Breach growth in sand-dikes

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About 60% of The Netherlands are protected against high waters by a system of dunes, dikes, dams, and quay walls, barrages and storm flood barriers. This enormous system of water defences has to protect The Netherlands against floods, which have occurred hundreds of times in the past. Almost all of these flooding resulted from failures of dikes, some with disastrous outcomes, thousands of deaths and enormous economical losses. Particularly the failure of numerous dikes in the 1953 flood disaster has induced a marked change in thinking about safety standards for flood defence structures.

The Technical Advisory Committee on Water Defences (TAW) in The Netherlands has decided in 1990 to replace the present design method for dikes based on a frequency of exceedance of the water level by an inundation risk approach. In this method safety levels will be expressed in terms of risks. Risk is here defined as the product of the probability of inundation and the expected damage caused by the inundation. It is necessary to predict the rate of inundation of the polder in order to be able to estimate this damage. This inundation rate depends heavily on the flow rate through the breach in the failing dike, which in its turn depends on the development of the breach in time. Hence, it is necessary to have a reliable dike-breaching model.

In this presentation a mathematical model will be discussed for the growth of the breach in a failing dike and for the inflow rate through the breach. It is assumed that the dike has been constructed with sand (at the moment a PhD-student is working on an extension of the model to dikes constructed with silt and clay) and that the clay-layers and the revetments on the slopes do not decelerate the erosion process. The model is based on the mechanism of breach erosion as observed in various tests in the laboratory and the field. It is assumed that the process starts with a small initial breach at the top of the dike. Then, five stages are distinguished in the resulting dike breaching process. In the first two stages, the breach eats its way into the dike, with hardly any increase of the breach inflow rate. In the third stage the growth of breach depth and width accelerates, and consequently also the discharge through the breach. After the wash-out of the dike in the breach at the end of the third stage, the breach growths further in the fourth stage, mainly laterally. In the fifth stage backwater in de polder decelerates the flow in the breach, and so also the increase of the breach width. Rising tailwater ultimately stops the flow of water through the breach.
The breach erosion process in the last two stages depends on the erodibility of the base of the dike, and on the stability of the toe construction of the dike or the height of the foreland in cases where the subsoil has low resistance against erosion. The model calculates the breach growth and the breach discharge as function of these boundary conditions.

Two experiments were performed to obtain data for the calibration and validation of the mathematical model, the Zwin'94 field experiment and a laboratory experiment. In both experiments increase of both width and depth of the breach, outside and inside water levels, flow velocities in and near the breach were observed in detail.

The calibration of the model with the data of the Zwin'94 experiment shows that application of the Bagnold-Visser sand transport formula gives good agreement in Stages I, II and III and the formulations of Van Rijn and (in some less degree) Engelund-Hansen in Stages IV and V. The agreement of the calibrated model with the data of the laboratory experiment is good.

The confrontation of the model with the data of the failure of the Noord Dike in Papendrecht in 1953 indicates a final breach width of about 110 m already present after about 2.5 hr, which is more or less in agreement with a crude eye-witness report. The Noord Dike failed at the location of an auxiliary spillway, where along a length of about 100 m the dike had a solid foundation of clay and the core of the dike was built of sand and not of clay. Computations with the model show that the solid clay-layer and the limited length of the sand-core have restricted the final inundation depth in the polder significantly.

As already described above, research is continued in order to be able to apply the model also to dikes constructed with cohesive sediments (silt and clay). It will be clear that this is the most difficult part of the investigation.

**Literature**

