Proceedings of the 9th International Conference on Physical Modelling in Coastal Engineering (Coastlab24)

Delft, Netherlands, May 13-16, 2024

Extended Abstract, DOI: 10.59490/coastlab.2024.733

LARGE SCALE PHYSICAL MODEL STUDY ON CLAY EROSION WITH GRASS COVER ON SEA DIKES

SUZANNA ZWANENBURG1, VERA VAN BERGEIJK1, BERT DE WOLFF2, MARK KLEIN BRETELER1

1 Deltares, The Netherlands, Suzanna.zwanenburg@deltares.nl, vera.vanbergeijk@deltares.nl, mark.kleinbreteler@deltares.nl
2 Waterschap Noorderzijlvest, The Netherlands, b.dewolff@noorderzijlvest.nl

KEYWORDS: Dikes, Coastal structures, Clay Erosion, Residual strength, Large Scale Physical Modelling.

1 INTRODUCTION

Sea dikes in the Netherlands consist of sandy or clay core with a clay layer with grass. The lower outer slope is often covered with a hard revetment, such as asphalt or a placed block revetment, to protect the dike material against wave impact. Since the strength of the clay layer with a grass subject to severe wave impact is unknown, the hard revetment needs to be constructed on a large part of the outer slope to ensure that the flood defence meets the safety requirements.

Therefore, a research programme was started to determine the strength of the clay layer with grass on the upper slope of a dike. As a first step, large scale physical model tests have been performed. In the second step the CFD model OpenFOAM has been used to extend the physical model results by computing the peak pressure of the hydraulic load on the clay for the tested geometries and additional geometries with varying parameters that may influence the erosion rate. With all results, it was possible to derive formulas for failure probability calculations in the final step. The knowledge development on the erosion of a clay layer with grass on the outer slope by wave attack resulted into formulas that are currently used in the safety assessment of dikes contributing towards safer deltas and resilient designs of dikes.

2 PHYSICAL MODEL TESTS

A full-scale model (scale 1:1) was built in the Delta Flume of Deltares using an undisturbed layer of clay and grass. The clay with grass was taken from a Wadden Sea dike in boxes of 2 m x 2 m with a height of 0.8 m and placed in the flume (Klein Breteler et al, 2012). With these blocks a clay layer with grass of 1.6 m thick was built. Several geometries were tested: with and without a berm, an upper slope of 1:4 and 1:5 and three types of clay. By loading the dike with extreme waves (H_{m0} = 2.0 m, T_p = 5.5 s), the erosion rate of the layer of clay and grass was experimentally determined, as shown in Figure 1.

Figure 1 Photo of the Delta Flume experiment

3 RESULTS

3.1 Physical model tests

The 1,6 m thick clay layer with grass on the upper slope (above SWL) was able to withstand 14 to 35 hours of wave loading. The tests in the Delta Flume showed that the erosion process consists of two phases. First, erosion proceeds vertically through the grass cover and creates a gradually growing hole in the revetment of the dike just above the transition between the hard revetment and the clay layer with grass (Figure 2). During this part of the erosion process, the erosion hole grows mainly in depth and the eroded volume increases quite slow. When the erosion depth progressed to about 0.5 m depth, the erosion process enters a second stage where the eroded volume increases considerably faster. In this stage a terrace and cliff of clay are formed where the base of the cliff is eroded by the waves, undermining the grass cover.

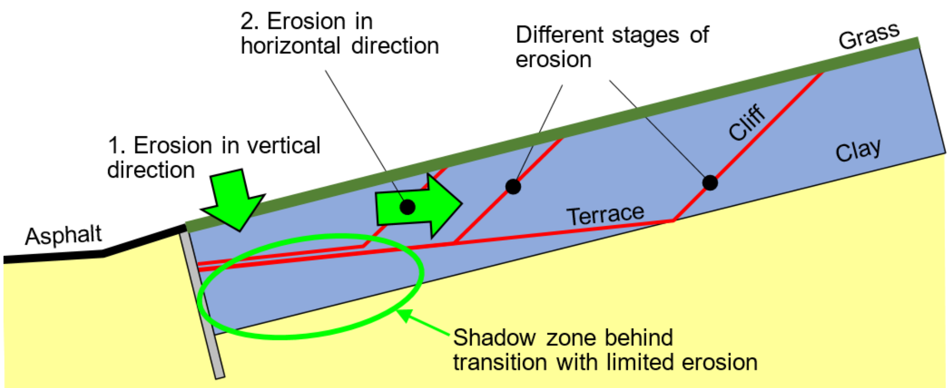

Figure 2 Schematization of the erosion process

3.2 OpenFOAM results

It is assumed that the peak pressures as the result of wave impact on the clay are the main driver of erosion (Kaste et al, 2015). The physical model tests are simulated in OpenFOAM to determine the peak pressures corresponding to the hydraulic load during the physical model tests. Based on the results of OpenFOAM and the physical model tests a relation between the calculated peak pressures and the measured erosion has been developed. As a next step, the effect of changes in the water level and wave conditions on the peak pressures are calculated in OpenFOAM. The results are combined to develop formulas for the erosion of a clay layer with grass on the upper slope. These formulas can be used in probabilistic calculations to determine the failure probability of coastal defences (Kaste et al, 2015).

4 CONCLUSIONS

A clay layer with grass is able to withstand high wave loading for a significant duration, such that it has an important contribution to flood protection. The results of the physical and numerical model study can be used to calculate the minimum required clay layer thickness on the upper slope, which is a useful tool for the safety assessment and design of sea dikes.

REFERENCES

M. Klein Breteler, M. Bottema, G.A.M. Kruse, G.C. Mourik and A. Capel, 2012. Resilience of Dikes after initial damage by wave attack. *Proceedings of the International Conference on Coastal Engineering*, July 2012, Santander, Spain.

D.L. Kaste, M. Klein Breteler and Y. Provoost, 2015. Development of a numerical model to predict the erosion of a dike after the failure of the revetment using time dependent boundary conditions. *E-proceedings of the 36th IAHR World Congress*, The Hague, the Netherlands