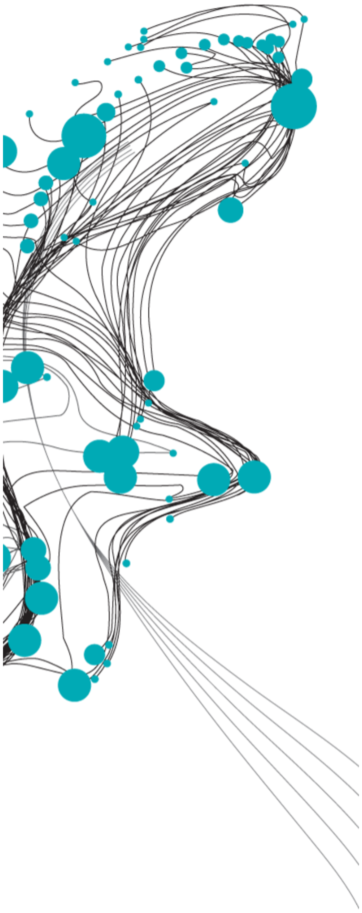
MODELLING THE GRASS COVER EROSION IN THE WAVE RUN-UP ZONE OF SEA DIKES

APPLYING AN OPENFOAM MODEL TO DELTA FLUME EXPERIMENTS



New flood standards came into effect recently whereby the design water level reached above the hard revetment of outer slopes of many sea dikes. Consequently, the grass revetment on the dike slope is subject to wave impact and wave run-up erosion whereby it is not known which erosion process is dominant. Scale tests are performed in the delta flume at Deltares in order to test the erosion resistance of the sea dikes along the Wadden Sea coast with the new flood standards. The erosion resistance of different grass and clay qualities are tested to provide insights into the effect of the cover layer quality on erosion rate. The objective of this study is to determine how grass covers on the outer dike slope erode and which hydraulic variables can be used to predict the erosion. This study is divided into three parts: (1) analysis of erosion data from the delta flume experiment, (2) creating a hydrodynamic model in OpenFOAM to simulate a dike from the delta flume experiments with and without grass cover erosion, and (3) computing the erosion using the OpenFOAM model results.

The results of the first part showed that the grass cover eroded three times faster when the grass is dried out compared to normal grass. Therefore, it is suggested that the effect of dry summers, especially in the wake of expected climate change, are considered in the design of dikes with grass covers. The analysis on clay erosion showed that the higher quality clay contributed to a roughly 35% increase in erosion resistance compared to low quality clay. However, the clay quality did not seem to have a significant effect on the erosion of the grass cover.
The model results of the second part showed that the hydraulic load on a dike with a significantly eroded grass revetment profile is generally lower than on the initial profile. In the model with grass cover erosion a cliff is present towards the end of the grass revetment surface, which endures high dynamic pressures, flow velocities and shear stresses.
For the third part, the results show that wave impact relations using dynamic pressures and wave run-up relations using flow velocities are both capable of describing the erosion depth of the grass revetment, which is mostly situated above the wave impact zone. However, dynamic pressures show to be the most accurate when replicating the erosion profile measured in the delta flume experiments (Figure 1). Additionally, a head cut erosion model was used to compute the cliff erosion present in the eroded dike profile.

To conclude; grass and clay quality have a major influence on the erosion rate of a grass revetment cover layer on the outer dike slope. The distribution of hydraulic variables on the grass revetment slope changes significantly when the grass revetment cover layer has eroded. Dynamic pressures can best be used for determining the erosion amount and the erosion depth, combined with a head cut erosion model to compute the erosion of significantly eroded cover layers.

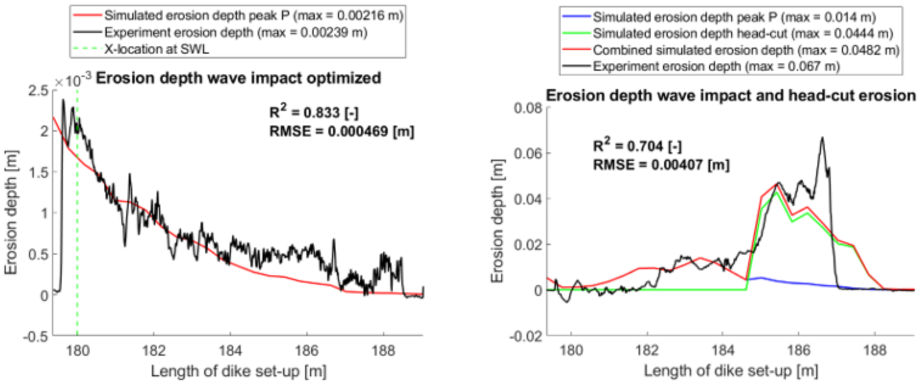


Figure 1: Erosion depth computed using calibrated erosion relations describing wave impact erosion using dynamic pressures obtained from the OpenFOAM model. The computed erosion is compared to measured erosion during delta flume experiments of the dike cover without erosion (left plot) and the dike cover with significant erosion (right plot). The goodness of the model is measured by the coefficient of determination (R^2) and Root Mean Square Error (RMSE), also included in the figure.

Niels G. Bijen

Graduation Date:
15 April 2021

Graduation committee:
University of Twente
Prof.dr. S.J.M.H Hulscher.
Chair supervisor
Dr.ir. J.J. Warmink
Committee member
V.M. van Bergeijk, MSc
Daily supervisor
W. Chen, MSc
Daily supervisor

TU Delft
Dr. J.P. Aguilar-López
External committee member

UNIVERSITY OF TWENTE.